

ANNUAL REPORT

2004

PROJECT IP-1

Bean Improvement for the Tropics



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PROJECT IP-1: BEAN IMPROVEMENT FOR THE TROPICS

PROJECT DESCRIPTION

Objective: To increase bean productivity through enhanced access and utilization of improved cultivars and management practices in partnership with NARS, regional networks, and farmers.

Outputs:

1. Higher and stable bean production with less dependency on inputs such as pesticides, fertilizers, and water.
2. Integration of traditional and advanced (e.g., marker-assisted selection) crop-improvement techniques and farmer participatory research approaches to facilitate rapid adoption of improved bean cultivars.
3. Institutional and organizational capacities of NARS, regional, and community organizations strengthened.
4. Increased access and adoption rates of bean based technologies through NARS, networks and farmers.

Gains: Improved varieties occupy 40% of bean area in Latin America and 15% in African network countries by 2005. Productivity and food security stabilized for poor rural and urban consumers in restricted areas. Pesticide use cut 20% in selected areas, reducing hazards to environment and health. Farmers growing new cultivars increase income from marketing beans by 10%-50%. Public and private researchers have access to beans with multiple-stress resistance and greater nutritional value. Research capacity strengthened through regional networks.

Milestones:

- 2005 Lines resistant to BCMV, BCMNV, stem maggot, root rots, CBB, anthracnose and angular leaf spot available to partners in Africa. Drought tolerant lines validated with partners. Lines tolerant to low nitrogen and low pH developed. *Pythium* root rot pathogen in Eastern Africa characterized and distribution established. ALS and *Pythium* resistance genes characterized. Progeny from marker-assisted selection for P-efficiency made available to partners.
- 2006 Nutritional quality traits incorporated into high-yielding, stress-tolerant cultivars. Heat tolerance incorporated into climbing beans. Lines tolerant to low nitrogen, phosphorus and acid soil complex available to partners in Africa. Method to quantify *Pythium* and Fusarium root rot pathogens in soil validated. Improved varieties to reach about 3 million people in Africa.
- 2007 An IPM system for whiteflies on snap beans has been adopted in major bean producing areas of the Andean zone. Gene combinations to manage major bean diseases and insect pests determined and deployed in improved varieties. Climbing beans adopted in at least 10 countries in Africa. Farmers growing new bean varieties realize a 10% increase in income from marketing beans.

Users: Small farmers in tropical America and Africa (mainly women) will obtain higher and more stable yields. Poor consumers, especially women and children, will benefit from low-cost protein and micronutrients. The environment and community at large will benefit from reduced pesticide and fertilizer use. Food legume researchers will access an enhanced knowledge base and germplasm.

Collaborators: *Regional networks:* ASARECA, SACCAR, AfNet, ECABREN and SABRN (Africa); SIGTTA (Central America). *NARS:* CORPOICA (Colombia), EMBRAPA (Brazil), and more than 30 other NARs in Latin America and Africa. *Germplasm improvement:* NARS and farmers by FPR and PPB. *IPDM:* ICRAF, CIMMYT, IITA, CIP, TSBFI, partners in the systemwide IPM program and African Highland Initiative (AHI). *Training in breeding and IPM:* Bean/Cowpea CRSP and ICIPE. *Diffusing technology:* NGOs, churches, relief and governmental agencies, and entrepreneurs. *International institutions:* CATIE and EAP-Zamorano (Central America), universities and other institutions in Australia, Belgium, Canada, France, Netherlands, Spain, Switzerland, UK, and USA. *Gene tagging:* CRSP and USDA.

CGIAR system linkages: Enhancement & Breeding (75%); Crop Production Systems (10%); Protecting the Environment (5%); Networks (5%); Training (4%); Information (1%).

CIAT project linkages: Germplasm (SB-1 / SB-2); IPM (PE-1), nutrient & water-use efficiency (PE-2), climate change (PE-6), communities & watersheds (PE-3), participatory research (SN-3), impact (BP-1).

CIAT: IP-1 PROJECT LOG FRAME (2005-2007)

PROJECT: BEAN IMPROVEMENT FOR THE TROPICS
Project Manager: STEPHEN BEEBE

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
<p>Goal To obtain a lasting increase in food availability and income for the poor through improved bean productivity.</p>	<p>Increased bean production, and better income distribution and nutrition with improved cultivars and management practices.</p>	<p>National production statistics.</p>	<p>Adoption continues at rates at least comparable with those in the past.</p>
<p>Purpose To increase bean productivity through enhanced access and utilization of improved cultivars and management practices in partnership with NARS, regional networks, and farmers.</p>	<p>Improved cultivars and/or ICM used by NARS, and farmers in 40% of Latin America and 15% of African network countries by year 2005. Adopting farmers increase bean income by 10%. Regional networks devolved to local management, with CIAT as a research partner.</p>	<p>Reports of NARS and regional networks. Adoption survey reports. Publications. CIAT reports. End-of-project and evaluation reports.</p>	<p>Core researchers and budgets maintained. Continued donor support to regional networks. Resources in challenge programs accessed. Regional bodies and national governments continue to give priority to bean production.</p>
<p>Output 1 Improved, small-seeded, bean germplasm resistant to major biotic and abiotic stresses with greater nutritional and market value.</p>	<p>2005 At least 40 breeding lines with BGMV, BCMV and anthracnose resistance plus drought tolerance available. 2005 Twenty lines resistant to stem maggot , or with two or more resistances to BCMV, BCNMV, root rots, CBB, anthracnose and/or angular leaf spot available to NARS, farmers and other partners (NGOs and community based organizations) in five countries in Africa (Uganda, Tanzania, Rwanda, DR Congo, and Kenya). 2005 Drought tolerant lines validated with partners in Nicaragua and available to four NARS in Africa (Kenya., Ethiopia, Tanzania, and Rwanda). 2005 Fifteen backcross progeny for enhanced nitrogen fixation delivered to Mexico. 2005 Ten lines tolerant to low nitrogen and low pH developed and made available to NARS in five countries in Africa (Malawi, DR Congo, Rwanda, Tanzania, and Kenya). 2006 High iron and zinc traits incorporated into at least 30 stress-tolerant breeding lines. 2006 Ten lines tolerant to low nitrogen and phosphorus and acid soil complex available to NARS, farmers and other partners in Africa (DRC, Kenya, Tanzania, Rwanda, Madagascar, Malawi, and Sudan). 2007 Approximately 30 F3-derived F5 families developed with tropical and temperate adaptation, 80% more minerals, abiotic tolerance and 2 resistances</p>	<p>Reports from NARS and regional networks. Annual reports. Publications.</p>	<p>Continued donor support to the African networks, LAC and CIAT. Continued input of (CIAT) breeders, molecular geneticist, and plant nutritionist.</p>

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
<p>Output 2 Improved, large-seeded, bean germplasm resistant to major biotic and abiotic stresses with greater nutritional and market value.</p>	<p>2005 Lines resistant to BCMV, BCMNV, stem maggot , root rots, CBB, anthracnose and/or angular leaf spot available to partners in Africa. 2005 Fifteen lines resistant to BCMV and CBB available to NARS in Uganda, Tanzania, Rwanda, Sudan, and Kenya. 2005 Five lines resistant to root rots, anthracnose and angular leaf spot available to four NARS in Africa (Kenya, DRC, Uganda and Rwanda) 2005: 15 bush bean lines resistant to BCMV and / or anthracnose and angular leafspot available to NARS in Bolivia, Colombia, Ecuador and Peru 2006: 15 climbing bean lines with heat tolerance distributed to NARS and network partners in Andean region, East Africa and Southern Africa 2006: low phosphorus tolerance screened for in Andean beans. 2007: High iron and zinc traits incorporated into 15 new large-seeded lines mainly in the red mottled and red seed classes (everyone - please add to this one as you see fit). 2007: 5 popping bean lines with BCMV resistance available to NARS in Bolivia and Peru (this one is optional and is not funded but was in our original milestones)</p>	<p>Reports from NARS and regional networks. Annual reports. Publications.</p>	<p>Continued donor support to African networks, LAC and CIAT. Input of breeder and molecular geneticist.</p>
<p>Output 3 Strategies developed for managing diseases and pests in bean-based cropping systems.</p>	<p>2005 <i>Pythium</i> root rot pathogen in Eastern Africa (Kenya, Uganda and Rwanda) characterized and species distribution established. 2005 ALS and <i>Pythium</i> resistance genes characterized in 8 sources of ALS resistance and 4 sources of <i>Pythium</i> resistance. 2006 Method to quantify <i>Pythium</i> and Fusarium root rot pathogens in soil validated. 2007 An IPM system for whiteflies on snap beans has been adopted in major bean producing areas of the Andean zone. 2007 Gene combinations to manage ALS, BCMV and BGYMV determined for varietal improvement.</p>	<p>Reports from NARS and regional networks. Annual reports. Publications.</p>	<p>Continued input of pathologist, entomologist, and virologist. Continued donor support to whitefly IPM project.</p>

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
<p>Output 4 Improved cultivars and management practices developed, evaluated and widely disseminated in partnership with NARS, regional networks, NGOs, and farmers.</p>	<p>2005 Improved ISFM practices adopted in 5 countries by 7 % of farmers: composting, integration of inorganic and organic amendments, use of different types of green manures, crop residue management, integration of varieties tolerant to low soil fertility conditions in Kenya, DRC, Uganda, Rwanda and Tanzania.</p> <p>2006 Improved IPDM practices adopted in 5 countries (Kenya, Malawi, Uganda, Sudan and Tanzania) by 7 % of farmers</p> <p>2006: Nationally-facilitated strategic alliances established with NGOs interested in sustainable seed production approaches and with seed companies (where these exist) in about 14 countries in Eastern and southern Africa.</p> <p>2006 Improved varieties or crop management technologies to reach about 3 million people in Africa.</p> <p>2007 Farmers growing new bean varieties realize a 10% increase in income from marketing beans. – (Uganda, Ethiopia, Rwanda, DRC, Malawi)</p> <p>2007 Climbing beans adopted in at least 10 countries in Africa (Rwanda, Uganda, Tanzania, Kenya, Malawi, Sudan, DRC, Zambia, Burundi, Madagascar, Ethiopia) and in Latin America (Bolivia, Colombia, Ecuador, Peru)</p>	<p>Trials on experiment stations and on farms. National statistics. Publications.</p>	<p>Continued donor support. Active collaboration with all partners involved, including farmers. Adequate support for socio-economic studies</p>
<p>Output 5 Strengthened institutional, organizational and collaborative capacity of NARS and sub-regional networks in Africa and Latin America</p>	<p>2005: National bean seed consultations and partnerships established in Uganda, Rwanda, Malawi, Ethiopia, DRC, Kenya, Tanzania, Mozambique and Zambia to facilitate seed diffusion.</p> <p>2005: Impact assessment of improved bean varieties backstopped by regional resource persons (from Uganda and Kenya) is completed in Rwanda, Tanzania, Ethiopia and Malawi.</p> <p>2005: Guidelines and manuals for enhancing capacity and skills of NARS partners in participatory plant breeding, marker assisted selection and participatory monitoring and evaluation developed.</p> <p>2005 Latin American networks with Central America, Mexico and Brazil revived around theme of biofortification</p> <p>2006: Participatory monitoring and evaluation of regional bean research program within NARS established in at least 12 PABRA countries.</p> <p>2006: Participatory plant breeding routinely applied in at least 12 PABRA countries (Kenya, Uganda, Ethiopia, Rwanda, Tanzania, Malawi, Uganda, Mozambique, DRC, Sudan and Zambia)</p>	<p>Reports from NARS, regional networks and PABRA. Annual Reports. PABRA reports,</p>	<p>Continued donor support. NARES scientists remain stable in their position. Partners commit resources to and incorporate innovative approaches</p>

Research Highlights in 2004

Output 1: Improved, small-seeded, bean germplasm resistant to major biotic and abiotic stresses with greater nutritional and market value

Activity 1.1 Developing germplasm tolerant to abiotic stresses of drought and low soil fertility

Highlights:

- More than 150 drought tolerant lines were identified from a second cycle of crosses to combine drought tolerance and resistance to BGYMV.
- The first group of lines with Brazilian grain types was selected. These will form the basis of crosses with high iron beans for north-east Brazil for the improvement of nutritional quality.
- Field evaluation of 36 promising bred lines and accessions over 2 seasons indicated that two accessions of *P. acutifolius* (G 40159 and G 40068) and two bred lines (RAB 650, SEA 23) were outstanding in their adaptation to water stress conditions. The superior performance of the two accessions of *P. acutifolius* under drought was associated with their ability to mobilize photosynthates to developing grain and to utilize the acquired N more efficiently for grain production.
- Field evaluation of 121 RILs of the cross MD 23-24 x SEA 5 indicated that two lines (MR 81, MR 25) were superior in their adaptation to drought stress conditions. The superior performance of these two lines was associated with higher values of pod harvest index and seed TNC content indicating the importance of mobilization of photosynthates to pods and seed in common bean under rainfed conditions.
- Greenhouse evaluation for differences in root distribution among 5 common bean genotypes grown in large soil cylinders indicated that SEA 5, BAT 477 and G 21212 were deep rooted compared with BAT 881 and MD 23-24.
- Field evaluation of 49 genotypes over 3 seasons indicated that two landraces (Carioca and G 21212) and two bred lines (MAR 1 and SEA 5) had the highest seed yield in Al-toxic soils. Significant negative relationship was observed between seed yield and seed P content indicating that greater seed filling and P use efficiency (g of seed produced per g of P uptake) contributed to higher yield in Al-toxic soils.
- Collaborative research with the University of Hannover showed that Al-induced callose formation is not a suitable parameter for assessing genotypic differences in Al resistance in common bean.
- Greenhouse screening of 66 RILs of the cross G 5273 x MAM 38 resulted in identification of four lines, HF14137-19, HF14137-26, HF14137-98 and HF14137-88 that were relatively more resistant to Al.
- Accessions of *Phaseolus coccineus* presented substantial vigor in a soil with high aluminum saturation, and may have important genes for tolerance to aluminum.
- Greenhouse screening of 30 RILs of the cross BAT 477 x DOR 364 resulted in identification of four lines BT21138-50, BT21138-83-1-3, BT21138-83-1-1 and BT21138-25 that were superior in their adaptation to low P supply based on total root length, number of root tips and total root biomass per plant.

- In Nicaragua and in Quilichao, tolerance to low soil fertility proved to be as important as drought tolerance or more so in confronting multiple abiotic stress.

Activity 1.2 Developing germplasm with multiple resistance to diseases

Highlights:

- Four genotypes (G 22623; G 10909; G 3005 y G 1368) that combined resistance to pathogens causing angular leaf spot, anthracnose and ashy stem blight were identified.
- Ten genotypes from accessions identified as variable for tannins were identified that had high levels of resistance to ashy stem blight (*Macrophomina phaseolina*)
- The sources of resistance to aphid- and whitefly-transmitted viruses identified by CIAT and collaborating NARIs, continue to be effective to control common mosaic, black root and golden yellow mosaic in newly developed common bean cultivars.
- Lines with good drought tolerance and carrying the bc-3 gene for resistance to BCMNV have been recovered in small black and small red seeded phenotypes.
- Markers for two important genes for resistance to BGYMV have been multiplexed in the PCR amplification, increasing greatly the efficiency of MAS.
- Conducted successful screening for sources of resistance to the new virus disease affecting snap beans
- Three new rust resistant snap bean lines selected after four years of evaluation with farmers in Uganda and distributed for regional evaluation
- Four new snap bean varieties with improved pod quality, resistance to rust and yield potential and adaptation selected in national performance trials with farmers, exporters and certification agency in Kenya.
- New breeding populations of snap runner bean segregating for adaptation to short day tropical conditions developed in Eastern Africa.

Activity 1.3 Developing germplasm with resistance to pests: *Thrips palmi*, bruchids, leafhopper, pod weevil, and bruchids

Highlights:

- Resistance to the bean weevil (*Acanthoscelides obtectus*) was identified in *Phaseolus vulgaris* x *P. acutifolius* hybrids
- Finished studies on molecular markers for *Thrips palmi* resistance
- Progress was made in the development of molecular markers for resistance to the pod weevil (*Apion godmani*)

Activity 1.4 Developing more nutritious small seeded bean varieties

Highlights:

- Lines combining a moderate level of drought tolerance with 50% higher level of iron have been recovered. These are still deficient in grain type and other agronomic traits but will form the basis for another cycle of recurrent selection.

- A study of G x E across CIAT's research sites suggests that some factor associated with low pH results in low seed iron concentration.
- Two varieties (Gofta and Roba-1) show high levels of iron and zinc concentration across locations and seasons
- Significant interaction of genotypes, soil conditions and P application can be exploited to enhance grain iron and zinc concentration
- Accessions of *Phaseolus coccineus* and *Phaseolus polyanthus* present levels of iron as much as 60% above checks and zinc only narrowly above checks in this trial. Confirmation of a wider advantage is necessary to justify interspecific crosses to improve iron concentration.
- New bean lines high in iron and zinc concentration identified in Eastern Africa and evaluated for agronomic characteristics by more than 20 farmers.

Output 2: Improved, large-seeded, bean germplasm resistant to major biotic and abiotic stresses with greater nutritional and market value

Activity 2.1 Developing germplasm resistant to diseases

Highlights:

- Over 1000 populations of different generations F₃-F₆ in various market classes were selected during this reporting period.
- Several lines were selected from the large red kidney and sugar bean market classes nurseries, which combined more than one attribute such as high yield, resistance to diseases (ALS and FLS) and tolerance to low soil fertility. These will be available for distribution to NARIs partners in SABRN.
- Four advanced lines (HGA 24, HGA 25, HGA 26, and HGA 27) were identified that combined resistance to rust, common bacterial blight, anthracnose and the angular leaf spot.
- The recessive *bc-3* gene is being successfully incorporated in climbing bean genotypes to control the increasing incidence of bean common mosaic in the American highlands. This gene confers total resistance to the causal viruses (BCMV and BCMNV), and facilitates the selection of virus resistant common bean genotypes possessing seed colors that exhibit genetic linkage problems (e.g. cranberry and red-seeded types).
- Several common bean genotypes possessing resistance to bean leaf crumple virus, a begomovirus transmitted by the whitefly *Bemisia tabaci*, have been identified in field screening plots planted in the Cauca Valley. The resistance sources identified are already present in many advanced common bean lines.
- Over 39 resistant and potential parental materials were evaluated under greenhouse conditions against nine isolates representing 6 *Pythium* species pathogenic to beans in eastern Africa. Thirty remained resistant.
- Over 500, F₂-derived F₅ lines and populations from simple, double and backcrosses were selected for *Pythium* and angular leaf spot resistance.
- Marker assisted selection for BCMV resistance continued this year in Andean bush and climbing beans with wide application of the SCAR markers ROC11 for the *bc-3* gene and

SW13 for the *I* gene. This work was expanded to collaboration with additional partners in the Andean region: CORPOICA, Universidad Nacional–Bogotá and PROMPEX-Peru.

- New heat tolerant, BCMV-resistant, red and cream mottled Andean climbing beans were produced. Peruvian varieties from the Alubia, Bayo, and Canario seed classes were also improved for BCMV resistance. Based on successes in marker assisted selection, a new project will begin next year for incorporating BCMV resistance into East African varieties with partners from Kenya, Rwanda and Uganda including ISAR, KARI, NARO, University of Nairobi and University of Rwanda.
- Marker assisted selection for anthracnose resistance genes was implemented in yellow, white and red seeded climbing beans using the SCAR markers SAS13 for the *Co-4²* gene and SAB3 for the *Co-5* gene. The SAB3 marker was found to work well under a range of PCR conditions while SAS13 marker amplification was improved. The anthracnose resistance genes are being pyramided into lines with BCMV resistance and commercial seed type. This project is important goal for breeding of Andean beans in both Africa and Latin America.

Activity 2.2 Developing germplasm resistant to insects

Highlights:

- Marker assisted selection of Arcelin-derived bruchid resistance was applied to advanced red mottled breeding lines and showed promise for substituting the serology-based assays presently in use for selection. These lines will be useful for Africa, the Andes and the Caribbean where *Zabrotes* weevils are prevalent in storage and cause severe losses.
- Tolerance to *Empoasca kraemerii* was confirmed in Andean bred lines.

Activity 2.3 Incorporating wider genetic diversity into beans

Highlights:

- Selections were made for low phosphorus tolerance in red and cream mottled Andean bush beans. Additionally, Colombian released varieties were compared for low phosphorus tolerance and yield index under low vs. high phosphorus conditions.

Activity 2.4 Developing more nutritious large seeded bean varieties

Highlights:

- The high iron NUA (Andean nutrition) breeding lines developed last year are being tested in on-farm trials with an NGO in Nariño and Valle departments, Colombia. Mineral analysis has confirmed the high iron status of four sister lines that are all well-adapted red mottled derivatives of CAL96. Low iron sister lines have also been identified and are also well adapted. Notably, one of the high iron sister lines, NUA56, has average iron content of 93 mg kg⁻¹ across three sites and up to 112 mg kg⁻¹ in one site, one of the highest seed iron values found to date. Additional Andean red seeded high iron varieties

have been identified. From this analysis we have identified potential genotypes to include in nutrition nurseries and hybridizations.

- At CIAT, we are analyzing genotype x environment interaction in trials with recombinant inbred lines and finding good correlations across sites for iron content.
- Mineral analysis is also being used to identify the highest iron content in Cerinza-derived red and red mottled advanced breeding lines (BIF series) and among all Colombian released varieties.
- A crossing block for nutritional improvement of bush and climbing beans from Africa and Latin America has generated a total of 120 combinations using high iron landraces and the breeding lines being developed above.
- QTL mapping of nutritional traits has become an important way to increase our understanding of how to breed common bean for better mineral content as part of the HarvestPlus Challenge Program. We are using a mix of traditional breeding, biochemistry, genetics and genomics to dissect nutritional quality traits.
- We are also studying the inheritance of soluble and insoluble tannins, which are implicated as anti-nutrients in mineral absorption. We have conducted a QTL analysis of five segregating populations of common bean. We have also analyzed a population for the seed darkening/non-oxidizing seed coat trait.
- Collaboration between CIAT and USDA-Houston is centering on a basic mechanism for mineral uptake in legumes using common bean as a model for the tropical legumes, namely iron reductase. Initial results suggest a relationship between a QTL for seed iron and one for iron reductase.

Output 3: Strategies developed for managing diseases and pests in bean-based cropping systems

Activity 3.1 Characterizing and monitoring pathogen and insect diversity

Highlights:

- The causal agents of three new diseases of common bean that have recently emerged in Colombia have been identified.
- We showed a lack of host differential interaction in the common bacterial blight/common bean pathosystem, and that the CBB pathogens might not have co-evolved with common bean gene pools.
- A molecular assay for specific detection and differentiation of CBB pathogens in bean seed, and the protocol for its application were developed.
- It was shown that the population structure of *C. lindemuthianum* is changing, as evidenced by the resistance of previously susceptible varieties.
- It was demonstrated that the varieties Widusa, Kaboon (Andean) and G 2333 (Mesoamerican) can be used to effectively manage all anthracnose races found in Colombia.
- The infection process of the angular leaf spot pathogen, *P. griseola*, was elucidated.
- The immune response of G 10474 to several pathotypes of *P. griseola* might be mediated through production of an antifungal compound.

- A protocol was developed for routine transformation of *P.griseola* and the fungus was transformed to express the GFP protein. Some transformants have lost their ability to infect bean (insertional mutagenesis).
- One hundred and thirty-four *Pythium* isolates from areas affected by bean root rots in Kenya and Rwanda were characterized by sequencing the ITS-1 region of ribosomal DNA and grouped into 22 species of which nine are new additions. Distribution maps for *Pythium* species were developed.
- Important changes in whitefly species composition in the target area were detected. Varying levels of resistance or susceptibility to some of the insecticides commonly used for whitefly control were observed.

Activity 3.2 Characterizing disease and insect resistance genes

Highlights:

- At least two resistance genes condition resistance of G 19833 to four races of *C. lindemuthianum*. The resistance genes in G 19833 are distinct from those in the Andean genotypes Michigan dark red kidney, Kaboon and Perry Marrow, and might be a new Andean resistance locus.
- Two AFLP markers linked to angular leaf spot resistance in Mexico 54 and G 10474 were successfully converted to STS markers and protocols for their use in MAS were developed. Similarly, the RAPD marker OPE4₇₀₉ linked to ALS resistance gene in Mexico 54 was converted to a SCAR marker and a protocol was developed.
- Two AFLP-derived SCAR markers (PF9 and PF11) were developed for G 10474 and Mexico 54.
- The allelic relationship of ALS resistance genes in Mexico 54 with G 10474, G 10909, G 10613, and Cornell 49242 were elucidated.
- Inheritance of resistance to *Pythium* root rot in five resistant genotypes was shown to be conditioned by single dominant genes. Allelism test using the diallel mating scheme revealed that the resistance is conditioned by the same resistance locus.
- Further progress was made on developing a SCAR marker for resistance to *Apion godmani*. A total of seven RAPD bands were cloned and five single copy markers developed which mapped to the same locations as the original RAPDs. In addition a peroxidase fragment was cloned from one of the chromosomal regions with the most consistent *Apion* resistance gene. These markers provide potential assays for use in marker assisted selection.
- Microsatellite and SCAR markers were evaluated for their utility in populations segregating for geminivirus resistance in a collaborative project with the University of Puerto Rico.

Activity 3.3 Developing integrated pest management components

Highlights:

- Diffusion of technology activities within the DFID-funded project on Sustainable Management of Whiteflies initiated.

- The second phase of the Tropical Whitefly IPM Project has demonstrated the importance of adopting IPM measures to recover common bean production in whitefly-stricken regions.
- Three potential biocontrol agents were identified and tentatively classified as *Paenibacillus polymyxa*, *Bacillus subtilis* and *Gluconobacter* spp. The antimicrobial compound is possibly proteinaceous in nature and one of the bacteria produces a heat resistant compound.
- Preliminary results showed *Calliandra calothyrsus* to be the best source of green manure for control of soil pathogens and to increase yields.
- Some of the *Pythium* species pathogenic to beans induced symptoms on and affected sorghum, millets, field peas and maize major crops grown in association with beans in south western Uganda.
- Some of the components useful in the integrated management of bean root rots were effective in reducing root damage and in increasing yield parameters on sorghum, millets, field peas and maize in bean based cropping system.

Output 4: Improved cultivars and management practices developed, evaluated and widely disseminated in partnership with NARS, regional networks, NGOs, and farmers

Activity 4.1 Supporting breeding programs in NARS, regional networks, farmers' associations, and CIALs with germplasm and technical knowledge

Highlights:

- A large number of breeding line nurseries and germplasm were distributed to bean network partners from CIAT-Headquarters
- Close collaboration between CIAT and breeding programs in the Andean region continued with exchanges of researchers and germplasm. Training programs were developed for researchers from CORPOICA and the Univ. Nacional in Colombia, PROMPEX-INIA in Peru and Univ. San Simon in Bolivia. One training project involved developing and confirming BCMV resistance in Peruvian dry beans, using marker assisted selection for the first time in Peruvian bean improvement. Another project involved selection of BCMV and anthracnose resistance in climbing beans using molecular markers.
- Lines bred for drought tolerance present as much as 50% yield advantage over elite cultivars under drought conditions in Nicaragua, confirming that tolerance mechanisms selected in CIAT-Palmira are effective in Nicaragua.
- Some top yielding cultivars across sites within SABRN (GCI-CAL-28-AR, AFR 708, CIM 9314 and CIM9314-2) combine acceptable market type (red mottled), high yield potential and resistance to ALS or FLS or both.
- The national bean research program in the southern highlands of Tanzania, this year released a CIAT-bred line DRK 124, calling it *Uyole 03* and another line selected from crosses generated by NRI on a collaborative project with Tanzania. Various nurseries and germplasm were distributed to bean network partners.

- Four new small red-seeded lines with tolerance to major diseases and better yield potential (up to 40%) compared to commercial cultivars were selected in three countries in Eastern Africa. Eight new small red lines perform significantly better than commercial checks in regional trials in two countries.
- Two new red mottled bean lines with improved yield potential over the best commercial checks and tolerant to major biotic stresses were identified in regional trials in four countries in East and Central Africa. An elite nursery of new red mottled bean lines was constituted for validation with farmers and other end-users in Eastern Africa.
- Five new red kidney bean lines show outstanding performance in regional trials and are selected in four countries in East and Central Africa. Thirteen new red kidney lines with better performance than the major commercial cultivar (Canadian Wonder) are selected in three countries.
- New releases of sugar bean become popular in south western Uganda as demand for sugar bean rises in east, central and southern Africa markets
- More than six new sugar bean lines with higher yield potential and combined resistance to angular leaf spot, anthracnose and rust identified in regional evaluations in East and Central Africa
- Sixty farmers from the Central and Eastern Highlands of Kenya, in collaboration with researchers, select 20 red mottled, 20 red kidney and 24 bean lines resistant to root rots and angular leaf spot from a genetically diverse germplasm pool. More than 120 farmers start bulking seed of their new red mottled and red kidney bean lines. Farmer's preference criteria for red mottled and red kidney bean cultivars identified.
- Farmers and researchers select 22 new climbing bean lines of major grain types preferred in the Central Highlands of Kenya and other areas in East and Central Africa from segregating populations. New climbing bean lines with farmer preferred traits distributed for wider evaluation and seed bulking in more than 15 districts in Kenya.
- 12 yellow, sugar, white-seeded bean cultivars show good adaptation to humid tropical lowlands (470masl)
- More than 14 agricultural NGOs, farmer associations and community based organization accelerate seed production and dissemination in lowland western Congo. Improved bean cultivars feature prominently in Kinshasa markets.
- Diffusion of improved bean cultivars to other countries in humid tropical lowlands of central and western Africa gains momentum.
- New bean lines of major market classes with high levels of tolerance to aluminium toxicity and acid low fertility soils identified. The Great Lakes region proves to be a potential source of germplasm with tolerance to low soil fertility conditions
- Five bean lines tolerant to drought identified in regional trials in eastern Africa. A regional drought nursery is constituted and distributed to five drought-prone countries in eastern Africa.

Activity 4.2 Development of sustainable seed systems to support wide dissemination

Highlights:

- There was a significant increase in number and diversity of partners for bean research and development in the PABRA region, particularly in support of decentralized seed

systems. Formalization of working relationships among partners was done through memoranda of understanding.

- Partners facilitated awareness creation, knowledge and skills enhancement about new or existing technologies through development and dissemination of diversified tools and approaches including promotional and training materials, field days, radio talks, agricultural shows, etc.
- Through enhanced partnerships, a total of about 12,000 M tonnes of assorted bean varieties were produced and made accessible to about 2.5 million farmers in PABRA region.
- Eight case studies on seed relief to assist disaster-affected and chronically stressed communities were completed are being compiled for publication.

Activity 4.3 Socio-economic activities

Highlights:

- Demand for beans on the market is influenced by grain color, and prior knowledge about cooking time and taste of the variety.
- Market studies of bean sub-sector in Uganda and Kenya show rising production and consumption trends of fresh and dry beans in Uganda but a stable consumption level in Kenya. Insufficient production in Kenya and demand in other countries offers opportunities for regional exports of dry beans from Uganda, while significant growth market opportunities for Kenya exist for green beans on international markets.
- The bean market price at the time of harvest in Malawi was primarily influenced by the supply and demand.
- Researchers and extension agents that work with farmers in both NARIs and NGOs in the Andean region should be aware of the profitability of bean production. For this reason we have started an analysis of the cost-benefit ratio of climbing versus bush beans in the production systems in practice in the region.

Output 5: Strengthened institutional, organizational and collaborative capacity of NARS and sub-regional networks in Africa and Latin America

Activity 5.1 Strengthened capacity of NARS: increasing the knowledge and skills of scientists and staff from NARIs, NGOs and Rural Service Providers

Highlights:

- In Latin America, two PhD candidates and one MSc candidates received their degrees, while in Africa two PhD and three MSc degrees to scientists working the bean project.
- In Africa a total of 408 persons attended courses or workshops, for a total of 1497 person-days of training.
- Participatory plant breeding was strengthened regionally with a course in Kenya attended by 22 scientists from the region, including four from SABRN
- Former IPM farmer groups in central Malawi have now taken up seed production as a business.

- Interaction between breeders in Africa and headquarters increased this year, with training in headquarters in marker assisted selection and with seed shipments renewed from Africa to Colombia, leading to closer integration of the breeding programs in Latin America and Africa.
- The ECABREN program assistant acquired skills in participatory monitoring and evaluation systems to support national bean programs
- 28 Biophysical scientists, NGOs partners, and technicians from Northern Tanzania were exposed to Participatory M&E organized by PABRA/ECABREN
- ECABREN partners in Tanzania and Uganda acquired knowledge in seed systems and distribution channels
- Two researchers from ISABU and Centre Technique Horticole d'Antananarivo, Madagascar developed knowledge and skills during training in production of promotional materials carried out at ATDT/ISAR project.
- Farmers and researchers in northern Tanzania select and name nine new marketable bean lines with tolerance to bean stem maggot and angular leaf spot after four years of participatory selection. Seed bulking by farmer groups and broader evaluation of new bean lines initiated.
- A compilation on participatory breeding experiences across crops, countries and regions of Africa was completed.

Activity 5.2 Collaborative projects developed and executed with NARS and regional networks

Highlights:

- The Swiss government extended its commitment to support the PABRA research network until 2007
- A system of competitive grants under the auspices of ASARECA is operational and CIAT is participating in project development
- A long term (6 year) project was approved by the Canadian government to improve Latin American crops for nutritional value, under CIAT's leadership
- The CIAT bean team is participating in two CGIAR Challenge Programs

Activity 5.3 Strengthen international collaboration through networks (Intra- and inter-network collaboration) and/or bi-lateral relations

Highlights:

- Four Future Harvest Centers (CIAT, CIMMYT, ICRISAT, and IITA) together with SSSN organized teamed up to sensitize various stakeholders on sustainable ways to produce and distribute seed of OPV and self-pollinated crop in Tanzania and Mozambique.
- Stakeholders selected in production to consumption chain defined three bean products for ECABREN research portfolio. These were beans for food and health; canning beans for domestic and export markets; snap bean and dry beans (white and sugar beans) for domestic, regional and international markets.

Progress Report

Output 1: Improved, small-seeded, bean germplasm resistant to major biotic and abiotic stresses and with greater nutritional and market value

Activity 1.1 Developing germplasm tolerant to abiotic stresses of drought and low soil fertility

Highlights:

- More than 150 drought tolerant lines were identified from a second cycle of crosses to combine drought tolerance and resistance to BGYMV.
- The first group of lines with Brazilian grain types was selected. These will form the basis of crosses with high iron beans for north-east Brazil for the improvement of nutritional quality.
- Field evaluation of 36 promising bred lines and accessions over 2 seasons indicated that two accessions of *P. acutifolius* (G 40159 and G 40068) and two bred lines (RAB 650, SEA 23) were outstanding in their adaptation to water stress conditions. The superior performance of the two accessions of *P. acutifolius* under drought was associated with their ability to mobilize photosynthates to developing grain and to utilize the acquired N more efficiently for grain production.
- Field evaluation of 121 RILs of the cross MD 23-24 x SEA 5 indicated that two lines (MR 81, MR 25) were superior in their adaptation to drought stress conditions. The superior performance of these two lines was associated with higher values of pod harvest index and seed TNC content indicating the importance of mobilization of photosynthates to pods and seed in common bean under rainfed conditions.
- Greenhouse evaluation for differences in root distribution among 5 common bean genotypes grown in large soil cylinders indicated that SEA 5, BAT 477 and G 21212 were deep rooted compared with BAT 881 and MD 23-24.
- Field evaluation of 49 genotypes over 3 seasons indicated that two landraces (Carioca and G 21212) and two bred lines (MAR 1 and SEA 5) had the highest seed yield in Al-toxic soils. Significant negative relationship was observed between seed yield and seed P content indicating that greater seed filling and P use efficiency (g of seed produced per g of P uptake) contributed to higher yield in Al-toxic soils.
- Collaborative research with the University of Hannover showed that Al-induced callose formation is not a suitable parameter for assessing genotypic differences in Al resistance in common bean.
- Greenhouse screening of 66 RILs of the cross G 5273 x MAM 38 resulted in identification of four lines, HF14137-19, HF14137-26, HF14137-98 and HF14137-88 that were relatively more resistant to Al.
- Accessions of *Phaseolus coccineus* presented substantial vigor in a soil with high aluminum saturation, and may have important genes for tolerance to aluminum.
- Greenhouse screening of 30 RILs of the cross BAT 477 x DOR 364 resulted in identification of four lines BT21138-50, BT21138-83-1-3, BT21138-83-1-1 and BT21138-25 that were superior in their adaptation to low P supply based on total root length, number of root tips and total root biomass per plant.

- In Nicaragua and in Quilichao, tolerance to low soil fertility proved to be as important as drought tolerance or more so in confronting multiple abiotic stress.

1.1.1 Drought tolerance

1.1.1.1 Development and testing of lines and segregating populations combining drought tolerance and disease resistance in small red, small black, navy and Brazilian grain types

Rationale: Drought tolerance must be combined with other traits to be employed in commercial varieties. In most regions where drought is a problem in the Americas, bean golden yellow mosaic virus (BGYMV) is also a serious limitation. For the Central American region, small red and small black grain type is required. In Africa a more diverse range of grain types are acceptable, although BGYMV is not yet a problem. However, recessive resistance to BCMNV is highly desirable. In Brazil angular leaf spot and *Fusarium* resistance must be combined with drought tolerance for the northeast of the country. Populations were evaluated under drought to seek combinations of multiples traits.

Materials and Methods: Last year we reported on positive results with F₈ families that represented the end of our first cycle of breeding for drought tolerance. Experience in Central America in November, 2003 indicated that higher levels of resistance to BGYMV were needed in these selections. The materials tested in 2004 combine first cycle drought selections with additional sources of virus resistance. In 2004 we evaluated second cycle F_{3.5} families in: three yield trials of red-seeded beans (each in 7 x 7 lattice design); two of black seeded beans (one 7 x 7 and one 6 x 6 lattice design); and a sixth of F_{4.6} families with Brazilian grain types (10 x 10 lattice). Yet another trial of crosses of drought sources with parents for high iron will be reported under Output 1.4. Trials were planted on-station at CIAT-Palmira in June 2004, receiving only three irrigations, amounting to about 200 mm water. The last irrigation was applied three weeks after planting and an additional 10-20 mm of rain fell one week later. Common checks were included across trials: red seeded commercial cv. Tio Canela; black seeded commercial cv. DOR 390; and an African cowpea cultivar bred for stress conditions, Mouride.

Additional new populations were created to combine high mineral content with drought tolerance, low fertility tolerance, and disease resistance, using the best combining parents for these traits, based on experience with crosses in 2003. A large set of approximately 3500 F_{1.2} families from 140 crosses was evaluated in the 2004 summer planting season.

Results and Discussion: During the crop cycle, day-time temperatures ranged from moderate (28°C) on cloudy days, to quite high (35°C) on clear days. Mid-day wilting was visible during the latter stages of flowering, and tensiometer readings increased gradually during pod filling, with readings of -700 millibars at the end of the crop cycle. Thus conditions resulted in severe terminal stress in nearly all plots, although it was evident that sections of fields with better soil structure suffered less stress. Although the DOR 390 check attained reasonable vegetative development, it produced very tiny, shriveled seed in most plots. However, check varieties yielded better than in past years in spite of drought, probably due to improved soil structure that permitted better root development, although grain quality was poor. As in past years, most selected lines produced commercial quality grain under even this level of stress.

Out of nearly 250 F_{3.5} families, 194 were selected for additional selection and testing. These presented a yield advantage of as much as 60% over Tio Canela in the case of the reds (Table 1) and 100% over the commercial check, DOR 390 in the case of the blacks (Table 2). Very few lines yielded as well as the cowpea check, which gave higher yields than in previous years. The Nicaraguan national program bean breeder revised the nursery and selected 108 red seeded and 15 black seeded families for immediate testing and selection in Nicaragua. Another set has been shipped to Guatemala for local selection. Planting in Central America will permit evaluation for resistance to BGYMV. In particular the red seeded materials represent an important advance in meeting the commercial requirements for Central America.

Within the trial of Brazilian types, families with excellent tolerance, yield potential and grain type were identified for the first time in CIAT (Table 3). These include several lines with carioca and cream (mulatinho) grain type, and one family with rosinha grain. These form part of the collaboration with EMBRAPA under the Generation Challenge Program and will contribute to food security in the drought-prone north-eastern states of Brazil. The Brazilian counterpart has selected 34 of these for testing in Brazil.

F₂ populations: Among nearly 3500 F₁-derived F₂ families, 812 were selected for additional study. Of these 558 were derived from crosses combining high mineral parents with sources of agronomic traits including drought tolerance. Compared to results from last year, the quality of populations had improved markedly, due to the use of reselected parental stocks for several traits. These will be selected for disease resistance and mineral content in F₃ and will be analyzed for iron and zinc content in F₄, to be tested in 2005 under drought as F_{3.5} families.

Table 1. Elite red seeded lines that yielded more than the check (P=0.05), identified in four separate yield trials.

Cross / Line	Yield as % checks ¹	Yield checks	Cross / Line	Yield as % checks	Yield check
(SXB 124 x (INB 35 x G23834E) x (SXB 123 x RIB 68)			(SXB123 x EAP9503-32B) x SXB 113		
MDSF 14742-3-MC-12Q-MQ	157	1191	SX 14816-66-MC-7P-MC	155	1191
(SXB 123 X EAP9653-16B-1) x SXB 125)			SX 14816-5-MC-15P-MC	154	1191
MDSX 14813-16-MC-6P-MQ	149	1530	SX 14816-5-MC-16P-MC	161	1417
MDSX 14813-37-MC-3P-MQ	143	1530	SX 14816-8-MC-34P-MC	159	1417
MDSX 14813-16-MC-18P-MQ	136	1530	SX 14816-8-MC-32P-MC	159	1417
MDSX 14813-61-MC-2P-MQ	143	1417	SX 14816-8-MC-21P-MC	153	1417
(SXB 123 x EAP9653-16B-1) x BFB 142			SX 14816-2-MC-1P-MC	149	1417
SXBF 14815-38-MC-2P-MQ	147	1417	SX 14816-66-MC-6P-MC	144	1197
SXBF 14815-10-MC-2P-MQ	145	1417	SX 14816-59-MC-20P-MC	143	1417
SXBF 14815-38-MC-3P-MQ	142	1417	SX 14816-8-MC-36P-MC	142	1417
SXBF 14815-21-MC-9P-MQ	139	1417	SX 14816-64-MC-9P-MC	138	1417
SXBF 14815-21-MC-6P-MQ	138	1417			

¹ Yields of lines were calculated as per cent of the yield of commercial check Tio Canela.

Table 2. Elite black seeded lines that yielded more than the check (P=0.05), identified in two separate yield trials.

Cross / Line	Yield as % checks ¹	Yield check	Cross / Line	Yield as % checks	Yield check
(SEA 18 x (FEB 192 x G21212)) x EAP9020-14			(SXB 114 x EAP9503-32B) x SXB 124)		
MR 14414-15-MC-1P-MQ-MC-55C-MC	211	863	MDSX 14808-24-MC-2P-MQ	160	1032
MR 14414-15-MC-1P-MQ-MC-54C-MC	192	863	(SXB 114 x DOR 605) x SXB 123		
MR 14414-15-MC-1P-MQ-MC-46C-MC	191	863	MDSX 14810-16-MC-20P-MQ	192	1032
(SXB 116 x DOR 677) x BFB 149			MDSX 14810-4-MC-9P-MQ	191	1032
SXBF 14799-1-MC-19P-MQ	192	1032	MDSX 14810-16-MC-10P-MQ	188	1032
SXBF 14799-11-MC-12P-MQ	173	1032	MDSX 14810-36-MC-12P-MQ	188	1032
SXBF 14799-1-MC-15P-MQ	169	1032	MDSX 14810-36-MC-5P-MQ	185	1032
SXBF 14799-9-MC-3P-MQ	163	1032	MDSX 14810-35-MC-5P-MQ	183	1032
SXBF 14799-11-MC-5P-MQ	147	1032			
(SXB 118 x EAP9503-32B) x SXB 111)			MDSX 14810-16-MC-14P-MQ	173	1032
MDSX 14801-31-MC-15P-MQ	230	1032	(SXB 123 x EAP9653-16B-1) x SXB 125		
MDSX 14801-25-MC-2P-MQ	201	1032	MDSX 14813-2-MC-3P-MQ	187	1032
MDSX 14801-31-MC-12P-MQ	198	1032			
MDSX 14801-43-MC-5P-MQ	197	1032	(SXB 123 x DOR 677) x SEN 34		
MDSX 14801-25-MC-1P-MQ	181	1032	SX 14820-37-MC-2P-MQ	181	1032
MDSX 14801-5-MC-1P-MQ	178	1032			
(SXB 118 x EAP9503-32B) x SEN 34			(MAB 95 x EAP9653-16B-1) x SEN 34		
MDSX 14802-46-MC-2P-MQ	180	1032	SXMA 14832-8-MC-10P-MQ	161	1032
(SXB 118 x EAP9503-32B) x BFB 140			SEN 34 x (MAB 105 x EAP9020-14)		
MDSX 14803-1-MC-4P-MQ	151	1032	SXMA 14833-39-MC-5P-MQ	202	1032
(SXB 114 x EAP9653-16B-1) x BFB145			SXMA 14833-39-MC-7P-MQ	178	1032
SXBF 14807-10-MC-7P-MQ	164	1032			

¹ Yields of lines were calculated as per cent of the yield of commercial check DOR 390.

Table 3. Elite drought tolerant lines that yielded more than the check (P=0.05) with cream striped, cream or pink grain color.

Cross / Line	Yield as % checks ¹	Yield check	Cross / Line	Yield as % checks	Yield check
(A686 x G21212) x (NXB 80 x Ligero)			(SAM 6 x Ligero) x (NXB 80 x SEA 15)		
BM 14521-3-MQ-MQ-5C-MC	160 n	1190	BM 14534-10-MQ-MQ-31C-MC	146 mu	1190
BM 14521-3-MQ-MQ-8C-MC	153 n	1190			
BM 14521-3-MQ-MQ-4C-MC	149 n	1190			
BM 14521-2-MQ-MQ-15C-MC	142	1190			
BM 14521-2-MQ-MQ-12C-MC	141 n	1190			
(A686 x A774) x (NXB80 x SEA 15)			(TAR 4 x SEA 15) x (NXB 80 x Tio Canela)		
BM 14524-3-MQ-MQ-8C-MC	161 mu	1190	BM 14535-10-MQ-MQ-3C-MC	152 car	1190
BM 14524-9-MQ-MQ-6C-MC	158 mu	1190	BM 14535-10-MQ-MQ-19C-MC	151 rs	1190
BM 14524-19-MQ-MQ-38C-MC	155 n	1190			
BM 14524-16-MQ-MQ-17C-MC	153 car	1190			
BM 14524-16-MQ-MQ-11C-MC	147 car	1190			
BM 14524-9-MQ-MQ-26C-MC	145 car	1190			
BM 14524-3-MQ-MQ-17C-MC	145 mu	1190			
BM 14524-16-MQ-MQ-35C-MC	145 mu	1190			
BM 14524-16-MQ-MQ-7C-MC	144 car	1190			
BM 14524-16-MQ-MQ-31C-MC	140 mu	1190			
BM 14524-16-MQ-MQ-25C-MC	139 mu	1190			
BM 14524-19-MQ-MQ-31C-MC	138	1190			
BM 14524-9-MQ-MQ-7C-MC	138	1190			

¹ Yields of lines were calculated as per cent of the yield of commercial check DOR 390.

Conclusions: Progress in drought tolerance continues with particular progress in F_{3.5} families with regard to grain color in several grain classes. The quality of populations with high mineral parents improved substantially over those of a year ago.

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1.1.1.2 Evaluation of drought resistance and associated traits in advanced lines

Rationale: Development of drought adapted bean varieties is an important strategy to minimize crop failure and improve food security in bean growing regions. Previous research indicated that the superior performance of common bean genotypes under drought was associated with their ability to mobilize photosynthates to developing grain and to utilize the acquired N and P more efficiently for grain production. Among the plant traits evaluated, grain filling index and seed P content were identified as useful traits to consider in the breeding program in addition to grain yield for identifying bean genotypes that are better adapted to drought. We evaluated drought adaptation of 36 promising bred lines and accessions over 2 seasons and the average values for those 2 trials are reported here.

Materials and Methods: Two field trials were conducted at Palmira in 2001 and 2002 (June to September) to determine differences in tolerance to water stress conditions. Both trials included 36 bred lines and germplasm accessions. Two levels of water supply (irrigated and rainfed) were applied. A 6 x 6 partially balanced lattice design with 3 replications was used. Details on planting and management of the trial were similar to those reported before (CIAT, 1998). Experimental units consisted of 4 rows, 5 m long by 0.6 m wide. A number of plant attributes were measured at mid-podfilling in order to determine genotypic variation in drought resistance. These plant traits included leaf area index; canopy dry weight per plant; shoot nutrient (N, P, K, Ca and Mg) uptake; shoot and seed ash content; and shoot and seed TNC (total nonstructural carbohydrates). At the time of harvest, grain yield and yield components (number of pods per plant, number of seeds per pod, 100 seed weight) were determined. Seed N, P, ash content and TNC were measured. Pod harvest index (dry wt of pods/dry wt of total biomass at mid-podfill x 100) and grain filling index (100 seed weight of rainfed/100 seed weight of irrigated) were also determined.

Measurements of photosynthetic efficiency of recently fully expanded intact leaves were made with a portable Plant Efficiency Analyzer (Hansatech, King's Lynn, UK). Leaves were dark adapted for 20 min using leaf clips before a 5-s light pulse ($1500 \mu\text{mol m}^{-2} \text{s}^{-1}$) was supplied by an array of red light-emitting diodes. The rapid turn-on of the light-emitting diodes allowed the accurate determination of F_o (minimal fluorescence intensity with all photosystem II reaction centers open while the photosynthetic membrane is in the non-energized state in the dark) and, hence, F_v (maximum variable fluorescence in the state when all non-photochemical processes are at a minimum, i.e., $F_m - F_o$). The ratio of variable to maximal fluorescence ($F_v/F_m = (F_m - F_o)/F_m$) (F_m = fluorescence intensity with all photosystem II reaction centers closed) is a measure of the maximal photochemical efficiency of photosystem II. Leaf chlorophyll content of fully expanded leaves was measured by using a non-destructive, hand-held chlorophyll meter (SPAD-502 Chlorophyll Meter, Minolta Camera Co., Ltd., Japan). The principle is based on the difference in light attenuation at wavelengths 430 and 750 nm. From the difference in light attenuation, a numerical SPAD (Soil Plant Analysis Development) unit, ranging from 0 to 80 is calculated by the microprocessor in the SPAD-502 Chlorophyll Meter.

Results and Discussion:

Palmira – Soil, temperature, rainfall and evaporation: The soil is a Mollisol (Aquic Hapludoll) with no major fertility problems ($\text{pH} = 7.7$), and is estimated to permit storage of 130 mm of available water (assuming 1.0 m of effective root growth with -0.03 MPa and -1.5 MPa upper and lower limits for soil matric potential). During the crop-growing season, maximum and minimum air temperatures in 2001 were 30.5 and $18.7 \text{ }^\circ\text{C}$ and in 2002 were, 30.6 and $19.2 \text{ }^\circ\text{C}$ respectively. The incident solar radiation ranged from 4.6 to $25.0 \text{ MJ m}^{-2} \text{ d}^{-1}$ in 2001 and 11.2 to $24.7 \text{ MJ m}^{-2} \text{ d}^{-1}$ in 2002. Total rainfall during the active crop growth was 122.7 mm in 2001 and 83.9 mm in 2002. The potential pan evaporation was of 432 mm in 2001 and 441 mm in 2002. These data on rainfall and pan evaporation indicated that the crop suffered high level of drought stress during active growth and development.

Grain yield and physiological traits: Under water stress conditions in the field, the seed yield of 36 genotypes ranged from 448 to 1268 kg/ha (Table 4). Among the genotypes tested, two

accessions of *P. acutifolius* (G 40159 and G 40068) and two bred lines (RAB 650 and SEA 23) were outstanding in their adaptation to rainfed (water stress) conditions. There was response to irrigation in most of the genotypes but not in all genotypes as evident from the mean values (Table 4; Figure 1). This was mainly due to high incidence of a leafhopper pest (*Empoasca kraemeri*) during reproductive development in the rainfed treatment and attack of a pod-boring insect (*Epinotia opposita*) in the irrigated treatment that affected the performance of several genotypes including G 21212 in 2001 season. The relationship between grain yield of rainfed and irrigated treatments indicated that G 40159, RAB 650, SEA 23 and SEA 15 were not only adapted to water stress but also responsive to irrigation (Figure 1). Among the 36 genotypes tested, INB 36 was the most poorly adapted bred line under rainfed conditions.

Pod harvest index (PHI) is a measure of mobilization of photosynthates from leaves and stems to pod formation. Relationship between irrigated PHI and rainfed PHI showed that the two accessions of *P. acutifolius* (G 40159 and G 40068) and Pinto Villa were outstanding in maintaining greater values of PHI under both rainfed and irrigated conditions (Figure 2). Grain filling index is a measure of mobilization of photosynthates to seed formation. Four genotypes (SEA 17, G 40068, RAB 650, RAB 609) were outstanding in their ability to fill the seed under rainfed conditions (Figure 3).

Under rainfed conditions, grain yield was not related to leaf area index (Table 4). This was because several genotypes (e.g., ICA Pijao, SEA 17) had greater leaf area values than the best performers such as the two accessions of *P. acutifolius* (G 40159 and G 40068) under rainfed conditions (Table 4). The superior performance of these two accessions could be due to better transport system for mobilizing photosynthates to developing grains as revealed by the greater levels of TNC in seed (Table 5). Under rainfed conditions, the two accessions of *P. acutifolius* (G 40159 and G 40068) yielded more than any line or accession of *P. vulgaris*, demonstrating the advantage that this species continues to display over *P. vulgaris*, and justifying our on-going breeding efforts in interspecific crosses. The red seeded breeding lines (sister lines RAB 650 and RAB 651) without directed selection for drought tolerance during their development performed well under rainfed conditions. It is important to note that seed TNC at harvest of the two *P. acutifolius* accessions (G 40068 and G 40159) under rainfed conditions was also greater than many genotypes (Figure 4).

Table 4. Influence of drought stress on grain yield, leaf area index and pod harvest index (dry wt of pods/dry wt of total biomass at mid-podfill x 100) of 36 genotypes evaluated in a Mollisol at Palmira over two seasons.

Line or accession	Grain yield (kg/ha)		Leaf area index (m ² /m ²)		Pod harvest index (%)	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
G 40159 (<i>P. acutifolius</i>)	1700	1268	1.06	0.65	60	64
G 40068 (<i>P. acutifolius</i>)	1096	1264	1.14	1.14	57	64
RAB 650	1307	1112	1.8	1.82	48	44
SEA 23	1379	1036	1.79	1.33	49	46
SEA 15	1558	992	1.93	1.3	49	48
SEA 18	1128	968	1.81	1.92	43	39
RAB 651	1397	916	2.2	2.06	44	40
SEA 16	1253	904	2.88	2.39	39	33
RAB 632	1080	844	1.69	1.63	45	41
TIO CANELA 75	1264	820	1.66	1.7	43	39
SEA 5	1066	817	2.43	2	35	27
SEA 19	1204	808	2.09	1.92	46	43
BAT 477	1262	795	1.87	2.04	41	38
PINTO VILLA	1452	779	1.56	1.29	52	60
SEA 21	1223	761	1.8	1.24	49	54
SEA 20	829	747	1.92	1.68	40	37
RAB 619	1127	745	2	1.71	47	43
SEA 17	1014	741	2.67	2.28	40	35
RAB 618	1044	732	1.61	1.41	45	41
SEA 22	1251	716	1.93	1.5	47	43
G 21212	840	707	1.79	2.04	35	27
RAB 609	1248	703	1.86	1.77	42	39
RAB 636	839	698	1.81	1.54	45	41
G 1977	621	686	2.12	2.06	23	19
RAB 620	1047	679	1.39	1.61	40	35
APETITO	770	671	1.94	1.71	32	21
RJB 7	1048	645	2.11	1.71	40	38
INB 37	1027	637	2.16	1.82	44	40
INB 35	1143	635	2.87	2.13	33	26
INB 39	1183	622	2.16	1.78	33	24
INB 38	997	593	2.54	1.91	34	26
RAB 608	854	591	1.83	1.76	39	33
ICA	786	561	1.44	1.25	46	43
QUIMBAYA						
DOR 390	979	538	2	1.44	40	37
ICA PIJAO	1212	477	2.75	2.17	36	31
INB 36	939	448	2.09	1.7	35	30
Mean	1116	769	1.97	1.71	48	37
LSD (0.05)	289	198	0.56	0.52	6	11

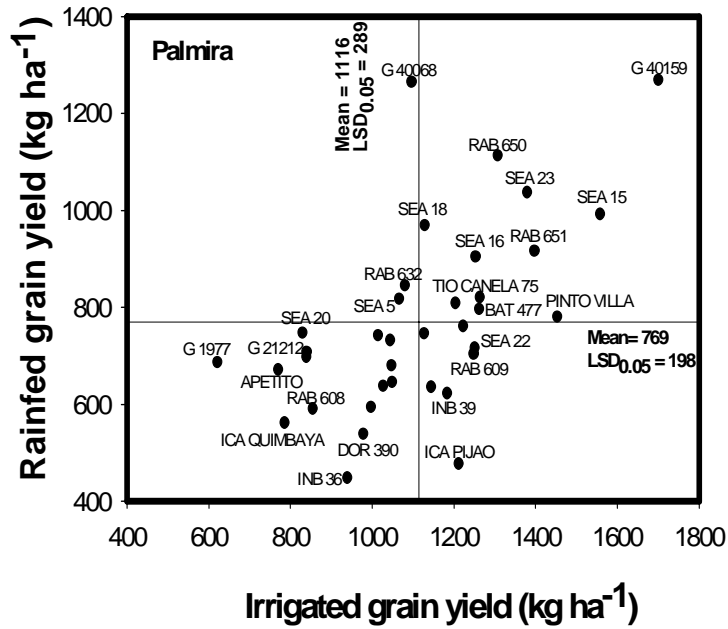


Figure 1. Identification of genotypes that are adapted to rainfed conditions and are responsive to irrigation to a Mollisol at Palmira. Genotypes that yielded superior with drought and were also responsive to irrigation were identified in the upper box of the right hand side.

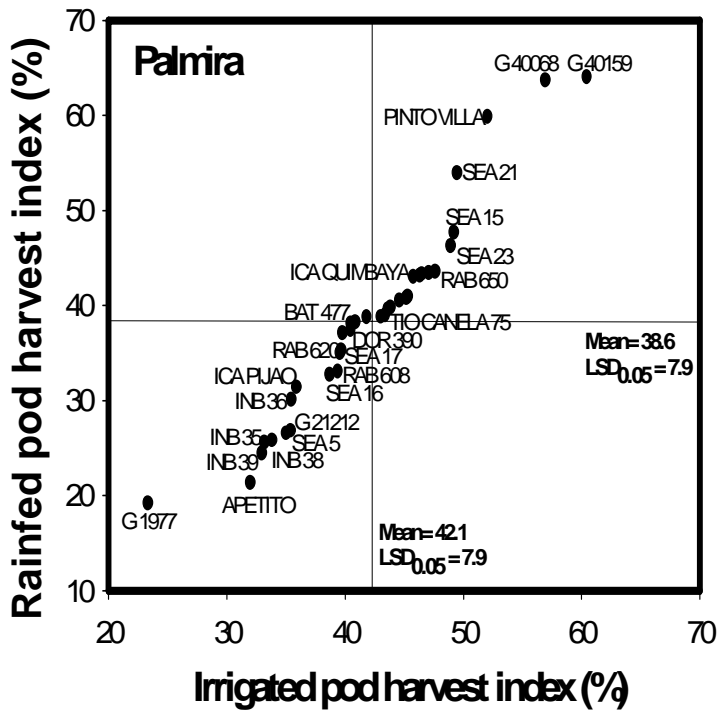


Figure 2. Identification of genotypes that are superior in mobilizing photosynthates to pod filling under both rainfed and irrigated conditions in a Mollisol at Palmira. Genotypes with greater pod harvest index (dry wt of pods/dry wt of total biomass at mid-podfill x 100) were identified in the upper box of the right hand side.

Table 5. Influence of drought stress on seed N, seed P and seed TNC content of 36 genotypes evaluated in a Mollisol at Palmira over two seasons.

Line or accession	Seed N content (%)		Seed P content (%)		Seed TNC content (mg g ⁻¹)	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
G 40159 (<i>P. acutifolius</i>)	3.53	3.69	0.54	0.52	352	343
G 40068 (<i>P. acutifolius</i>)	3.93	3.76	0.58	0.57	357	379
RAB 650	3.67	3.78	0.56	0.59	370	334
SEA 23	4.02	4.12	0.62	0.63	342	289
SEA 15	3.99	3.86	0.64	0.55	357	324
SEA 18	3.25	3.92	0.61	0.53	360	311
RAB 651	3.80	4.01	0.60	0.54	337	364
SEA 16	3.78	3.85	0.58	0.5	317	343
RAB 632	4.20	4.15	0.63	0.65	341	332
TIO CANELA 75	3.82	4.02	0.58	0.56	319	332
SEA 5	3.99	4.02	0.66	0.52	359	339
SEA 19	3.79	4.05	0.54	0.54	368	330
BAT 477	4.44	4.28	0.64	0.57	343	319
PINTO VILLA	3.55	4.05	0.50	0.54	396	292
SEA 21	3.60	3.93	0.53	0.52	363	314
SEA 20	3.77	3.92	0.59	0.54	381	367
RAB 619	3.87	3.96	0.55	0.57	360	322
SEA 17	4.17	4.09	0.72	0.56	357	294
RAB 618	3.61	4.02	0.54	0.54	385	306
SEA 22	3.76	3.81	0.57	0.55	379	313
G 21212	3.76	4.03	0.58	0.55	320	361
RAB 609	3.84	3.98	0.62	0.56	363	338
RAB 636	3.70	3.99	0.46	0.53	423	378
G 1977	4.21	4.20	0.62	0.52	282	271
RAB 620	3.68	3.99	0.61	0.54	353	362
APETITO	3.79	3.8	0.59	0.56	367	320
RJB 7	3.80	4.05	0.61	0.57	367	335
INB 37	4.11	4.30	0.64	0.61	314	296
INB 35	4.19	4.24	0.63	0.53	329	298
INB 39	3.93	4.30	0.55	0.58	279	285
INB 38	3.81	4.17	0.61	0.51	311	300
RAB 608	3.78	4.17	0.62	0.65	329	334
ICA QUIMBAYA	3.66	4.09	0.61	0.63	354	315
DOR 390	4.03	4.17	0.63	0.52	341	282
ICA PIJAO	4.22	4.11	0.60	0.53	293	326
INB 36	3.98	4.29	0.66	0.55	295	288
Mean	3.86	4.03	0.59	0.55	346	323
LSD (0.05)	0.43	0.26	0.06	0.06	76.6	59.7

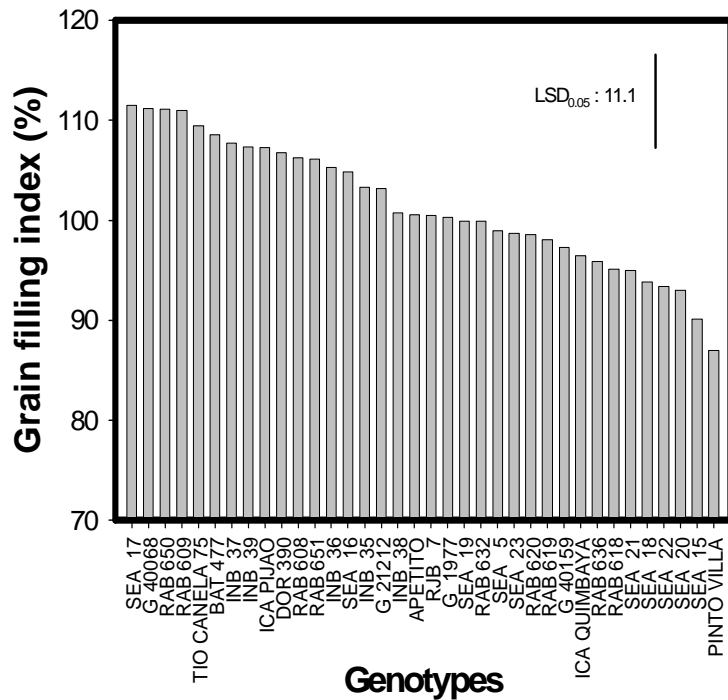


Figure 3. Genotypic differences in grain filling index (100 seed weight of rainfed/100 seed weight of irrigated) among 36 genotypes of common bean grown in in a Mollisol at Palmira.

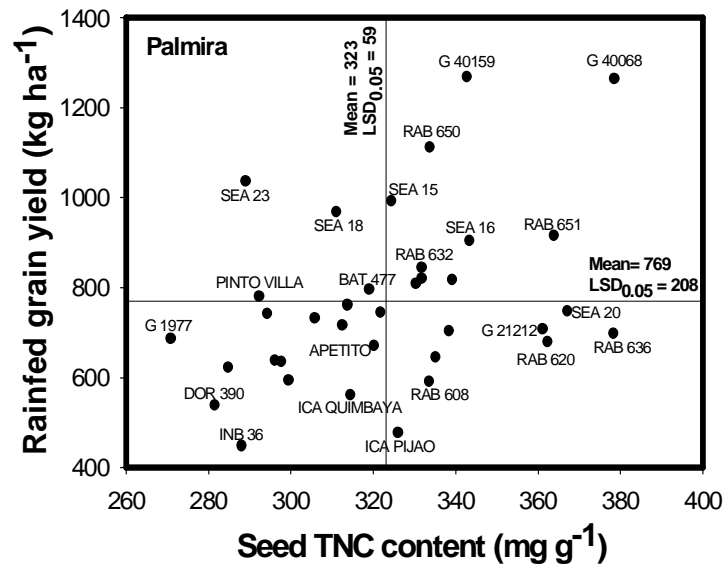


Figure 4. Identification of genotypes that combine superior seed yield with higher TNC content in seed when grown under rainfed conditions in a Mollisol at Palmira. Genotypes that were superior in grain yield and higher seed TNC were identified in the upper box of the right hand side.

Previous research showed that the superior performance of certain bean genotypes under rainfed conditions could be related to lower seed P content. We tested this relationship further by measuring seed nutrient (N, P) content (Table 5) and seed ash (total mineral) content. Several superior performers combined high grain yield with lower seed N, P and ash content. The bred line SEA 23 was outstanding in combining greater yield with higher level of seed N (protein) under rainfed conditions (Table 5). The two *P. acutifolius* accessions (G 40068 and G 40159)

showed lower seed ash content than most of the genotypes tested under rainfed conditions. Although the two *P. acutifolius* accessions (G 40068 and G 40159) were outstanding in grain yield under rainfed conditions, these two accessions showed lower levels of seed N indicating greater N use efficiency (g of grain yield per g of N uptake). One of the bred lines RAB 650 was similar to the two *P. acutifolius* accessions in its outstanding ability to utilize acquired N and P for grain production.

Correlation coefficients between final grain yield and other shoot attributes indicated that greater seed yield under rainfed conditions was positively related to pod harvest index and negatively related with seed N and P content (Table 6). Leaf area production was negatively associated with seed yield under rainfed conditions indicating that mobilization of photosynthates to grain was limiting seed yield. Significant negative relationship was also observed between seed yield and seed N and P content under rainfed conditions. This observation indicates that the superior performers mobilized greater amounts of photosynthates to seed per unit amount of N and P in the seed. Seed yield under rainfed conditions was also negatively associated with the photosynthetic efficiency and total chlorophyll content of recently expanded leaves.

Table 6. Correlation coefficients (r) between final grain yield (kg ha⁻¹) and other plant attributes of 36 genotypes of common bean grown under rainfed and irrigated conditions over 2 seasons in a Mollisol at Palmira.

Plant traits	Irrigated	Rainfed
Leaf area index	0.431***	-0.205**
Seed N content	-0.295***	-0.454***
Seed P content	-0.337***	-0.193**
Seed TNC content	0.027	0.024
Seed Ash content	0.203**	-0.009
Pod harvest index	-0.192**	0.183**
Photosynthetic efficiency (Fv/Fm)	0.180**	-0.255**
Total chlorophyll content (SPAD)	0.184**	-0.185**

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively.

It appears that the two accessions of *P. acutifolius* (G 40068 and G 40159) and two bred lines (RAB 650 and SEA 23) could mobilize greater amounts of photosynthates from leaves and stems to grain during water stress. Use of these genotypes in the breeding program could contribute to greater yield potential under rainfed conditions due to greater utilization of photosynthates. The superior adaptation of these genotypes to drought was found to be due to their efficient utilization of N and P for grain production in addition to the mobilization of photosynthates.

Conclusions: This field study indicated that two accessions of *P. acutifolius* (G 40159 and G 40068) and two bred lines (RAB 650, SEA 23) were outstanding in their adaptation to water stress conditions. The superior performance of the two accessions of *P. acutifolius* under drought was associated with their ability to mobilize photosynthates to developing grain and to utilize the acquired N more efficiently for grain production.

References:

CIAT 1998. Bean Project Annual Report 1997. CIAT, Cali, CO. 197 p. (Working Doc. No. 177).

Contributors: I. M. Rao, S. Beebe, J. Polania, J. Ricaurte, C. Cajiao, and R. García

1.1.1.3 Evaluation of drought resistance and associated traits in recombinant inbred lines (RILs)

Rationale: We evaluated 32 promising bred lines and 4 checks over 2 seasons for their adaptation to drought stress under field conditions. The results from these field studies indicated that two accessions of *P. acutifolius* (G 40068 and G 40159) and two bred lines (RAB 650 and SEA 23) were outstanding in their adaptation to water stress conditions. The superior performance of these four genotypes under drought was associated with their ability to mobilize photosynthates to developing grain and to utilize the acquired N and P more efficiently for grain production. We evaluated drought adaptation of 121 RILs of the cross MD 23-24 x SEA 5 to obtain phenotypic data for eventual gene tagging. The bred line SEA 5 is very well adapted to drought while MD 23-24 is superior in commercial grain quality.

Materials and Methods: The field trial was conducted at Palmira in 2003 (June to September) to determine differences in tolerance to water stress conditions. The trial included 121 RILs of MD 23-24 x SEA 5 along with 5 checks and 2 parents. An 11 x 11 partially balanced lattice design with 3 replicates was used. Two levels of water supply (irrigated and rainfed) were applied. Details on planting and management of the trial were similar to those reported before (CIAT, 1998). Experimental units consisted of 4 rows, 5 m long by 0.6 m wide. A number of plant attributes were measured at mid-podfilling in order to determine genotypic variation in drought resistance. These plant traits included leaf area index; canopy dry weight per plant; shoot nutrient (N, P, K, Ca and Mg) uptake; shoot and seed ash content; and shoot and seed TNC (total nonstructural carbohydrates). At the time of harvest, grain yield and yield components (number of pods per plant, number of seeds per pod, 100 seed weight) were determined. Seed N, P, ash content and TNC (total nonstructural carbohydrates) were also measured.

Results and Discussion:

Palmira – Soil, temperature, rainfall and evaporation: During the crop-growing season, maximum and minimum air temperatures were 34 and 15.8 °C, respectively, while incident solar radiation ranged from 11.2 to 24.7 MJ m⁻² d⁻¹ (Figure 5). The total rainfall during the active crop growth was 43.2 mm. The potential pan evaporation was of 337 mm. These data on rainfall and pan evaporation indicated that the crop suffered intermittent drought stress during active growth and development.

Under intermittent drought stress conditions in the field, the seed yield of 121 RILs ranged from 300 to 2250 kg/ha (Figure 6). Among the lines tested, two lines MR 81 and MR 25 were outstanding in their adaptation to rainfed (water stress) conditions. These two lines were also responsive to irrigation. The relationship between grain yield of rainfed and irrigated treatments indicated that several RILs lines were superior to the best parent, SEA 5 and the 5 checks.

Among the 121 lines tested, MR 114 was the most poorly adapted bredline under rainfed conditions.

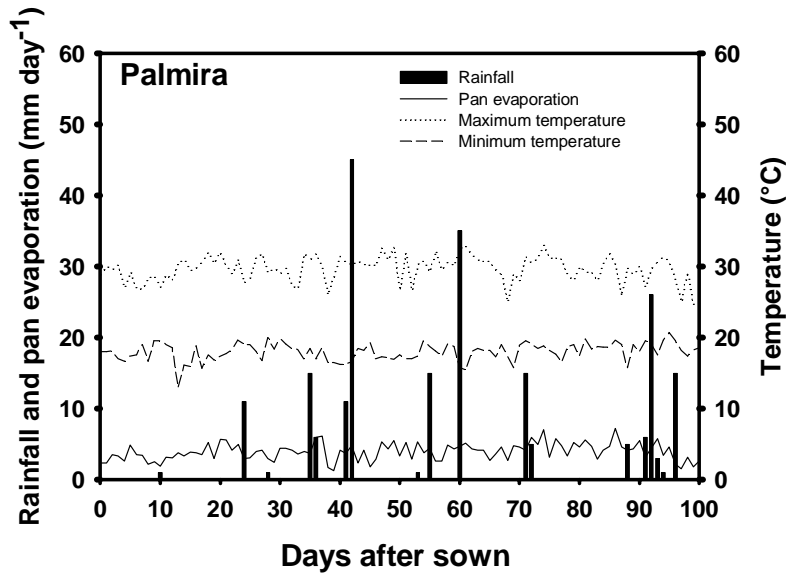


Figure 5. Rainfall distribution, pan evaporation, maximum and minimum temperatures during crop growing period at Palmira.

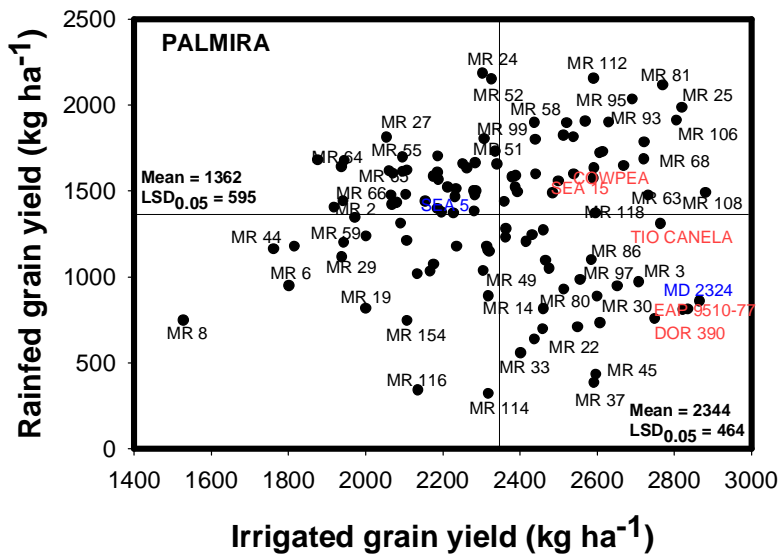


Figure 6. Identification of genotypes that are adapted to rainfed conditions, and are responsive to irrigation in a Mollisol at Palmira. Genotypes that yielded superior with drought and were also responsive to irrigation were identified in the upper box of the right hand side.

Results on the relationship between irrigated pod harvest index (PHI) and rainfed PHI showed that several RILs were superior to the drought adapted parent, SEA 5 in mobilizing photosynthates to pods (Figure 7). The PHI values of cowpea were markedly lower than those of

the common bean. Higher values of PHI indicate greater mobilization of photosynthates to pod formation while higher values of grain filling indicate greater mobilization to seed filling.

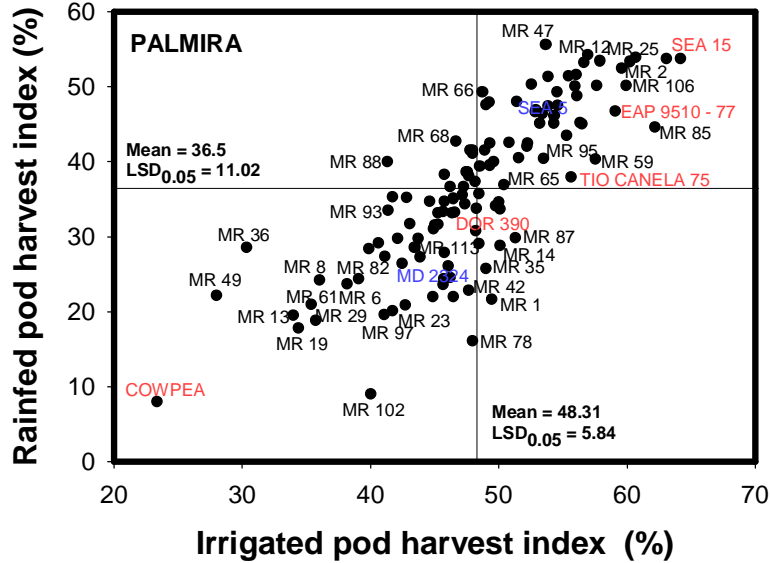


Figure 7. Identification of genotypes that are superior in mobilizing photosynthates to pod filling under both rainfed and irrigated conditions in a Mollisol at Palmira. Genotypes with greater pod harvest index (dry wt of pods/dry wt of total biomass at mid-podfill x 100) were identified in the upper box of the right hand side.

It is important to note that seed yield under rainfed conditions is positively associated with PHI, leaf area index and seed TNC content in this study (Table 7).

Table 7. Correlation coefficients (r) between final grain yield (kg ha⁻¹) and other plant attributes of RILs of common bean grown under irrigated and rainfed conditions in a Mollisol in Palmira.

Plant traits	Irrigated	Rainfed
Leaf area index	0.136**	0.394***
Seed P content	-0.041	0.013
Seed TNC content	0.026	0.176***
Seed ash content	-0.073	-0.024
Pod harvest index	0.113	0.437***

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively.

The relationship between rainfed seed yield and other plant attributes indicated that the superior performance of line MR 81 was associated with lower levels of seed P and higher level of seed TNC content. Lines MR 24 and MR 52 combined the attributes of greater level of seed TNC with seed yield under rainfed conditions (Figure 8).

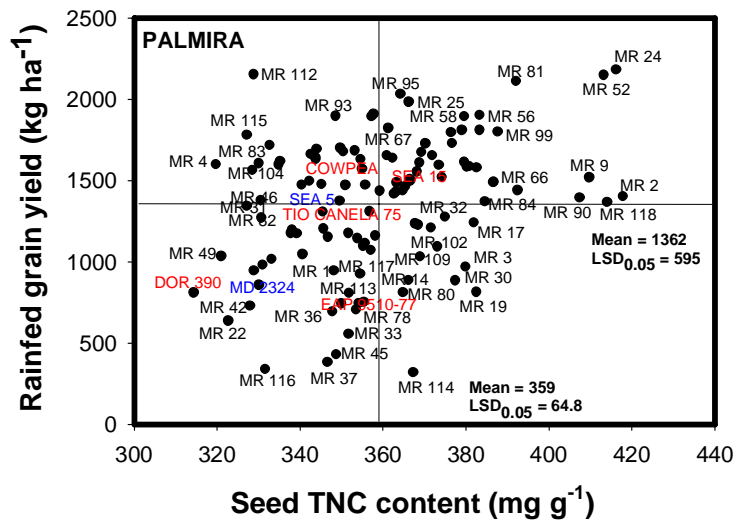


Figure 8. Identification of genotypes that combine superior seed yield with higher seed TNC when grown under rainfed conditions in a Mollisol at Palmira. Genotypes that were superior in grain yield and higher seed TNC were identified in the upper box of the left hand side.

Conclusions: Results from this field study indicated that among the 121 RILs of the cross MD 23-24 x SEA 5, two lines (MR 81, MR 25) were superior in their adaptation to drought stress conditions. The superior performance of these two lines was associated with higher values of pod harvest index and seed TNC content indicating the importance of mobilization of photosynthates to pods and seed in common bean under rainfed conditions. Therefore, these traits are candidates for gene tagging in a later phase of this work.

References:

CIAT 1998. Bean Project Annual Report 1997. CIAT, Cali, CO. 197 p. Working Document No. 177

Contributors: I. M. Rao, S. Beebe, J. Ricaurte, C. Cajiao and R. García

1.1.1.4 Genotypic differences in root distribution and drought tolerance of RIL parents

Rationale: Identification of shoot and root attributes that are associated with superior drought adaptation will help to develop rapid and reliable screening methods. These methods are needed to develop bean genotypes that combine drought adaptation with other desirable attributes. Field studies for the past few years indicated that one germplasm accession, G 21212 and two bred lines, SEA 5 and BAT 477 are superior in their adaptation to drought. RILs of BAT 881 x G 21212 and SEA 5 x MD 23-24 were also evaluated under field conditions to identify QTLs related to drought adaptation. A greenhouse study was conducted to characterize shoot and root responses to 3 different levels of water supply in these RIL parents using BAT 477 as a check for deep rooting ability and drought adaptation.

Materials and Methods: A greenhouse study was conducted using an andisol from Darién, Colombia. The trial comprises 5 entries, including 4 RIL parents (BAT 881, G 21212, SEA 5, MD 23-24) and a check (BAT 477). Plants were grown in large plastic cylinders (100 cm long and 15 cm diameter) covered with PVC tubes. The trial was planted as a randomized block in split-plot arrangement with three levels of water supply: 100% field capacity (well-watered),

60% field capacity (moderate drought stress) and 30% field capacity (severe drought stress) as main plots and genotypes as sub-plots. Soil was fertilized with an adequate level of nutrients (the equivalent in kg ha⁻¹ of 80 N, 50 P, 100 K, 101 Ca, 29.4 Mg, 20 S, 2 Zn, 2 Cu, 0.1 B and 0.1 Mo). Treatments of water stress were imposed after two weeks of initial growth of plants established with seed. Water stress was maintained by weighing each cylinder every week and applying water to the soil at the top of the cylinder. After 7 weeks of stress treatment (at 85 days after germination), shoot biomass distribution, root biomass and root length distribution in different soil depths, and leaf and stem nutrient composition, ash content and TNC (total nonstructural carbohydrates) contents were determined.

Results and Discussion: Reducing the water supply to 30% of field capacity (FC) markedly decreased the leaf, stem and pod biomass of the five genotypes (Figure 9). Total biomass production was greater with 60% FC than at 100% FC. This appeared to be due to soil compaction and poor drainage at 100% FC.

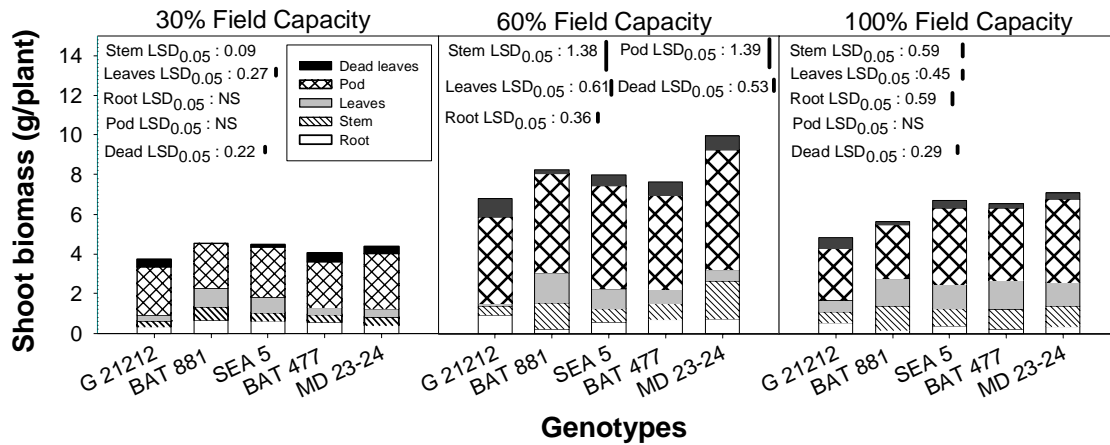


Figure 9. Influence of three levels of water supply (100%, 60% and 30% of field capacity) on dry matter distribution among leaves, stem and roots of five common bean genotypes.

Results on root length distribution showed that G 21212 and MD 23-24 were relatively unaffected by drought stress (Figure 10). Water stress at 30% FC resulted in no penetration of roots beyond 50 cm soil depth in BAT 881 and MD 23-24. These 2 genotypes are sensitive to drought under field conditions. Among the 5 genotypes, SEA 5 showed greater root length distribution at 50 to 100 cm soil depth at all three levels of water supply indicating its deep rooting ability. We noted problems of compaction in some cylinders. Therefore we conducted some additional studies to overcome these problems and found that use of 2:1 of soil and sand in smaller plastic tubes (50 cm long and 5 cm diameter) could overcome some of the problems encountered with large cylinders. Use of small cylinders will also facilitate evaluation of a larger number of genotypes for root penetration in subsoil layers and root branching ability in subsoil.

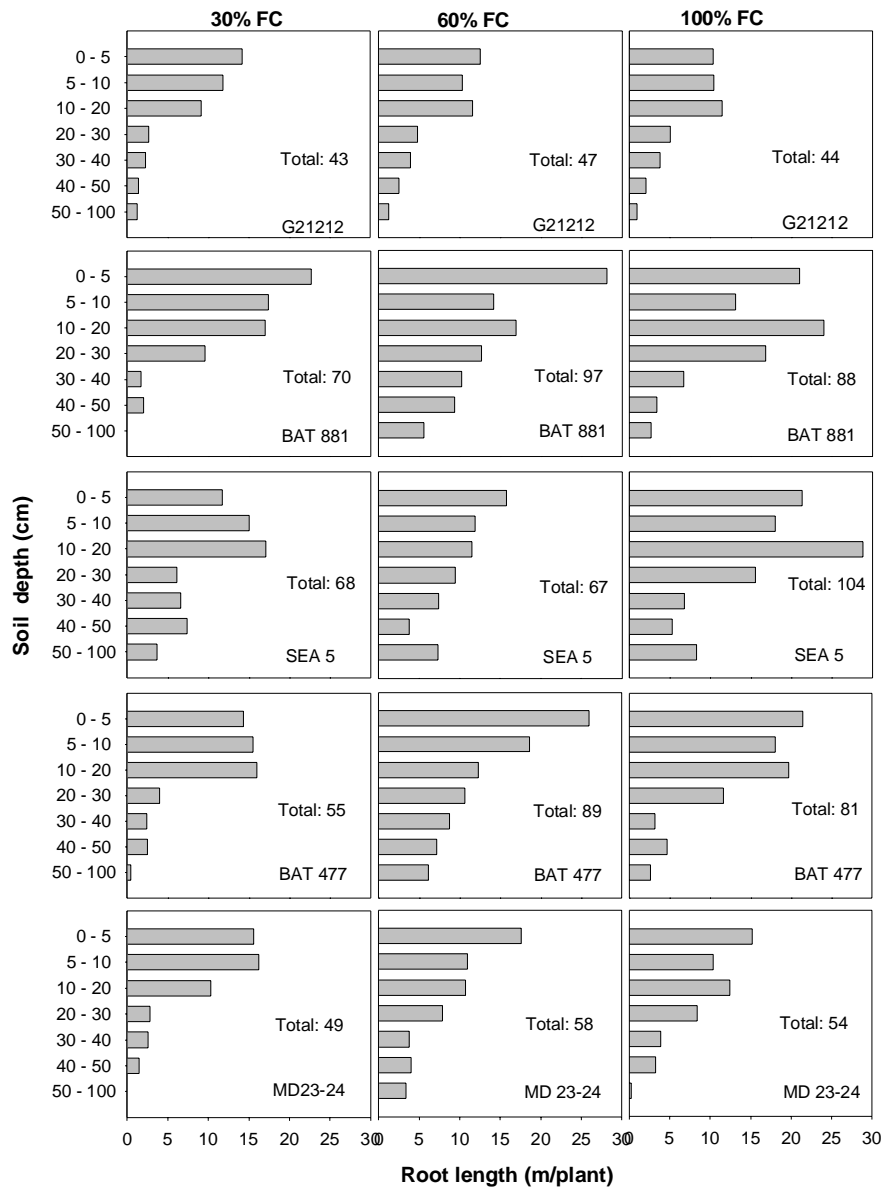


Figure 10. Influence of three levels of water supply (100%, 60% and 30% of field capacity) on root length distribution across soil depth in five common bean genotypes.

Results on the determination of N, P, ash (mineral) and TNC contents in leaves, stem and pod tissue indicated that water stress could markedly increase P content in pods. But leaf N, P, ash and TNC contents were only slightly influenced by water stress conditions.

Further work is in progress to evaluate the usefulness of fine root production in topsoil, root penetration in subsoil and root branching in subsoil as indicators of drought tolerance in common bean.

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1.1.2 Aluminum tolerance

1.1.2.1 Common bean (*Phaseolus vulgaris* L.) genotypes tolerant to aluminum-toxic soils in the tropics

Rationale: Toxicity of Al in acid soils in the tropics is a serious problem and amending soils with lime is difficult and prohibitively expensive. Common bean needs significant improvement in Al tolerance to reduce farmer dependence on lime and fertilizer. Field screening of 5000 germplasm accessions and breeding lines in Al-toxic soils with and without lime (65% Al saturation) indicated significant genotypic variation in seed yield (Rao, 2001). These genotypic differences in seed yield could be related to differences in tolerance to Al, acquisition and utilization of nutrients for transport of photoassimilates to developing seeds. Genotypes that are adapted to Al toxic soils are capable of acquiring essential nutrients in a low pH and high Al soils. Identification of plant traits that are linked to acid soil adaptation is fundamental to developing efficient screening procedures for genetic enhancement of common bean.

Materials and Methods: A set of 49 genotypes including germplasm accessions and breeding lines was evaluated at Quilichao (990 masl; Oxisol – Plinthic Kandiodox), Colombia for identification of plant attributes for adaptation to Al-toxic acid soils. A partially balanced lattice design with three replicates was used for three years. Two fertility levels were used. Plots with high fertilizer (HF) received banded application of P (40 kg/ha) in the form of triple super phosphate and two foliar application of urea (1 kg/ha). Plots with no fertilizer (NF) received no application of nutrients. Soil characterization data of NF plots showed toxic levels of exchangeable Al (66% Al saturation) and Mn (8 to 10 mg/kg) and low availability of Ca (1.4 cmol_c/kg) and Mg (0.51 cmol_c/kg) while P availability was adequate for plant growth and development. Plots of HF showed toxic levels of Mn (14 to 21 mg/kg) with very low levels of exchangeable Al. Leaf area index, shoot biomass, shoot nutrient (N, P, K, Ca and Mg) uptake and shoot total nonstructural carbohydrates (TNC) were measured at mid-podfilling (R8). Also, number of pods per plant, number of seeds per pod, 100 seed weight, seed yield and seed N, P and TNC contents were determined.

Results and Discussion: Among the 49 genotypes tested, two landraces (Carioca and G 21212) and two breeding lines (MAR 1 and SEA 5) were found to be higher yielding in Al-toxic soils (Figure 11). In NF environment, seed yield ranged from 21 to 399 kg/ha while in HF the range was from 93 to 1374 kg/ha. Relationship between seed yield in NF and HF indicated that VAX 1 was better adapted to both environments (Figure 11). In NF environment, BAT 477 exhibited greater leaf area index at mid-podfilling. This was mainly because of the ability of this genotype to acquire greater amounts of N, P, Ca and Mg from soil in the presence of toxic level of Al. Shoot Ca content of G 3593 was markedly greater than that of the most other genotypes.

Genotypes that were higher yielding in Al-toxic soils were also superior in their ability to acquire Ca and Mg from NF environment. This observation indicates the importance of Ca and Mg acquisition to seed yield when grown in Al-toxic soil. BAT 477 and SEA 5 were outstanding in combining greater seed yield with high content of N in seeds in NF environment. It appears that these two breeding lines are not only tolerant to toxic levels of Al in soil but also capable of mobilizing a greater proportion of shoot N to developing seeds. FEB 190 was also noteworthy

for its high N content in seed with moderate seed yield in NF environment. The breeding line A 785 and the landrace G 21212 were high yielding in NF but were moderate in seed N content.

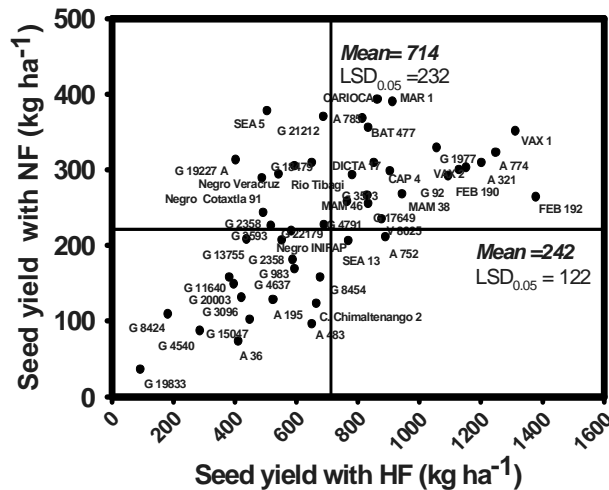


Figure 11. Identification of common bean genotypes that are adapted to Al toxic soil and are responsive to application of lime and P inputs to an Oxisol at Quilichao. Genotypes that yielded better with no fertilizer (NF) and were also responsive to application of high fertilizer (HF) were identified in the upper right hand quadrant.

Correlation coefficients between seed yield and other traits indicated that leaf area index was positively related to seed yield in NF environment (Table 8). Seed yield was also positively related to shoot nutrient uptake in both NF and HF environments. Seed yield in NF was also positively associated with shoot TNC content. A significant negative relationship was observed between seed yield and seed P and N content in NF indicating that greater P and N use efficiency contributed to superior adaptation to Al toxic soils. Results from these field studies in Quilichao indicate that two breeding lines (MAR 1 and SEA 5) and two landraces (Carioca and G 21212) were superior in their tolerance to Al-toxicity. This study also showed that it is possible to combine Al resistance with high seed N (protein) content.

Conclusions: Two landraces (Carioca and G 21212) and two breeding lines (MAR 1 and SEA 5) had the highest seed yield in Al-toxic soils. Significant negative relationship was observed between seed yield and seed P content indicating that greater seed filling and P use efficiency (g of seed produced per g of P uptake) contributed to higher yield in Al-toxic soils.

References

Rao IM 2001. Role of physiology in improving crop adaptation to abiotic stresses in the tropics: The case of common bean and tropical forages. In: M. Pessarakli (ed). *Handbook of Plant and Crop Physiology*. Marcel Dekker, Inc., New York, USA pp. 583-613.

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Table 8. Correlation coefficients (r) between seed yield (kg ha⁻¹) and other plant traits at mid-podfilling (R8) of 49 genotypes of common bean grown with no fertilizer (NF) or high fertilizer (HF) to an Oxisol at Quilichao.

Plant traits	NF	HF
Leaf area index (m ² /m ²)	0.62***	0.44***
Shoot biomass (kg/ha)	0.66***	0.58***
Shoot N uptake (kg/ha)	0.61***	0.52***
Shoot P uptake (kg/ha)	0.64***	0.50***
Shoot K uptake (kg/ha)	0.56***	0.52***
Shoot Ca uptake (kg/ha)	0.61***	0.41***
Shoot Mg uptake (kg/ha)	0.63***	0.52***
Shoot N content (%)	-0.27***	-0.24***
Shoot P content (%)	-0.22***	-0.25***
Shoot Ca content (%)	0.36***	0.05
Shoot Mg content (%)	0.17***	-0.02
Seed N content (%)	-0.24***	-0.09
Seed P content (%)	-0.27***	-0.04
Shoot TNC (g/kg)	0.19***	0.17*
Seed TNC (g/kg)	0.05	0.003

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively.

1.1.2.2 Aluminium-induced callose formation is not a suitable parameter for assessing genotypic differences in aluminum resistance in *Phaseolus vulgaris*

Rationale: Poor growth of common bean in acid soils can be correlated to Al toxicity. However, other factors like toxicities of protons and Mn, and deficiencies of P, Ca and Mg may also play a role (CIAT, 1999). At pH values below 4.5 (required for Al screenings), protons may cause plant injury in proton-sensitive plant species such as common bean (Lazof and Holland, 1999). Proton toxicity can be ameliorated through an increased supply of calcium in the nutrient solution. Formation of callose is a common plant response to different stresses. Callose induction by Al in roots has been demonstrated for monocotyledonous and dicotyledonous plant species (Horst et al., 1997). In beans, clear differentiation in Al resistance has not been found (Massot et al., 1999). The present work aimed at determining the basic nutrient solution composition to be used in assessing genotypic differences in Al resistance of common bean independently of interactions with proton toxicity; and the possible use of Al-induced callose formation for assessing genotypic differences in Al resistance.

Materials and Methods: Seeds of common bean cultivars were germinated in peat substrate (pH 5.5) and precultured in 5 mM CaCl₂, 0.5 mM KCl and 8 μM H₃BO₃ under controlled environmental conditions. After pH adjustment, plants were treated with Al and solution pH was maintained at pH 4.5 ± 0.1. Root length was measured before and after 36 h of Al treatment, and was expressed in percentage of the controls without Al. Callose content in the 10 mm root apices was quantified according to standard methods.

Results and Discussion: The nutrient solution used successfully for the screening of maize for Al resistance (Horst et al., 1997) proved to be unsuitable for common bean because at pH 4.3 and 0.5 mM Ca²⁺ root elongation was greatly reduced making it difficult to select for Al resistance because of the lack of a proper control (Figure 12). However, proton toxicity could be avoided by adjusting the pH to 4.5, increasing the Ca supply to 5 mM Ca²⁺, and adding 0.5 mM K⁺. This did not affect the Al sensitivity of the plants.

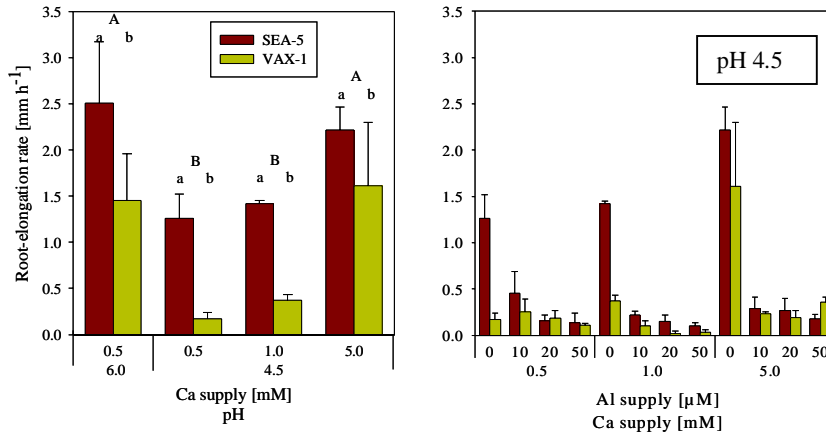


Figure 12. Root-elongation rate of two common bean grown in nutrient solution for 36 h as affected by Ca, and Al supply. Bars represent means \pm SD, n = 4. Different letters indicate significant differences ($p < 0.05$) between cultivars (a,b) or pH/Ca supply (A,B)

The thus modified treatment solution allowed clear separation of a larger set of genotypes for Al resistance using Al-induced inhibition of root elongation as a parameter. After 36 h of Al treatment large differences in Al resistance among the 28 cultivars tested could be identified (Figure 13).

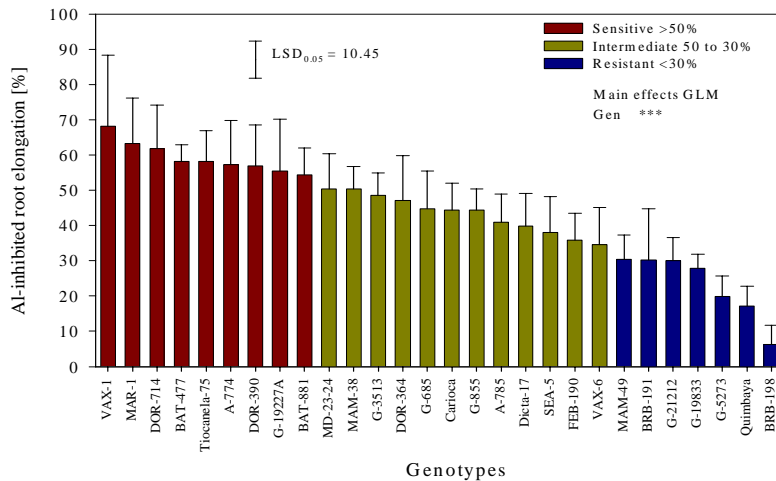


Figure 13. Aluminum-induced inhibition of root elongation of 28 common bean cultivars grown in a solution containing 5 mM CaCl₂, 0.5 mM KCl, and 8 μ M H₃BO₃, pH 4.5 for 36h with or without 20 μ M Al, pH 4.5. Bars represent means \pm SD, n = 8.

As in maize (Horst et al., 1997) and soybean (Wissemeier and Horst, 1995), in common bean Al induced formation of callose in the root apices. However, maximum callose contents were found at 4 h of Al treatment and decreased thereafter. There was no clear differentiation between the cultivars that differed in Al resistance: no relationship existed between Al resistance as expressed by Al-induced inhibition of root elongation and callose formation (Figure 14)

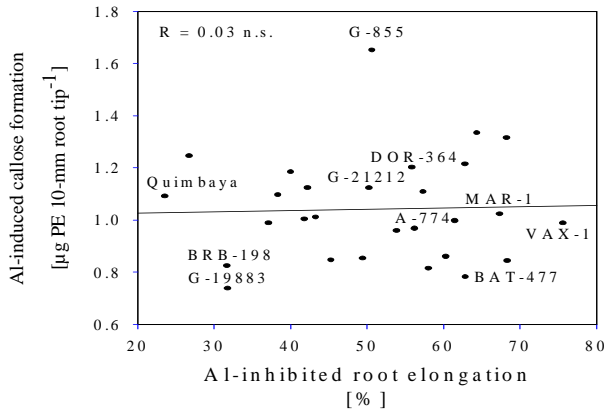


Figure 14. Relationship between Al-induced callose formation in 10 mm root apices after 4h of Al treatment, and Al-induced inhibition of root elongation after 36h of Al treatment. A total of 28 common bean cultivars were treated with 20 µM Al in a solution containing 5 mM CaCl₂, 0.5 mM KCl, and 8 µM H₃BO₃, pH 4.5.

The results suggest that in common bean Al-induced callose formation after short-term Al treatment leading to maximum callose contents in the root apices, is not a suitable parameter for assessing cultivar difference in Al resistance. These results are not in agreement with Massot et al. (1999). The main reason might be that common bean belongs to the pattern II plant species (Ma et al., 2001), where Al resistance mechanisms are only switched on after a lag phase of a few hours. Thus, after 4 h of Al treatment, all cultivars react as sensitive to Al as suggested by callose formation. The elucidation of Al resistance mechanisms in common bean requires a clear separation and better understanding of short and medium-term responses to Al.

Conclusions: Proton toxicity did not allow the screening of common bean genotypes using the established protocol for maize (0.5 mM CaCl₂, 8 µM H₃BO₃, pH 4.3). Increasing the pH to 4.5 and the Ca²⁺ concentration to 5 mM, and addition of 0.5 mM KCl fully prevented proton toxicity and allowed establishing large differences in Al resistance between 28 cultivars using inhibition of root elongation by treatment with 20 µM Al for 36 h as parameter of Al injury. Al induced callose formation in root apices with a maximum after 4 h of Al treatment. However, no relationship existed between Al-induced callose formation after 4h and inhibition of root elongation after 36h. Therefore, Al-induced callose formation is not a suitable parameter for assessing genotypic differences in Al resistance in common bean.

References:

- CIAT 1999: Meeting demand for beans in Sub-Saharan Africa in sustainable ways. Annual Report of the project IP-2. CIAT, Cali, Colombia.
- Horst, W. J., Püschel, A. K., and Schmohl, N. 1997. Induction of callose formation is a sensitive marker for genotypic aluminium sensitivity in maize. *Plant Soil*. 192, 23-30.
- Lazof, D. B. and Holland, J. M. 1999. Evaluation of the aluminium-induced root growth inhibition in isolation from low pH effects in *Glycine max*, *Pisum sativum* and *Phaseolus vulgaris*. *Aust. J. Plant Physiol.* 26, 147-157.
- Ma, J. F., Ryan, P. R., and Delhaize, E. 2001. Aluminium tolerance in plants and the complexing role of organic acids. *Trends in Plant Science*. 6, 273-278.
- Massot, N., Llugany, M., Poschenrieder, C., and Barcelo, J. 1999. Callose production as indicator of aluminium toxicity in bean cultivars. *J. Plant Nutr.* 22, 1-10.
- Wissemeyer, A. H. and Horst, W. J. 1995. Effect of calcium supply on aluminium-induced callose formation, its distribution and persistence in roots of soybean (*Glycine max* L. Merr.). *J. Plant Physiol.* 145, 470-476.

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1.1.2.3 Selection of families and lines of common bean with acid-soil tolerance

Rationale: As part of a restricted core project funded by BMZ-GTZ of Germany, field studies were carried out at Quilichao (990 masl; Oxisol – Plinthic Kandiudox) to select parental stocks and segregating populations for tolerance to an acid soil complex in which aluminum toxicity is a major component. Genetic differences have been observed for many years for the ability to produce grain under aluminum toxic conditions in Quilichao. With this effort we sought to exploit this variability and to increase levels of tolerance through conventional breeding techniques.

Materials and Methods: Germplasm that had presented superior performance in the low pH soil in Quilichao in previous years were selected for crossing (VAX 1, G24601, G21212, RAB 655, Apetito, SEA 15, A 774). In addition, Durango and Jalisco germplasm including Flor de Mayo accessions were tested both in Quilichao and in Rwanda, and elite accessions were identified (G19024, G1816, G2285, G21164, G11049, G13538, G19168, G22401). Physiological analysis subsequently demonstrated that some of these have a high number of root tips that favor calcium uptake, thus justifying their inclusion in crosses. Special attention was given to crosses that incorporate a small contribution of Andean genes (using BRB 191, BRB 198, and G5273) into a Mesoamerican background, to attempt to introduce the reaction expressed in Andean accession G5273 into Mesoamerican types. Crosses that combine even 25% of Andean genes in crosses with Mesoamerican types tend to be poorly adapted, so the Andean contribution was reduced to 6.25-12.5% in most cases.

Results and Discussion: Progress has been very slow, probably due to a combination of the narrow genetic variability and the very complexity of the acid soil problem (multiple problems that occur at low soil pH: besides aluminum *per se*, manganese toxicity and calcium and magnesium deficiencies). That said, several promising crosses (pending confirmation) combine an Andean parent in a small proportion with Mesoamerican parents (see Table 9). For example,

the cross ((G 24601 x (MAM 38 x BRB 198)F₁)F₁ x G 11015)F₁ X (MAM 38 x G 21212)F₁ produced promising progenies. Among the parents of this complex cross, BRB 198 is the only Andean type and here represents only one-sixteenth of the genetic constitution. Our expectation is that it is contributing genes for the same reaction that is observed in the greenhouse hydroponic test, and that these are combining with genes for vigorous root development from other parents. If this is confirmed, it would be a unique example in the case of common beans in which physiology led breeding in identifying useful traits that could not be recognized under conventional field breeding.

Conclusions: Progress in improving the tolerance of bean to aluminum toxicity has been extremely slow, due to narrow genetic diversity and the complexity of the acid soil problem. A definitive conclusion on degree of progress is pending.

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Table 9. Families in F₃ to F₇ generations evaluated in Quilichao 2003B – 2004A. Andean parents appear in bold type.

Code	Num	Identification	Families Evaluated Q03B	Families Selected Q03B	Ind. Plant sel. Q03B	Families Evaluated Q04A	Families Selected Q04A	F n
AL	14300	G 24601 X (G 22041 x BRB 198)F ₂ /-	5	3	5	3	1	F3
AL	14709	G 21212 X (G 22041 x BRB 198)F ₁ /-	22	5	12	11	0	F3
AL	14710	(G 1759 x G 5273)F ₁ X G 21212/-	4	0	0	0	0	F3
AL	14711	(SEA 15x G 5273)F ₁ X G 21212/-	20	0	0	0	0	F3
AL	14712	(VAX 1x BRB 191)F ₁ X G 21212/-	25	8	32	27	8	F3
AL	14713	(BRB 198)F ₂)F ₁ /- (MAM 38xG 21212)F ₁ X (G 24601x(G 22041x BRB	10	3	14	12	3	F3
AL	14714	(BRB 198)F ₂)F ₁ /- (RAB 655xG 21212)F ₁ X (G 24601x(G 22041x BRB	14	8	49	41	6	F3
AL	14715	(BRB 198)F ₂)F ₁ /- (SEA 15x(A 774xG 21212)F ₁)F ₁ X (G 24601x(G 22041x	8	0	0	0	0	F3
AL	14716	(BRB 198)F ₂)F ₁ /- (MAM 49xG 21212)F ₁ X (G 24601x(G 22041x BRB	15	1	3	2	0	F3
AL	14717	(BRB 198)F ₂)F ₁ /- (SEA 15xDICTA 17)F ₁ X (G 24601x(G 22041x BRB	2	0	0	0	0	F3
AL	14718	(BRB 198)F ₂)F ₁ /- (G 1759xG 21212)F ₁ X (G 24601x(G 22041x BRB	5	1	4	4	0	F3
AL	14719	(BRB 198)F ₂)F ₁ /- (G 22041xG 21212)F ₁ X (G 24601x(G 22041x BRB	27	4	15	14	0	F3
AL	14722	(MAM 38xG 21212)F ₁ xG 19073)F ₁ X (SEA 15xDICTA 17)F ₁ /-	7	2	11	9	0	F3
AL	14723	((MAM 38xG 21212)F ₁ X G 19073)F ₁ X G 13637/-	9	2	7	5	0	F3
Total			173	37	152	128	18	F3

Table 9. cont'd.

Code	Num	Identification	Families Evaluated Q03B	Families Selected Q03B	Ind. Plant sel. Q03B	Families Evaluated Q04A	Families Selected Q04A	F n
SF	13953	SEA 15 x (A 774xG 21212)F ₁ /-	1	1	4	4	0	F 4
AL	14300	G 24601 X (G 22041 x BRB 198)F ₂ /-	5	2	11	10	1	F 4
AL	14367	(MAM 38xG 21212)F ₁ X G 19073/-	16	1	41	39	12	F 4
AL	14586	((G 24601x(MAM 38 x BRB 198)F ₁)F ₁ xG 11015)F ₁ X	13	5	40	39	12	F 4
AL	14587	(9824-47-1/F ₇ xG 21212)F ₁ /-	5	1	11	11	3	F 4
AL	14588	(RAB 655x(G 22041xRIB 66)F ₁)F ₁ xG 11015)F ₁ X (MAM	9	2	4	4	1	F 4
AL	14595	21212)F ₁ /-	11	4	31	27	3	F 4
AL	14589	((G 24601x(MAM 38xRIB 66)F ₁)F ₁ xG 19017)F ₁ X (MAM	1	0	0	0	0	F 4
AL	14591	(RAB 655x(MAM 49xRIB 66)F ₁)F ₁ xG 19017)F ₁ X	2	1	5	5	0	F 4
AL	14592	(MAM 38xG 21212)F ₁ /-	2	0	0	0	0	F 4
AL	14593	((G 24601x(MAM 49xRIB 66)F ₁)F ₂ xG 15989)F ₁ X (MAM	1	0	0	0	0	F 4
AL	14594	15xDICTA 17)F ₁ /-	4	2	18	15	4	F 4
		((G 24601x(MAM 49xRIB 66)F ₁)F ₂ xG 15989)F ₁ X (9824-						
		1459447-1/F ₇ xG 21212)F ₁ /-						
		Total	70	19	165	154	36	F 4
AL	14300	G 24601 X (G 22041 x BRB 198)F ₂ /-	28	6	13	13	4	F 5
AL	14362	(RAB 655 X (G 22041xRIB 66)F ₁)F ₁ X G 11015/-	1	0	0	0	0	F 5
AL	14547	G 19017 X (SEA 15xDOR 714)F ₁ /-	1	0	0	0	0	F 5
AL	14557	G 15989 X (DOR 714 xMAM 49)F ₁ /-	1	0	0	0	0	F 5
AL	14544	G 11037 X (SEA 15xDOR 714)F ₁ /-	1	0	0	0	0	F 5
AL	14561	TIO CANELA 75 X (MUS 131xG 24601)F ₁ /-	1	1	13	9	2	F 5
SX	14508	(SEA 15xDOR 714)F ₁ X (9824-47-1/F ₇ xG 21212)F ₁ /-	1	0	0	0	0	F 5
		Total	34	7	26	22	6	F 5
SF	13952	SEA 15 x (RAB 655 x G 21212)F ₁ /-	1	1	5	2	0	F 6
AL	14301	RAB 655 X (G 22041xRIB 66)F ₁ /-	1	0	0	0	0	F 6
AL	14304	RAB 655 X (MAM 49xRIB 66)F ₁ /-	2	2	15	12	4	F 6
		Total	4	3	20	14	4	F 6
		Grand Total	281	66	363	318	64	
		Number of crosses	34	21	21	21	12	

1.1.2.4 Screening of RILs of G 5273 x MAM 38 for resistance to aluminum using nutrient solution

Rationale: Previous research showed that an Andean germplasm accession, G 5273 is relatively resistant to Al in nutrient solution culture while MAM 38, a Mesoamerican advanced line, is sensitive based on the rate of tap root elongation in the presence of Al. Moreover, G 5273 is also known to be tolerant to both anthracnosis and angular leaf spot diseases. The objective of this study is to evaluate the recombinant inbred lines (RILs) of G 5273 x MAM 38 for their tolerance to Al in low ionic strength nutrient solution under greenhouse conditions using relative root elongation and root architecture. The results from this study are useful to identify QTLs associated with Al resistance in common bean.

Materials and Methods: The two parents and the 66 RILs (recombinant inbred lines) were evaluated using low ionic strength nutrient solution in the presence or absence of aluminum (50 μ M) at pH 4.5. Each genotype is replicated 3 times using plastic containers with 20 L nutrient solution. The details on composition of nutrient solution were reported before (CIAT, 2002). Differences among genotypes in root architecture (length, diameter and number of root tips) were quantified using WinRhizo® software program after 3 days with or without Al treatment. Root system was stained with methelene blue or neutral red (0.1% in deionized water). Total dry wt of roots was determined by drying roots at 65 °C in an oven for 48 h. Specific root length was determined based on root dry wt and root length. The % decrease in total root length or average root diameter was determined as reported before (CIAT, 2003).

Results and Discussion: Based on total root length per plant and average root diameter per plant, the RILs HF14137-19, HF14137-104, HF14137-26, HF14137-101 and HF14137-98 were identified as outstanding in their resistance to Al for combining greater root length with finer root system while the RILs HF14137-97, HF14137-17, HF14137-1, HF14137-77 and HF14137-5 were identified as Al sensitive (Figure 15).

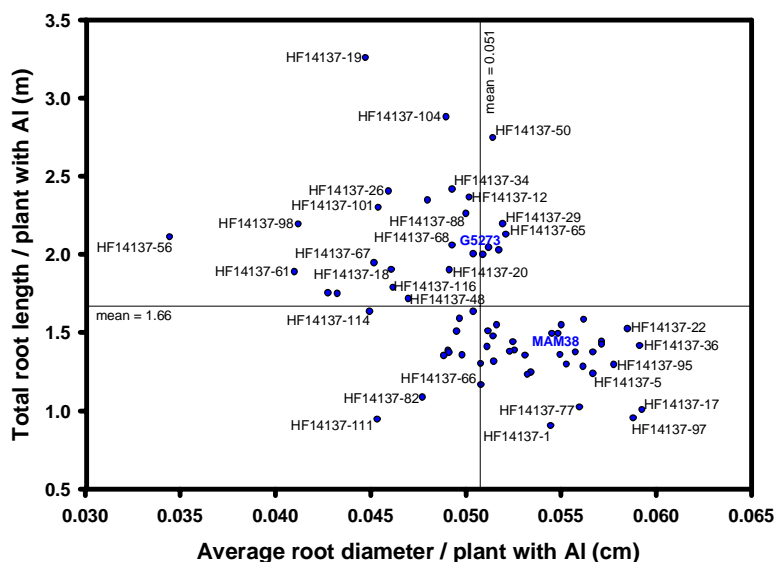


Figure 15. Relation between total root length and average root diameter with Al (50 μ M) in nutrient solution for 3 days.

Three RILs HF14137-12, HF14137-98 and HF14137-101 were outstanding in terms of combining greater root length per plant with number of root tips per plant. The greater number of root tips found in these RILs could improve acquisition of Ca from infertile acid soils since root tips are the principal sites of Ca acquisition. On the other hand, five RILs HF14137-1, HF14137-82, HF14137-111, HF14137-97 and HF14137-17 showed lower values for these two attributes (Figure 16).

The increase in average root diameter per plant and the decrease in total root length per plant are indicators of the effect of Al toxicity as the Al resistant plants show longer and finer roots. Four RILs HF14137-19, HF14137-98, HF14137-88 and HF14137-26 showed lower values for these two attributes indicating greater level of Al resistance. Three RILs HF14137-7, HF14137-77 and HF14137-28 showed greater sensitivity to Al (Figure 17).

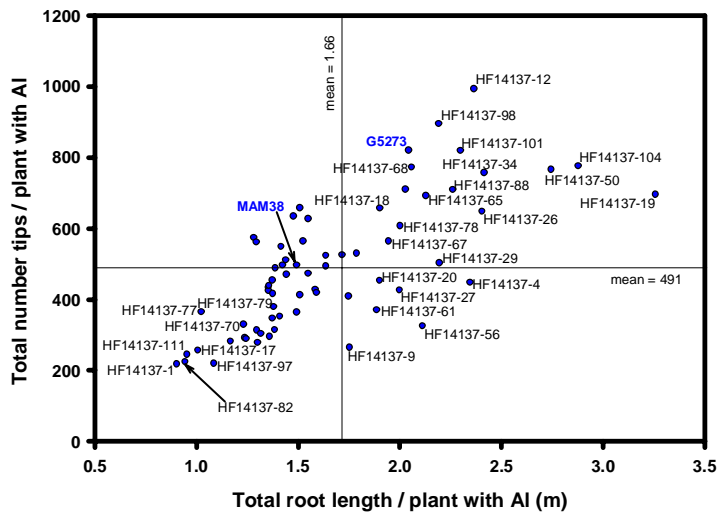


Figure 16. Relation between total number of root tips and total root length with aluminum (50 μM) in nutrient solution for 3 days.

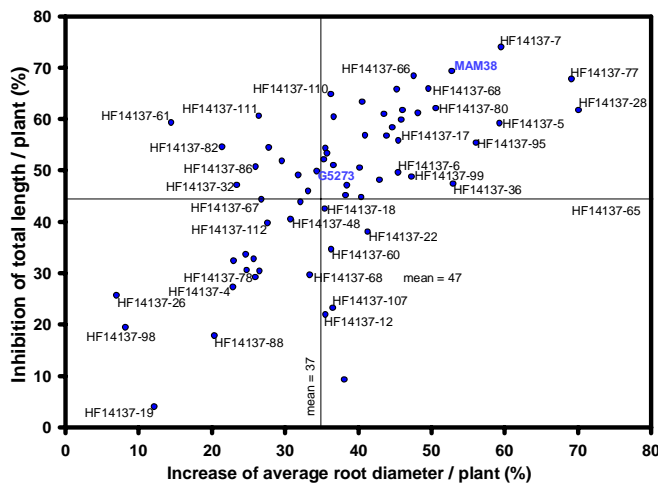


Figure 17. Relation between inhibition of total root length and increase of average root diameter in the presence of Al (50 μM) in nutrient solution for 3 days.

Conclusions: Results from this study indicate that four lines, HF14137-19, HF14137-26, HF14137-98 and HF14137-88 were relatively more resistant to Al.

References:

- CIAT. 2002. Annual Report 2002 Project IP-1. Bean improvement for the tropics. CIAT, Cali, CO.
CIAT. 2003. Annual Report 2003 Project IP-1. Bean improvement for the tropics. CIAT, Cali, CO.

Contributors: G. Manrique, I.M. Rao and S. Beebe

1.1.2.5 Evaluation of a core collection of *Phaseolus coccineus* and *P. polyanthus* for field tolerance to aluminum

Rationale: In previous years, a core collection was established that is composed of sister species of the secondary gene pool of common bean. *P. coccineus* and *P. polyanthus* evolved on volcanic soils in moist highland environments. Although soil organic matter tends to be high in these soils, aluminum can be a problem of intermediate intensity. Both species are cross compatible with common bean, and *P. coccineus* in particular presents broad genetic variability.

Materials and Methods: Seed of 155 accessions of the core collection were obtained from the Genetic Resources Unit and planted in the field in Santander de Quilichao (990 masl; Oxisol – Plinthic Kandiodox) in unreplicated single row plots, to evaluate vegetative vigor under aluminum stress. A tolerant common bean check of VAX 1 was planted every 10 rows for comparison. Accessions were evaluated visually when the common bean check was entering flowering.

Results and Discussion: Wide variability in vigor was observed in the field, with several accessions accumulating far more biomass than the common bean checks. Although the core collection is approximately 50% *P. polyanthus*, only accessions of *P. coccineus* were identified as presenting unusual vigor. This tends to confirm that selection was not random and reflected genetic potential in adaptation to these conditions. Nineteen accessions were selected for additional study in both field and greenhouse hydroponic tests (Table 10). Some of these had been identified previously for their resistance to biotic constraints (BGYMV and Bean Stem Maggot). If the tolerance to aluminum is confirmed, this will represent a potential breakthrough for the common bean, as *P. coccineus* crosses readily with *P. vulgaris*. By using the greenhouse screening method that has been developed, it could be possible to backcross the respective genes to common bean with confidence, and recover the common bean phenotype with relative ease.

Conclusions: *P. coccineus* may offer a significant advantage over common bean in tolerance to aluminum. This possible advantage must be confirmed to determine if it is warranted to make interspecific crosses or to screen existing interspecific hybrid progeny.

Contributors: S. Beebe, I. Rao, C. Cajiao

Table 10. Accessions of *P. coccineus* selected from the core collection of the secondary gene pool for adaptation to infertile soil with high aluminum saturation.

Accession	Country of Origin	Other traits ¹
G 35023	MEX	Res. to BSM
G 35025	TUR	
G 35066	MEX	
G 35103	MEX	
G 35105	MEX	
G 35157	MEX	
G 35172	RWA	Res. to BGYMV
G 35266	HND	
G 35341	MEX	Res. to BSM
G 35346	MEX	Res. to BSM
G 35369	CRI	
G 35405	MEX	
G 35448	MEX	
G 35464	MEX	
G 35609	MEX	
G 35621	MEX	
G 35777	GTM	
G 35884	YUG	
G 36022	ROM	

¹BSM = Bean Stem Maggot, BGYMV = bean golden yellow mosaic virus

1.1.3 Tolerance to low phosphorus

1.1.3.1 Screening of RILs of BAT 477 x DOR 364 for tolerance to low phosphorus using nutrient solution

Rationale: Last year, we reported on a screening method to evaluate bean germplasm for low phosphorus supply in nutrient solution based on number of basal roots (CIAT, 2003). This year, we used the same screening method to evaluate 30 RILs of BAT 477 x DOR 364 for their root architecture using WinRhizo® software program. The main objective of this study was to determine differences in root architecture among RILs and use that information to identify QTLs for root architecture related to low P adaptation.

Materials and Methods: A total of 36 genotypes including 2 parents (BAT 477 and DOR 364), 2 non-nodulating lines of the parents (BAT 477NN and DOR 364NN), 30 RILs and 2 checks (G 21212 and V 8025), were evaluated at 2 levels of phosphorus in nutrient solution. The details on two levels of P (low and high) and the nutrient solution composition were reported last year (CIAT, 2003). Each genotype was replicated with 8 plants per each treatment of low and high P. After 9 days of treatment with low P, the plants were harvested and the root systems were scanned and the root architecture was analyzed using WinRhizo® software program. Shoot and root biomass was determined after drying the samples in an oven at 65 °C for 48 h.

Results and Discussion: Four RILs BT21138-4, BT21138-50, BT21138-115, BT21138-25 and an advanced line V 8025 were outstanding in their ability to produce greater root length per plant under both low and high P supply while three RILs BT21138-104, BT21138-3, BT21138-16 were less adapted to low P and less responsive to high P. The greater value of total root length per plant indicates that the plant could explore greater volume of soil to acquire P from low fertility soils that are deficient in P supply (Figure 18).

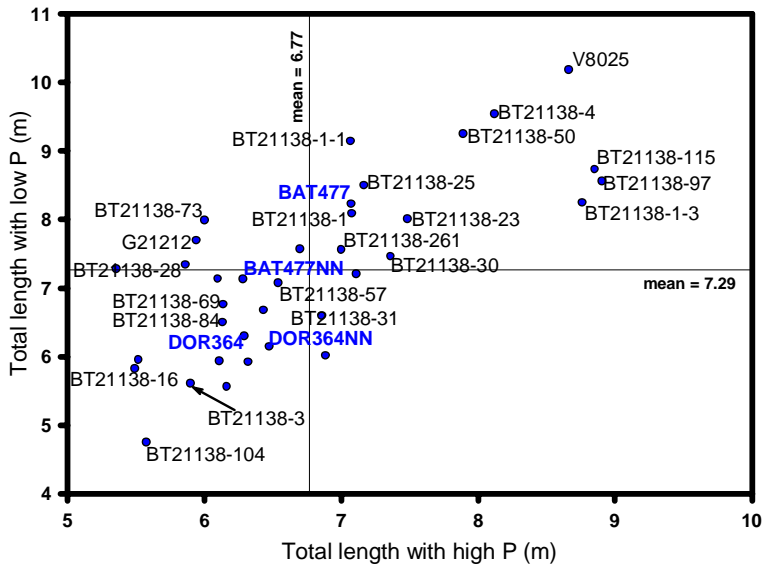


Figure 18. Relationship between the total root length with low and high P supply in nutrient solution.

We also found that six RILs BT21138-50, BT21138-83-1-1, BT21138-1-3, BT21138-1, BT21138-4 and BT21138-25 were superior in their root architecture by combining greater root length with greater number of root tips per plant with low P supply (Figure 19). This observation indicates that these genotypes could be capable acquiring greater amounts of P from soil with their branched root system. We identified five RILs BT21138-104, BT21138-124-1-2, BT21138-16, BT21138-3 and BT21138-31 that were markedly inferior in their ability to develop vigorous root system.

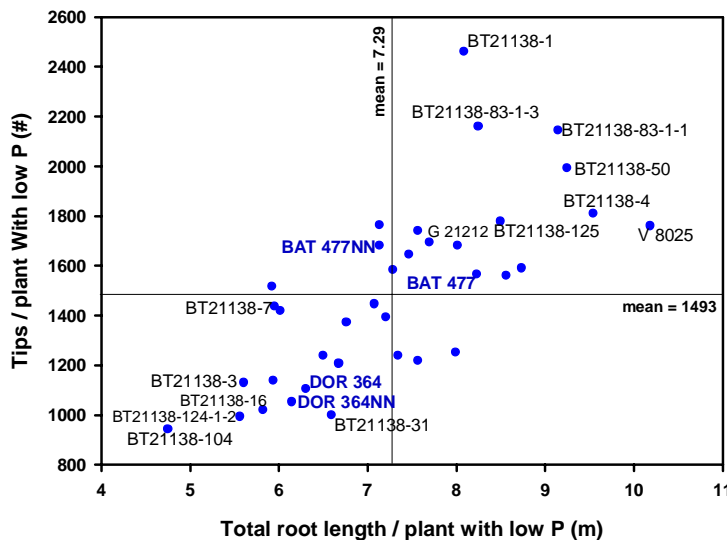


Figure 19. Relationship between the total root length per plant and the number of tips per plant in nutrient solution with low P

The greater production of root biomass per plant with low P supply was observed with four RILs BT21138-83-1-1, BT21138-83-1-3, BT21138-50 and BT21138-115, while RILs BT21138-31, DOR364NN, BT21138-96 and BAT477NN were markedly inferior in their ability to produce root biomass (Figure 20).

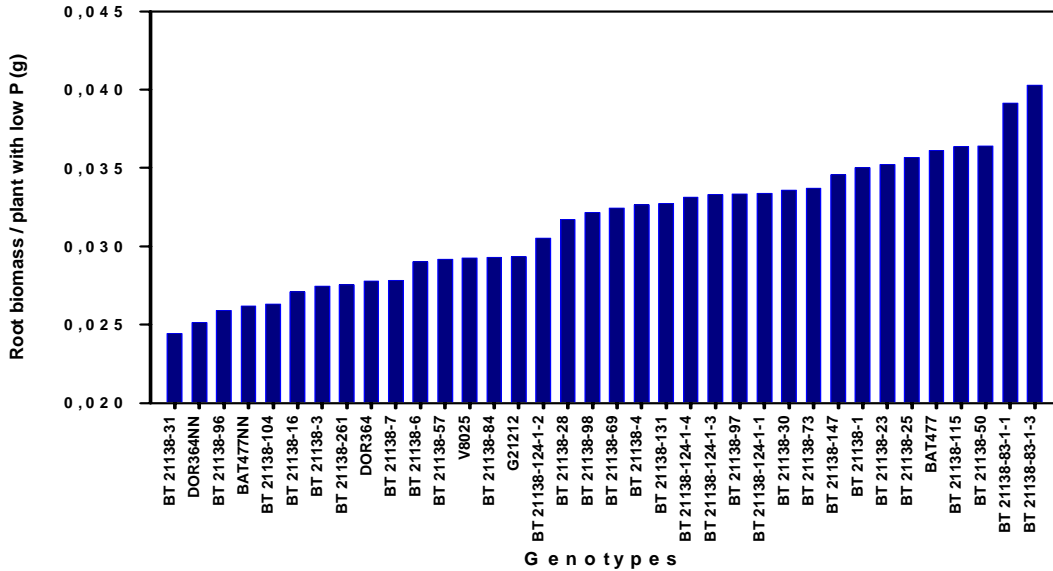


Figure 20. Root biomass per plant in nutrient solution with low P

Conclusions: Results from this study indicated that four RILs BT21138-50, BT21138-83-1-3, BT21138-83-1-1 and BT21138-25 are superior in their adaptation to low P supply based on total root length, number of root tips and total root biomass per plant.

References:

CIAT. 2003. Annual Report 2003 Project IP-1. Bean improvement for the tropics. CIAT, Cali, CO.

Contributors: G. Manrique, I.M. Rao and S. Beebe

1.1.3.2 Effect of low P availability on shoot and root development of six common bean genotypes grown in nutrient solution

Rationale: Last year we reported the effect of low P availability on total number of basal roots of RIL's of BAT 477 x DOR 364 (CIAT, 2003). We found that low P treatment for 9 days influenced basal root development but had limited effect on shoot development. This year, we conducted a study to evaluate the effect of low P supply for extended time of up to 3 weeks to determine the effects on both root and shoot development to determine the optimum time for screening under low P conditions.

Materials and Methods: A group of 6 genotypes including 2 landraces (G 19833 and G 21212) and 4 bred lines (DOR 364, DOR 390, BAT 477 and VAX 1) were evaluated with two P levels in nutrient solution at three intervals. The P levels were 0.25 μM for low and 75 μM for high and the evaluations were done at 1, 2 and 3 weeks after exposure to both P levels. Details on nutrient solution composition were reported last year (CIAT, 2003). Each genotype was replicated with three plants in each treatment with low or high P. After 7, 14 21 days of treatment, the plants were harvested and the root systems scanned and then analyzed with the WinRhizo® program. The shoot and root biomass were determined after drying in an oven at 65°C for 48 hours.

Results and Discussion: As reported before (CIAT, 2002 and 2003), the effects of the low P availability were evident from the first week on both total root length and leaf area production, which decreased around 15% and 35% respectively, with no significant genotypic differences among 6 genotypes (Figure 21; Table 11). After two weeks, the differences among the 6 genotypes increased showing reduction of up to 40% in both root length and leaf area production. After 3 weeks of low P treatment, total root length decreased up to 50% (Figure 21) while leaf area production diminished by 80% (Figure 21). Decrease in leaf area production was more marked between 2 and 3 weeks after treatment. After 3 weeks of low P treatment, two genotypes G 21212 and VAX 1 were superior to the other genotypes in their adaptation to low P supply in terms of total root length and leaf area production shoot growth. Among the 6 genotypes, DOR 390 was least adapted to low P supply. In general, all genotypes showed an increase in tap root length and a decrease in lateral root development with low P supply (Figure 22).

Low P treatment after 3 weeks markedly diminished the number of root tips per plant and increased the mean root diameter (Table 11). Total root length/leaf area increased markedly with low P treatment at the end of 3 weeks. VAX 1 was outstanding in its ability to produce greater number of root tips with low P treatment for 3 weeks. G 21212 responded better to high P supply by producing greater number of root tips. Genotypic differences in shoot and root traits became more evident at 3 weeks of low P supply than at 2 or 1 week of low P supply.

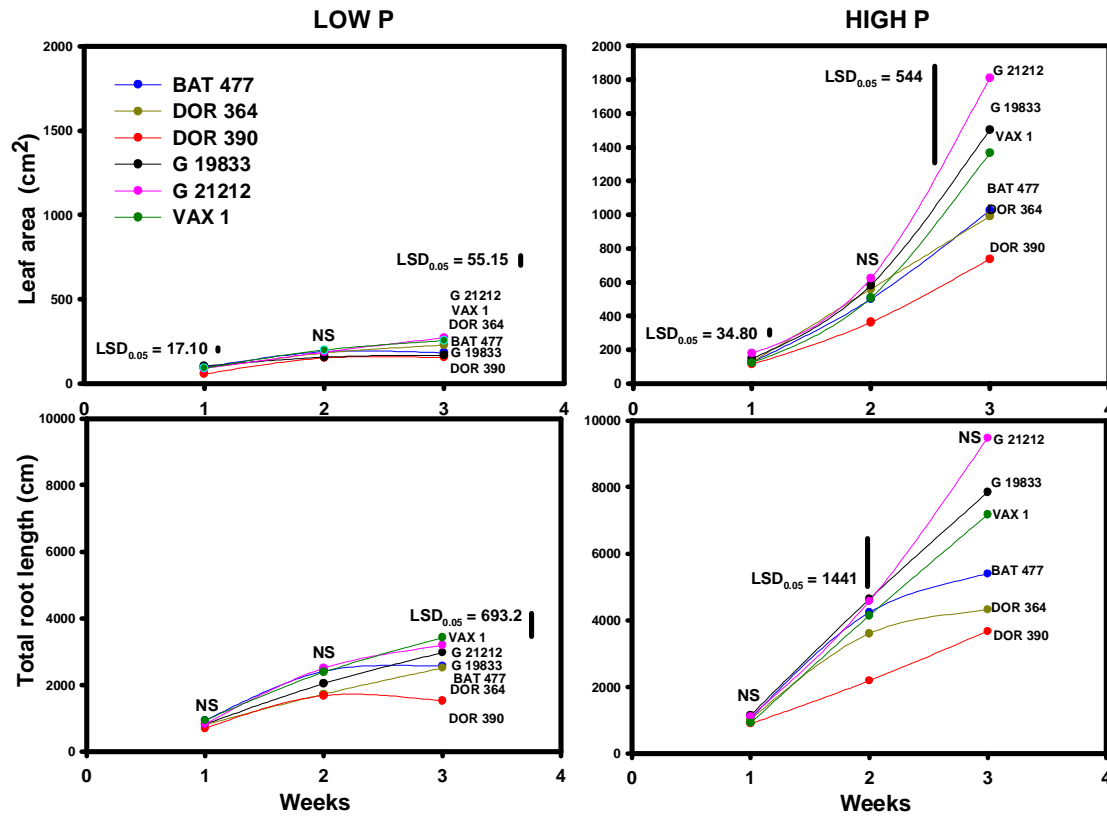


Figure 21. Effect of duration of low P or high P treatment on total root length and leaf area in 6 genotypes of common bean with low and high P in nutrient solution.



Figure 22. Common bean plants with three weeks of exposure to high and low P in nutrient solution.

Table 11. Effect of duration of low P or high P treatment on root traits of six genotypes.

Weeks of P treatment	Genotype	High P			Low P		
		Mean root diameter (mm)	Number of root tips	Root length / leaf area (m cm ⁻²)	Mean root diameter (mm)	Number of root tips	Root length / leaf area (m cm ⁻²)
1	BAT477	0.341	2055	0.083	0.352	2134	0.096
	DOR364	0.373	1868	0.081	0.363	1298	0.091
	DOR390	0.335	1994	0.079	0.299	1428	0.124
	G19833	0.370	2616	0.078	0.378	1517	0.080
	G21212	0.353	3268	0.062	0.336	1355	0.092
	VAX1	0.355	1998	0.074	0.330	1990	0.103
	Mean	0.354	2300	0.076	0.343	1620	0.098
	LSD _{0.05}	NS	NS	NS	0.030	NS	NS
2	BAT477	0.293	7024	0.085	0.338	3378	0.128
	DOR364	0.311	4886	0.064	0.361	3703	0.095
	DOR390	0.311	3064	0.060	0.342	2871	0.111
	G19833	0.318	8506	0.080	0.369	2871	0.131
	G21212	0.281	6217	0.073	0.333	4070	0.134
	VAX1	0.285	5880	0.082	0.340	3632	0.120
	Mean	0.300	5929	0.074	0.347	3421	0.120
	LSD _{0.05}	NS	3288	0.012	NS	NS	NS
3	BAT477	0.290	6409	0.053	0.335	2873	0.141
	DOR364	0.334	5953	0.044	0.356	3369	0.110
	DOR390	0.305	4926	0.050	0.370	2175	0.099
	G19833	0.262	7787	0.052	0.349	3323	0.176
	G21212	0.261	11108	0.052	0.346	4112	0.117
	VAX1	0.290	9706	0.053	0.336	4745	0.135
	Mean	0.290	7648	0.051	0.349	3433	0.130
	LSD _{0.05}	0.047	NS	NS	NS	1314	0.022

Conclusions: Results from this study indicate that the effects of low P supply on shoot and root growth parameters become more pronounced over time and screening for genotypic differences is possible at 3 weeks after low P treatment.

References:

- CIAT. 2002. Annual Report 2002 Project IP-1. Bean improvement for the tropics. CIAT, Cali, CO.
- CIAT. 2003. Annual Report 2003 Project IP-1. Bean improvement for the tropics. CIAT, Cali, CO.

Contributors: G. Manrique, I.M. Rao and S. Beebe

1.1.4 Testing of elite lines selected for low phosphorus tolerance or drought tolerance in multiple stress environments

Rationale: In small farmer production environments, crops often confront multiple stresses. Low soil fertility is a widespread limitation on production of common bean in LAC and Africa. Among several nutrients, soil phosphorus (P) is often especially limiting, due to low native P and also P fixing clays in soil that immobilize P in forms unavailable to plants. Drought stress is occasional and is exacerbated by infertile soils. Early plant vigor derived from low P tolerance might confer a degree of drought tolerance if it leads to better root development. The present trial was designed to test the relative value of low P tolerance and drought tolerance under conditions of single or multiple abiotic stresses.

Materials and Methods: Sixteen elite bean lines were selected based on their genetic potential, for evaluation under single or combined stress factors: A774, RAB 655 and MCD 2004 for low P tolerance; SEA's 5, 15, 21, 23 and RAB's 609, 612, and 651 for drought tolerance; G21212 and BAT 477 for multiple tolerance; BAT 881 for universal susceptibility; and DOR 364, EAP 9510-77, and Tio Canela as commercial checks. Trials were established in San Dionisio, Nicaragua in the second season of both 2002 and 2003, with no and moderate fertilization. In both years drought was a determining factor in the bean yields. In addition, the same trial was established in Santander de Quilichao in 2003 under high fertility and adequate rainfall; and under terminal drought that was created by a late planting date plus fertility stress. In 2004 three treatments were established in Quilichao: high fertility and adequate rainfall; low fertility and adequate rainfall; and terminal drought plus fertility stress.

Results and Discussion: There was evidence that the groups of genotypes formed according to their particular stress tolerance were performing differently under different conditions. In the combined analysis the group x treatment factor was significant ($p < 0.001$). This interaction seemed to derive from the trials in Quilichao (where this term was significant) and not from Nicaragua (where it was not significant).

The ANOVA of results from Nicaragua, from Quilichao and the combined analysis suggested significant differences among the groups of genotypes, but principally between the commercial types and/or the susceptible check versus other materials (Table 12). Groups of genotypes selected for low fertility tolerance or multiple tolerance (i.e., drought plus low fertility tolerance) were consistently the best group in all of the analyses. This was expected in Quilichao where the stress seemed to be dominated by low soil fertility, and where several genotypes were actually selected on site for this trait. However, the same tendency was observed in Nicaragua. This suggests that in multiple stress conditions, some degree of tolerance to low soil fertility is required to assure plant vigor and adequate root development for the expression of drought tolerance.

Nonetheless, there was some difference between 2002 and 2003 in Nicaragua, where a slight ($p = 0.05$) interaction of year x group was detected. In 2003 when drought was more severe, SEA 15, which has excellent drought tolerance, was the best line in Nicaragua, and was the second best yielding line across all nine trials. It is likely that in 2003 in Nicaragua the effect of drought tolerance was more evident. Besides SEA 15, bred lines A774, RAB 655 and RAB 651 were all

consistently among the best yielders. EAP 9510-77 was the best commercial cultivar but was much less stable than the stress-selected lines.

Table 12. Yields by groups of genotypes classed by adaptation to abiotic stress.

	Combined	Nicaragua	Quilichao
Low fertility tolerant (3)	1580a	1860a	1356a
Low fertility + drought tolerant (2)	1497a	1659a	1368a
Drought tolerant (7)	1388a	1699a	1140a
Commercial varieties (3)	1368a	1520a	1246a
Susceptible check (1)	871b	915b	835b

Conclusions: Multiple stresses occur on farm in many production regions. Drought tolerance alone may not be expressed adequately if soil fertility is inadequate. A degree of low fertility tolerance will likewise be required to improve yields on farm.

Contributors: S. Beebe, I. Rao, C. Cajiao (IP-1)
P. P. Orozco, J. A. Beltrán (PE-3: Communities and Watersheds)

Progress towards achieving output milestones:

- Tolerance to drought has been combined with a wider range of commercial grain types and highly desirable traits, and elite lines will form the basis for breeding improved nutritional status into agronomically superior varieties.
- Lines developed for drought tolerance also carry resistance to several diseases. Several selections identified this year carry recessive resistance to BCMNV. Some also carry resistance to the angular leaf spot pathogen.
- A few landraces and several advanced lines that were identified as better adapted to drought are currently being used in the breeding program to combine with biotic stress adaptation and commercial grain type.
- Greenhouse screening methods were implemented for phenotypic characterization for resistance to aluminum and tolerance to low P supply. Recombinant inbred lines are being evaluated to identify quantitative trait loci (QTLs) and candidate genes for further use in marker assisted selection.
- Breeders from national programs are using several parents/populations/lines to develop/identify genotypes tolerant to drought and low soil fertility conditions.

Activity 1.2 Developing germplasm with multiple resistance to diseases

Highlights:

- Four genotypes (G 22623; G 10909; G 3005 y G 1368) that combined resistance to pathogens causing angular leaf spot, anthracnose and ashy stem blight were identified.
- Ten genotypes from accessions identified as variable for tannins were identified that had high levels of resistance to ashy stem blight (*Macrophomina phaseolina*)
- The sources of resistance to aphid- and whitefly-transmitted viruses identified by CIAT and collaborating NARIs, continue to be effective to control common mosaic, black root and golden yellow mosaic in newly developed common bean cultivars.
- Lines with good drought tolerance and carrying the bc-3 gene for resistance to BCMNV have been recovered in small black and small red seeded phenotypes.
- Markers for two important genes for resistance to BGYMV have been multiplexed in the PCR amplification, increasing greatly the efficiency of MAS.
- Conducted successful screening for sources of resistance to the new virus disease affecting snap beans
- Three new rust resistant snap bean lines selected after four years of evaluation with farmers in Uganda and distributed for regional evaluation
- Four new snap bean varieties with improved pod quality, resistance to rust and yield potential and adaptation selected in national performance trials with farmers, exporters and certification agency in Kenya.
- New breeding populations of snap runner bean segregating for adaptation to short day tropical conditions developed in Eastern Africa.

1.2.1 Identification of genotypes with resistance to multiple constraints

1.2.1.1 Sources of multiple resistance

Rationale: Root rots are becoming a major bean production constraint, especially with declining farm sizes, lack of rotation and the increase in low soil fertility problems. Several pathogen cause root rots, and these often occur in complex. The prevalence of some pathogens is associated with high soil humidity and rain conditions (e.g. *Pythium* spp, *Fusarium* spp), while others are associated with water deficit and drought conditions (e.g. *Macrophomina phaseolina*). Identification of genotypes that are resistant to the largest number of root rot causing pathogens would be a major contribution towards the development of genotypes resistant to multiple constraints. Such materials would be useful as parents in breeding programs, or they can be deployed in areas where these pathogens are a major production constraint. Towards this goal, we have started evaluating genotypes from the core collection, that have previously been found to have resistance to other bean pathogens and pests, including *Colletotrichum lindemuthianum* and *Phaeoisariopsis griseola*.

Materials and Methods: Sixty genotypes representing a portion of the core collection known to have resistance to *P. griseola* and *C. lindemuthianum* were evaluated for *M. phaseolina* under greenhouse conditions. Ten plants were established for each genotype and were inoculated with a mixture of *M. phaseolina* from Quilichao, Darién and Palmira at the rate of 3grams of sclerotia

kg⁻¹ of soil. Inoculation and plant evaluations were done as described previously (CIAT, 2002). The same genotypes were also evaluated for their reaction to *Rhizoctonia solani* using conditions described earlier (Abawi and Pastor-Corrales, 1989). In addition, accessions selected from the core collection for contrasting tannin content (41 genotypes) were also evaluated for their reaction to *M. phaseolina*.

Results and Discussion: Several genotypes had good levels of resistance to *M. phaseolina* (Table 13). However, no genotype had high levels of resistance to *R. solani*, only tolerance. However, these genotypes are also resistance to *M. phaseolina*, *P. griseola* and *C. lindemuthianum* and these genotypes are good candidates to use as parents in breeding programs. Among the 41 genotypes selected for tannins, 10 had high levels of resistance to *M. phaseolina* (Table 14). Efforts are underway to test these materials to as wide a range of bean pathogens as possible, in the hopes of identifying those that combine resistance to the greatest number of pathogens.

Conclusion: The following genotypes (G 22623; G 10909; G 3005 y G 1368) were identified to combine resistance to *M. phaseolina* and several races of *P. griseola* and *C. lindemuthianum*, and these should be considered in breeding programs as multiple constraint sources. Evaluation for resistance to other root rot causing pathogens (*Fusarium solani*, *Fusarium oxysporium*, *Pythium* spp, *Scletinia rolfsi* etc) is in progress.

References

CIAT 2002. Annual Report, Bean Program 2002. CIAT, Cali, Colombia

Contributors: C. Jara, J. Fory, G. Castellanos, J.B. Quasquer, G. Mahuku

Table 13. Response of 60 anthracnose and angular leaf spot resistant genotypes from the core collection, to inoculation with mixtures of *Macrophomina phaseolina* and *Rhizoctonia solani* isolates under greenhouse conditions.

Accession	Mp	<i>R. solani</i>	Accession	Mp	<i>R. solani</i>
G 22623	1.0	4.0	G 2494	6.9	3.9
G 15805	1.0	4.8	G 10979	7.2	3.5
G 19227 A	1.0	6.1	G 23778	7.4	3.2
G 1368	1.6	4.1	G 14675	7.4	4.9
G 16291	1.7	6.3	G 11780 D	7.6	4.1
G 2218	2.6	5.1	G 4380	7.7	4.2
G 10909	2.8	3.7	G 2328 C	7.7	5.5
G 3005	3.8	3.7	G 1727	7.7	
G 11785	4.2	3.1	G 21132	8.1	4.0
S 31476	4.2	3.9	G 14711	8.1	
G 19833	4.5	3.5	G 23806 A	8.1	3.3
G 18970	4.5	4.1	G 16145	8.2	3.6
G 12182	5.0	3.0	G 17172	8.2	4.1
G 11732	5.0	3.5	G 1373	8.2	5.0
G 3970	5.0	4.3	G 5476	8.2	6.0
G 6873	5.3	4.3	G 18141	8.2	
G 23578 A	5.6	4.6	G 13910	8.4	4.1
G 21135	5.6	5.6	G 18996	8.5	3.7
G 148	5.7	5.0	G 19235	8.5	4.5
G 7962	5.8	4.0	G 16374	8.5	6.3
G 2769	5.8	4.6	G 11728	8.6	3.1
G 2482	5.8	5.1	G 23777	9.0	2.9
G 17650	6.0	4.2	G 8209	9.0	4.0
G 20729	6.1	4.0	G 23614	9.0	4.0
G 20824	6.2	3.9	G 13054 B	9.0	4.1
G 3511	6.2	4.7	G 16267	9.0	4.7
G 4721	6.3	3.4	G 23814 D	9.0	4.8
G 2359	6.4	5.4	G 8925	9.0	6.3
G 14016	6.5	4.7	G 799	9.0	
G 19120	6.6	4.4	G 4278	9.0	
BAR 477	1.0				
A 70	9.0				
SEA 15	3.3				
Sanilac		4.8			
Ica Tui		3.0			
P.Sintetico		2.3			

Table 14. Response of 41 bean genotypes from the core collection to inoculation with mixtures of *Macrophomina phaseolina* under greenhouse conditions.

Genotype	Seed color	Seed size	Disease severity	Genotype	Seed color	Seed size	Disease severity
G 58	8	P	1.0	G 4756	2	M	6.6
G 2494	8	P	1.0	G 995	8	M	6.6
G 2769	8	P	1.0	G 16157	7M	G	6.6
G 5481	2M	G	1.0	G 11957	2M	G	7.2
G 22291	6M	P	1.0	G 7945	6M	M	7.3
G 19497	2R	P	1.2	G 11640	5	P	7.4
G 20592	2	P	1.8	G 1400	6	P	7.4
G 4495	8	P	2.8	G 18264	7	M	7.4
G 13778	7M	G	3.0	G 6639	8	G	7.4
G 16664	2	M	3.2	G 1083	2M	M	7.4
G 9384	2	P	3.6	G 12169	7M	G	7.4
G 3815	2M	M	3.7	G 6981	6	P	7.7
G 12171	6M	G	4.2	G 17166	6M	M	7.8
G 22365	7M	M	4.2	G 2906	5	M	7.9
G 4790	8	P	4.7	G 5285	6	M	8.0
G 22805	6	P	5.1	G 16072	2M	M	8.2
G 18244	7	M	5.9	G 13177	2M	M	8.2
G 14778	7R	G	6.0	G 23283	5	M	9.0
G 5758	8	P	6.3	G 4258	6	P	9.0
G 17913	2	G	6.5	G 3821	2M	M	9.0
G 2276	5	M	6.6				
Resistant controls				Susceptible checks			
DOR 500	8	P	1.4	CALIMA	6M	G	7.6
SEA 15		P	2.1	A 70	2M	P	6.7
NEP 2		P	2.6				

1.2.1.2 Selection of multiple resistance in Mesoamerican types for southern Africa

The program evaluated fixed lines of various market classes for adaptation, yield and reaction to diseases at Chitedze and Bembeke, and for tolerance to low soil fertility stress at Bembeke. The small seeded bean cultivars, although not very popular among the market classes in southern Africa, often feature among the mixtures at household level. They are mainly used at domestic level for food security, because of their high yielding potential and tolerance to diseases.

Materials and Methods: Nurseries for specific market classes included: carioca (50 lines) and small reds (44 lines). At Bembeke, a set of sugar and red kidney lines were also planted in a low soil fertility stress block. The soil fertility stress block has been used over years to identify potential bean lines, which can perform well under low P, low N and low pH complex conditions. The nurseries were planted during the second week of January, in single row plots

without replication. Data were collected on yield and reaction to diseases in both sets of nurseries, under with and without low soil fertility stress conditions.

Results and Discussion: The crop at Chitedze was adversely affected by the wide spread of virus-like symptoms, which appeared at early pod formation stage. This affected both, the expression of other diseases and the yield performance. As such the data from Chitedze were excluded from this report. This section therefore focused at data from Bembeke, a site, which continued to offer considerable disease pressure for ALS and floury leaf spot (FLS), but less of CBB, ascochyta (ASC) and anthracnose (ANT). This pattern was consistent across all nurseries. The data presented in the subsequent tables capture only the top 10 lines in each market class, which are compared to a control cultivar.

i. Small red lines

Among the top 10 lines, some like MR 13557-16-2, MR 13426-9-3 and MR 13508-7 had a good combination of high yield, ranging from 2800 to 4100 kg ha⁻¹, and good levels of resistance to ALS and FLS (Table 15).

Table 15. Yield performance and reaction to diseases of top 10 small red lines at Bembeke, 2004.

Identity	Disease Score				Grain Yield (kg ha ⁻¹)
	ALS	CBB	ASC	FLS	
MR 13557-16-2	3	1	3	3	4107
MR 13568-5-4	4	3	3	5	3746
MR 13425-57-4	6	1	2	4	3386
MR 13557-16-7	4	2	2	5	3330
MR13456-12-3	2	1	2	7	3136
RAB 608	3	2	3	6	3108
MR 13426-9-3	3	2	2	4	3025
MR 135557-16-3	4	1	4	4	2969
MR 13508-7	3	2	2	4	2858
EAP-12-88 (DON)	4	1	2	4	2831
VAX 6 (Control)	6	2	3	2	777
Mean					756

ii. Carioca lines

Among the top 10 of the 50 carioca lines evaluated at Bembeke, were MN 13223-1, MC 12832-129-9, and MC 12832-129-5, all with good resistance to such diseases as ALS and FLS. Their yield levels were all above 4000 kg ha⁻¹, well above the control cultivar A286, 666 kg ha⁻¹, a carioca type released in many countries in southern Africa. The control cultivar was also below the site mean, 834 kg ha⁻¹ (Table 16). Thus the regional breeding program has several better lines in the carioca market class that offer good diseases resistance to two diseases, but also give much higher yields.

Table 16. Yield performance and reaction to diseases of top 10 carioca lines evaluated at Bembeke, 2004.

Identity	Disease Score					Grain Yield (kg ha ⁻¹)
	ALS	CBB	ASC	ANT	FLS	
MN 13223-1	2	1	2	1	1	4884
MC 12832-129-9	3	1	6	1	1	4440
MC 12832-129-5	3	1	5	1	1	4190
MC 12832-129-7	5	1	4	1	1	4190
MC 12832-129-2	3	1	7	1	1	4135
MC 12832-129-4	2	2	6	1	1	3941
MC 12832-129-10	2	1	7	1	1	3941
MC 12832-129-11	2	1	6	1	2	3830
RM 13387-17	2	1	6	1	1	3774
MA 12129-66	2	1	4	1	7	3691
Carioca (A 286-Control)	7	1	4	1	7	666
Mean						834

Conclusion: The regional breeding program continued to make progress in screening breeding materials for multiple attributes. Further progress has been achieved this season in selecting high yielding genotypes of various grain market classes that combine more than one attribute. Although Mesoamerican types are less popular than Andean types in southern Africa, .

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Collaborators: S. Beebe, G. Mahuku, R. Buruchara, P. Kimani and Malawi Bean Team

1.2.2 Resistance to viruses

1.2.2.1 Bean common mosaic and bean golden yellow mosaic viruses

This year, Bean Virology inoculated and evaluated 700 common bean germplasm accessions for their reaction to bean common mosaic and bean common mosaic necrosis (black root), bringing the total of BCMV/BCMNV-tested entries in the Common Bean Germplasm Collection of CIAT, to a total of 25,600 accessions. This information is critical to breeders, who must know the BCMV/BCMNV reaction of the parental materials used in their breeding projects, before making crosses.

A total of 157 small-seeded common bean entries belonging to different projects (e.g. drought, iron content, and other breeding materials identified as SEA) were also evaluated for their reaction to bean common mosaic and black root. Bean Virology also screens materials generated

by collaborators outside CIAT for their reaction to selected viruses. This year, 47 white-seeded materials from Peru were evaluated at CIAT.

Different whitefly-transmitted viruses (begomoviruses) affect common bean production in tropical America since the mid 1970s. CIAT pioneered the first international search for sources of begomovirus resistance and development of virus-resistant common bean cultivars, which led to the awarding of the prestigious King Baudouin Prize to CIAT in 1984. Since that year, Bean Virology has identified and characterized most of the sources of begomovirus resistance used to date. Based on these preliminary work, various other scientists and institutions have produced molecular markers to detect the resistance genes involved, and use these molecular tools in common bean improvement programs.

Thanks to these efforts, some NARIs and other international institutions, such as the Panamerican School (Zamorano) in Honduras, have been filling the gap left by the downsizing of CIAT's Bean Program, in terms of producing new common bean cultivars with resistance to bean golden yellow mosaic. Two good examples of these new cultivars produced by Dr. Juan Carlos Rosas in El Zamorano are: Tio Canela and CENTA-San Andrés. Bean Virology supported the evaluation and release of the latter cultivar in El Salvador, through the collaborative agreement subscribed on behalf of the Tropical Whitefly IPM Project financed by DFID. This new cultivar has recovered bean production in areas where this crop had been abandoned due to the high incidence of BGYMV, particularly during the prolonged dry season that affects Central America.

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Collaborators: S. Beebe, D. Debouck, Carlos A. Perez (CENTA).

1.2.2.2 Bean common mosaic virus (BCMV) and bean golden yellow mosaic virus (BGYMV) for Central America

Rationale: Central America is a priority region for poverty alleviation and for bean production. Therefore, the mainstream breeding program continues to focus on small red and small black beans, largely for Central America. Most of the improved varieties in the small red class have a darker tone of red than the landraces, which command better prices and are even preferred for export markets to the USA. Recovering the light red color has been a challenge since the inception of the bean team, due to a genetic linkage between the *I* gene for BCMV resistance and the dark red color. The solution to this problem lies in the deployment of the recessive *bc-3* gene for BCMV resistance, which in addition to not suffering linkage to poor color, also avoids the problem of a necrotic reaction with the Severe Mosaic virus that occurs with frequency in the region. The *bc-3* gene is also important for Africa to confer resistance to BCMNV which results in whole-plant necrosis when the *I* gene is present. Although the *bc-3* gene had been introduced into tropically adapted lines several years ago, this had not been accomplished specifically with an eye to recovering the soft red color of the Central American landraces.

Materials and Methods: Several breeding lines carrying the *bc-3* gene had been developed at CIAT and elsewhere. One of these obtained from the University of Puerto Rico was crossed to a

landrace from El Salvador, Rojo de Seda (G4090) and to a source of resistance to BGYMV in a triple cross. Grain color and the *bc-3* gene were selected phenotypically to obtain lines denominated RCB 136 and RCB 137 that were in turn crossed to sources of drought tolerance and another source of BGYMV resistance. Lines were selected for color, evaluated in the greenhouse for resistance to the necrotic strain of BCMNV, and evaluated for drought tolerance in the field. Additionally, a series of black seeded lines were evaluated in similar fashion.

Results and Discussion: Most families selected for grain color and adaptation in the field did not carry the *bc-3* gene. Out of 79 families with *bc-3* parents, only 7 expressed resistance to necrotic BCMV in most plants, and another 9 appeared to be segregating (Table 17). Although it has been particularly difficult to obtain *bc-3* in elite rustic materials, some of the selected lines (especially the black seeded) express a degree of drought tolerance. Among the red seeded lines several have the highly commercial grain color that is sought in Central America, and were selected by the a national program bean breeder for immediate testing in Nicaragua. MDSX 14826-13-MC-14P-MQ presented very good grain quality under drought and is the most promising among the reds. The elite lines have been incorporated into crosses for another round of selection.

Table 17. Small red and black seeded lines expressing a resistant phenotype or segregation for resistance to necrosis caused by BCMNV.

Pedigree	Color	Reaction to BCMNV		None (<i>bc-3</i>)	Drought yield % check ¹	Check
		Necrosis	Mosaic			
(SXB 116 X EAP9653-16B-1) x RCB 136						
MDSX 14797-6-MC-2P-MQ	Red	1	-	15	103	1275
MDSX 14797-6-MC-6P-MQ	Red	-	12	5	96	1275
(SXB 123 x EAP9653-16B-1) x RCB 136						
MDSX 14814-7-MC-8P-MC	Red	-	-	18	103	1644
MDSX 14814-7-MC-11P-MC	Red	-	-	15	102	1644
MDSX 14814-8-MC-1P-MC	Red	8	-	4	101	1644
MDSX 14814-8-MC-4P-MC	Red	1	-	15	123	1191
MDSX 14814-8-MC-5P-MC	Red	-	-	20	124	1191
MDSX 14814-21-MC-3P-MC	Red	8	3	9	93	1275
(SXB 122 x EAP9653-16B-1) x RCB 137						
MDSX 14826-13-MC-14P-MQ	Red	1	-	13	124	1275
MDSX 14826-13-MC-31P-MQ	Red	5	-	10	90	1275
(SXB 118 X EAP9503-32B) x SEN 34						
MDSX 14802-38-MC-2P-MQ	Black	12	-	8	204	1032
(SXB 123 x DOR 677) x SEN 34						
SX 14820-37-MC-1P-MQ	Black	1	-	15	202	1032
SX 14820-37-MC-13P-MQ	Black	8	-	8	171	1032
SX 14820-37-MC-14P-MQ	Black	12	-	6	255	1032
SX 14820-37-MC-16P-MQ	Black	5	-	9	176	1032
SEN 34 x (MAB 105 X EAP9020-14)						
SXMA 14833-39-MC-2P-MQ	Black	1	-	14	163	1032

¹The check for the red-seeded trials was Tio Canela, and for the black seeded trial, DOR 390. All black seeded families but no red seeded families yielded significantly more than the respective checks.

Conclusions: Families were obtained that represent significant advance in combining the *bc-3* gene with important agronomic traits for Central America and Africa in these grain types.

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1.2.2.3 Mainstream breeding applying MAS for two genes for resistance to BGYMV (*bgm-1* and W12)

Rationale: Bean golden yellow mosaic virus (BGYMV) continues to be an indispensable breeding priority for Central America. We have reported extensively on the use of a marker for *bgm-1* gene in the past. In addition, a second marker identified as W12 was converted to a SCAR by USDA-Prosser, Washington. Both markers were employed to evaluate the presence or absence of key viral resistance genes in F₁ plants of triple or double crosses.

Materials and Methods: This year we tested more than four thousand F₁ plants for the presence of the *bgm-1* and the W12 markers. A broader description of the derived families and their performance under drought pressure is reported in section 1.1.1.1 above. Here we deal with the results of the marker screening. Fine-tuning the amplification protocol permitted multiplexing the amplification of the two markers and streamlining the evaluation.

Results and Discussion: The *bgm-1* marker was present in 51% of the plants, and the W12 in 44%. The marker for *bgm-1* was detected in either the heterozygous or homozygous state in combination with the W-12 marker in 1182 out of 4498 total F₁ plants tested, or in 26% of plants (Table 18). This was the first time that we insisted in the combination of the two markers, with the expectation that this will improve the frequency of derived families with resistance. Of course, this resulted in a substantial reduction in the number of families that were tested in the drought nursery.

Table 18. Number of F₁ plants expressing or lacking two markers for resistance to BGYMV among 4498 plants that were evaluated.

		State of <i>bgm-1</i> *		
		Homozygous	Heterozygous	Absent
State of W12	Present	1086	96	797
	Absent	1080	73	1366

*The *bgm-1* is codominant for the resistant and susceptible allele and thus permits defining heterogeneous class.

Conclusions: Marker assisted selection continues to be a pillar of our work to serve Central American breeding programs and bean producers. The large-scale evaluation that has been deployed is the result of continual improvements in routine laboratory protocols. Multiplexing markers in the amplification phase is a major achievement in this regard.

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1.2.3 Snap beans

1.2.3.1 Developing snap bean breeding lines resistant to *Ascochyta* blight and anthracnose

Rationale: *Ascochyta* and anthracnose are very destructive diseases of bean in the rainy higher altitude regions of the Andean zone and Africa. Climbing snap beans are a high value horticultural crop with great potential in both the Andes and in Africa. Snap beans are especially susceptible to *ascochyta*, and an *ascochyta* attack early in the season is often the stimulus that triggers a vicious cycle of pesticide abuse. Thus, *ascochyta* resistance is an important component of an IPM strategy for snap beans. Anthracnose attacks both leaves and pods, and lesions on pods are unacceptable in the market. In other environments represented by Pradera in Valle de Cauca (~1000 masl) rust and occasionally angular leaf spot (ALS) are important limitations.

Materials and Methods: In previous years we reported on progress in implementation of resistance from interspecific crosses. While significant progress was made in combining resistance with snap bean characters, even the best selections did not present truly commercial snap bean pod type. Therefore, resistant families from previous semesters were incorporated into crosses with commercial varieties and improved lines. F₂ populations were planted in Popayán under natural attack of *ascochyta* and anthracnose in 2003, and in 2004 F₂-derived F₃ families were evaluated under similar conditions. Checks of Blue Lake (Lago Azul), the commercial snap bean, were planted every ten rows, together with rows of G685 (a Guatemalan climbing dry bean), ICTA Hunapú, and a resistant ASC bred line.

Results: In Popayán the commercial check 'Blue Lake' presented severe symptoms of both anthracnose and *ascochyta*, even without inoculation. The resistant checks presented far fewer symptoms than 'Blue Lake' for both *ascochyta* and anthracnose. Within the F₆ families most were either intermediate or moderately resistant to the two diseases. A drought occurred at flowering and for three weeks afterward, and this resulted in more fiber development in pods that we had seen in previous years. We therefore made an additional round of individual plant selections seeking to minimize pod fiber. A total of 113 individual plant selections were made in Popayán in F₆ for this purpose (Table 19).

Additionally, another 6 F₂ populations were selected in a second round of breeding, to continue to improve pod type in resistant lines (Table 20). A total of 161 individual plants were selected in F₂ and 221 in F₃ generations for resistance to cool season diseases. Meanwhile, crosses were initiated for resistance to gemini viruses that occur in production regions close to CIAT headquarters.

Table 19. F₅ and F₆ families of snap beans with climbing habit selected in Popayán, 2003B – 2004A.

Code	Cross number	Identification	F ₅ families evaluated P03B	F ₆ families evaluated P04A and selected for shipment	Individual F ₇ selections P04A
SB	14565	HAV 129 X SBB 170/-	132	34	113
SB	14566	G 17647 X SBB 170/-	9	0	0
SB	14567	G 8992 X SBB 170/-	3	1	0
SB	14568	HAV 130 X SBB 171/-	1	0	0
Total			145	35	113

Table 20. F₂ y F₃ families of snap beans with climbing habit selected in Popayán, 2003B – 2004A.

Code	Cross number	Identification	F _{1,2} families evaluated P03B	F ₃ families evaluated P04A	Individual F ₄ selections P04A
SB	14896	(G 17723xHAV 124)F ₁ X SBB 167/-	1	4	8
SB	14897	(G 17723xHAV 124)F ₁ X SBB 168/-	5	22	42
SB	14898	(G 17723xHAV 124)F ₁ X SBB 165/-	1	4	7
SB	14899	(G 17723xHAV 124)F ₁ X SBB 166/-	1	3	6
SB	14900	HAV 129 X SBB 165/-	6	17	23
SB	14901	HAV 131 X SBB 166/-	26	111	135
Total			40	161	221

Conclusion: In spite of the strict commercial criteria for pod characteristics of snap beans in Colombia, progress toward combining these pod characters with resistance to foliar diseases continues. We expect to distribute lines to collaborators in 2005.

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1.2.3.2 Breeding snap bean for smallholder production in East and Central Africa

Rationale: Snap bean is the probably the most important bean grown in East and Central Africa for export markets, and has been prioritized by ASARECA as a research priority. It is a major source of income for smallholder farmers especially in Kenya, Uganda, Sudan and Tanzania. There is growing interest to increase snap bean production for domestic and export markets in Rwanda, Ethiopia, Burundi, Madagascar and other countries in East and Central Africa. Snap bean is also grown by large commercial companies for export to overseas supermarkets and for canning industries. Yield of snap bean in smallholder farmers' fields varies from 2 to 8 t ha⁻¹ (Ndegwa, 2002), compared to over 14 t ha⁻¹ among large scale producers. Smallholder production is constrained by diseases especially rust, angular leaf spot, root rots, bean common mosaic virus and pests especially bean stem maggots, thrips and nematodes. The intensive nature of cultivation of this crop leads to high disease and insect pressure, and consequently excessive use of pesticides. Smallholder production is further constrained by high costs of seed because most of the varieties produced by private companies are protected by legislation. Thus seed produced by contract in the region is exported for processing and packaging, and re-imported for production. The few varieties developed by public institutions (especially in Kenya) are often susceptible to diseases and pests. Very little has been done to develop improved snap bean varieties freely accessible to smallholder farmers and informal seed producers (who supply over 90% of dry bean seed grown in the region) in the region. Due to the high quality demands, smallholder farmers rely on fungicides and insecticides to reduce production and post harvest losses associated with diseases and pests. This is no longer a viable option because recently instituted minimum residue levels, together with preference by importers to source produce from large scale producers, threaten to push smallholder farmers out of business. In East and Central Africa, production is based on determinate types. Unlike their counterparts in South America, East African farmers normally do not grow the indeterminate types, which are higher yielding and have longer harvest duration. Breeding for high yield, disease and pest resistance, tolerance to abiotic stresses, general adaptation to tropical conditions and acceptable market quality is a critical component of an integrated strategy to address constraints to snap bean production in the region. A regional program was therefore started in 2001 to support the development of improved snap bean varieties with high yield potential, resistance to biotic stresses and pod quality for smallholder production. This report highlights progress in this program.

Materials and Methods: The regional snap bean program is based at four institutions: one at Kawanda Research Institute in Uganda, and three in Kenya : Moi University in Eldoret; National Horticultural Research Centre, KARI-Thika, and a back-up program at the Department of Crop Science, University of Nairobi. Work at Kawanda has focused on screening snap bean varieties with farmers and developing production packages. At Moi University, crosses were made to develop locally adapted snap bean cultivars with improved pod yield, resistance to anthracnose and rust, and marketable pod quality (van Rheenen et al 2003). After six generations of selection, 23 lines were identified. Following preliminary evaluations in 2002, the number of lines was reduced to 12. In 2003, the 12 lines were evaluated in national performance trials at six locations (Eldoret, Thika, Kakamega, Marigat, Lanet and Njoro) in collaboration with Kenya Plant Health Inspectorate (KEPHIS), which represents the national variety release committee. The trial

included three commercial cultivars as checks. KARI-Thika focused on developing a working collection of snap and runner bean varieties and development of segregating populations. At the University of Nairobi, crosses were made to transfer rust resistance to popular commercial varieties, and development of short-day snap runner beans.

Results and Discussion: At Kawanda Agricultural Research Institute, three lines were finally selected after four years of evaluation with farmers. These were HAB 433, J12 and L3. Further evaluations of snap bean lines were conducted in DR Congo, Kenya and Sudan. Results are pending.

The characteristics of the 12 lines selected at Moi University in the national performance trials at six locations are presented in Table 21. Flowering was earliest at Thika (37 days) and latest at Njoro (50 days). Duration to first picking was shortest at Thika (56 days) and longest at Njoro (62 days). Picking period varied from 22.6 days at Marigat to 36 days at Njoro and 40 days at Thika. On an average, Lanet and Njoro showed better pod quality scores than Marigat and Eldoret. The pod quality at the latter location was poorest, probably due to the poor plant growth in general. The interaction between locations x trial entry was highly significant, suggesting that different entries respond differently to environmental conditions in respect of pod quality. The variety differences for reaction to rust were significant. The entry with the severest symptoms was No. 1, showing a mean score of 7.6. It differed significantly from those that had a score of 6.6 or less. Entry No. 7 had the lowest rust score of 1.2, differing significantly from those having a score of 2.2 or more. On an average, Marigat showed significantly more severe rust symptoms than other locations. The interaction between location x entry was significant, suggesting that possible differences in rust races occur. Variety differences for fresh pod yield were significant. The entry with the lowest yield was No. 3 with an average of 9.6 t ha⁻¹, followed by No.1 with 9.7 t ha⁻¹. These differed significantly only from those that had 12 t ha⁻¹ or more. Entry No. 11 had the highest yield of 13.1 t ha⁻¹, differing significantly from those having a yield of 11 t ha⁻¹ or less. The locations differed significantly pair-wise: Marigat and Njoro had the highest yields; Lanet and Kakamega were intermediate, and Eldoret and Thika lowest. The mean yields per location ranged from 3.1 t ha⁻¹ at Thika to 19.7 t ha⁻¹ at Marigat. No significant interaction between location and trial entry was observed which indicates that varieties had no differential response to environment. It suggests that the yield adaptation of the entries to different environments was similar.

Fifteen snap bean and five runner bean accessions were collected at KARI-Thika. All the snap bean accessions were determinate bush. Four of the runner bean accessions had a vigorous indeterminate growth habit and one was determinate. Success rate for crossing was higher for snap bean (80%) but lower for runner bean due to a high incidence of flower and pod abscission and seedless pods. Flower and pod abscission was higher for crosses done during the warmer period of the year. Twenty F₄ selections from a cross between a commercial variety and a locally improved rust resistant variety ('Kutuleless') were made. Two promising F₄ lines showed a type 1 growth habit, good ground-pod clearance, high pod load (30 to 40 pods per plant), acceptable pod characteristics (pencil shaped, round cross section, smooth texture) and good snapping ability. These were advanced to F₅. At Kabete, five F₃ populations were developed from crosses between a long-day commercial runner snap variety and five short-day dry grain type varieties. Three F₂ populations were developed in crosses among three commercial, rust-

susceptible snap bean cultivars and two rust-resistant lines. Seed of 27 lines with combinations of *Ur* genes was increased.

Table 21. Days to flowering, first and last day of pod picking, pod quality, rust score and fresh pod yield of snap bean lines selected at Moi University, Eldoret, Kenya

Line*	Days to 50% flowering	Days to first pod picking	Days to last pod picking	Pod quality*	Rust score***	Fresh Pod yield t ha ⁻¹
1	45.1	59.0	89.7	3.8	7.6	9.7
2	43.5	57.1	89.7	3.3	4.6	11.4
3	43.6	57.2	88.9	3.6	2.4	9.6
4	44.8	57.3	89.2	2.3	2.1	12.9
5	43.0	58.1	89.2	3.1	2.1	11.7
6	42.6	56.6	89.4	3.9	6.4	10.6
7	46.1	58.9	89.8	4.0	1.2	12.2
8	43.6	56.7	89.8	3.5	2.3	13.0
9	43.0	56.9	89.3	3.7	4.2	10.3
10	44.4	57.3	89.4	3.9	2.3	11.2
11	45.5	56.8	89.4	2.7	2.0	13.1
12	43.8	59.1	89.4	3.8	4.3	10.3
Mean	44.1	57.6	89.5	3.5	3.5	11.3
CV (%)	6.7	3.57	1.52	12.7	28.7	28.9
LSD .05	1.94	1.35	NS	0.36	0.94	2.2

* Lines 1, 4, 7 and 11 were checks

** Pod quality on a scale of 1= best and 5=worst.

*** Rust on CIAT scale, 1-3 =resistant, 4-6= intermediate and 7-9=susceptible at three locations- Marigat, Lanet and Njoro.

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Collaborators: KEPHIS, KARI- Thika, Kakamega, Marigat, Lanet and Njoro, and S. Musaana (Kawanda Agric. Research Institute)

Progress towards achieving output milestones:

- Several accessions that combine resistance to several angular leaf spot and anthracnose races, *Macrophomina phaseolina* and tolerance to *Rhizoctonia solani* were identified. These constitute potential parents in programs breeding for improved resistance to foliar and soil-borne pathogens.
- Bean Virology has the responsibility to detect, characterize and manage plant viruses affecting common bean production around the world. Project milestones include the development of common bean cultivars that possess resistance to the three major bean viruses present in the Tropics: Bean common mosaic virus (BCMV) and the whitefly-borne Bean golden mosaic (BGMV) and Bean golden yellow mosaic viruses.

Activity 1.3 Developing germplasm with resistance to pests: *Zabrotes*, *Acanthoscelides*, *Empoasca*, *Apion*, *Thrips palmi*, leafhopper, pod weevil, and bruchids

Highlights:

- Resistance to the bean weevil (*Acanthoscelides obtectus*) was identified in *Phaseolus vulgaris* x *P. acutifolius* hybrids
- Finished studies on molecular markers for *Thrips palmi* resistance
- Progress was made in the development of molecular markers for resistance to the pod weevil (*Apion godmani*)

1.3.1 Screening for sources of resistance to major insect pests

Rationale: Identification of sources of resistance to major insect pests of beans is a continuous activity. Additional work is conducted trying to identify and characterize the mechanisms of resistance to specific major pests.

Materials and Methods: Bruchid nurseries are tested in the laboratory simulating normal storage conditions (20° C, 80% R.H., and 14 % seed humidity). Genotypes are tested using 3-5 replications of 50 seeds per genotype. Evaluation units (replicates) are infested with 7 pairs of *Z. subfasciatus* per 50 seeds or two eggs per seed in the case of *A. obtectus*. *T. palmi*, leafhopper and pod weevil nurseries are planted in the field under high levels of natural infestation, usually with 3-4 replicates per genotype in randomized complete block designs. Evaluations for resistance include damage and bean production ratings, insect counts, damage counts, and in some cases, yield components and yields.

Results and Discussion:

Bruchids

Acanthoscelides obtectus

Using a novel Double Congruity Backcross technique developed at CIAT, the Biotechnology Unit has been able to develop fertile interspecific *Phaseolus vulgaris* - *P. acutifolius* (common x tepary) bean hybrids using the tepary genotype NI576 (a genotype competent to *Agrobacterium*-mediated genetic transformation). Some of these crosses involve the tepary accession G 40199 an excellent source of resistance to the bean weevil, *Acanthoscelides obtectus*. In 2002 and 2003 we identified several progenies containing both *P. vulgaris* and *P. acutifolius* cytoplasm with very high levels of antibiosis resistance to *A. obtectus*. In 2004, emphasis was placed upon the reconfirmation of resistance in previously selected progenies. As shown in Table 22, one hybrid containing *P. vulgaris* cytoplasm and seven containing *P. acutifolius* cytoplasm showed high levels of resistance to the insect (< 20% adult emergence). Resistance in some cases was as high as that of G 40199, the resistant check.

Table 22. Resistance to *Acanthoscelides obtectus* in selected F_{3.5} hybrid progenies derived from interspecific *Phaseolus vulgaris* x *P. acutifolius* crosses

Code and generation	Cross	Percentage adult emergence	Days to adult emergence	Percentage seeds damaged
Interspecific <i>P. vulgaris</i> - <i>P. acutifolius</i> hybrids with <i>P. vulgaris</i> cytoplasm				
T7K – 2F F ₃	V-DCBC5 x V-DCBC4	67.5	38.7	66.6
T7K – 2E F ₃	V-DCBC5 x V-DCBC4	7.1	71.0	10.0
T7K – 2 8B F ₄	V-DCBC5 x V-DCBC4	100.0	39.2	100.0
T7K – 2 8A F ₄	V-DCBC4 x GNV	99.2	39.6	100.0
T7K – 2 - 6 F ₅	V-DCBC5 x V-DCBC4	100.0	38.6	100.0
Interspecific <i>P. vulgaris</i> - <i>P. acutifolius</i> hybrids with <i>P. acutifolius</i> cytoplasm				
GKA – 12R F ₃	A-DCBC7-2 x A6	54.8	53.9	86.1
GKA – 12R F ₃	A-DCBC7-2 x A6	77.4	44.5	96.0
GKX – 6B F ₃	A-DCBC8-2	12.7	48.0	33.3
GNVAV – 200A F ₅	{[(G40022 x NI576)x V5] x A3} x VS42-7	12.2	44.4	20.7
GNVAV – 200B F ₅	{[(G40022 x NI576)x V5] x A3} x VS42-7	88.2	42.9	100.0
GNVAV – 200D F ₅	{[(G40022 x NI576)x V5] x A3} x VS42-7	2.7	41.0	8.7
GNVAV – 200G F ₅	{[(G40022 x NI576)x V5] x A3} x VS42-7	1.1	67.0	3.3
GNVAV – 200H F ₅	{[(G40022 x NI576)x V5] x A3} x VS42-7	0.0	N.E.	0.0
GVV – 101 F ₃	{[(G40022 x NI576)x V5] x A3} x VS42-7	55.9	47.1	76.7
GVV – 102 F ₃	{[(G40022 x NI576)x V5] x A3} x VS42-7	71.1	47.1	90.0
GVV – 104 F ₃	{[(G40022 x NI576)x V5] x A3} x VS42-7	55.6	49.4	79.3
GVV – 107 F ₃	{[(G40022 x NI576)x V5] x A3} x VS42-7	57.1	45.5	100.0
GVV - 108 F ₃	{[(G40022 x NI576)x V5] x A3} x VS42-7	11.1	56.6	36.1
GVV - 108 F ₃	{[(G40022 x NI576)x V5] x A3} x VS42-7	62.2	44.2	75.0
GVV - 110 F ₃	{[(G40022 x NI576)x V5] x A3} x VS42-7	36.3	48.6	57.8
Checks				
G 12882 Arc 1	Susceptible wild <i>P. vulgaris</i> accession	78.3	35.8	100.0
G 12952 Arc 4	Susceptible wild <i>P. vulgaris</i> accession	75.0	46.3	100.0
G 40168	Susceptible <i>P. acutifolius</i> accession	88.3	41.8	100.0
G 25410	Susceptible <i>P. lunatus</i> accession	93.3	42.7	100.0
RAZ 44	Susceptible <i>P. vulgaris</i> line	98.3	36.9	100.0
ICA Pijao	Susceptible <i>P. vulgaris</i> cultivar	96.6	31.7	100.0
G 40199	Resistant <i>P. acutifolius</i> accession	3.3	85.7	12.2
G 25042	Resistant <i>P. lunatus</i> accession	1.6	80.0	5.3

After multiplication of resistant seeds in the greenhouse, some of these hybrids again showed high resistance to *A. obtectus* (< 20% adult emergence) in replicated tests (Table 23).

Table 23. Resistance to *Acanthoscelides obtectus* in selected F_{5,6} hybrid progenies derived from interspecific *Phaseolus vulgaris* - *P. acutifolius* crosses

Cross code	Hybrid number	Cross	Percentage adult emergence	Days to adult emergence	Percentage seeds damaged
Hybrids					
GNVAV	200A9 F ₆	{[(G40022 x NI576)x V5] x A3} x VS42-7	18.7	54.0	32.6
GNVAV	200D21 F ₆	{[(G40022 x NI576)x V5] x A3} x VS42-7	47.9	51.2	52.6
GNVAV	200D22 F ₆	{[(G40022 x NI576)x V5] x A3} x VS42-7	31.9	52.7	63.8
GNVAV	200G16 F ₆	{[(G40022 x NI576)x V5] x A3} x VS42-7	14.4	58.1	31.3
GNVAV	200G17 F ₆	{[(G40022 x NI576)x V5] x A3} x VS42-7	30.6	52.0	45.2
GNVAV	200G18 F ₆	{[(G40022 x NI576)x V5] x A3} x VS42-7	0.6	71.0	1.8
GNVAV	200G19 F ₆	{[(G40022 x NI576)x V5] x A3} x VS42-7	13.0	56.0	25.5
GNVAV	200H5 F ₆	{[(G40022 x NI576)x V5] x A3} x VS42-7	0.8	71.0	2.8
GVV	110G F ₅	{[(G40022 x NI576)x V5] x A3} x VS42-7	5.2	58.0	18.8
GVV	110 I F ₅	{[(G40022 x NI576)x V5] x A3} x VS42-7	21.1	48.9	36.6
GVV	108 N F ₅	{[(G40022 x NI576)x V5] x A3} x VS42-7	14.6	55.7	37.0
Checks					
G 12882 Arc1	Susceptible wild <i>P. vulgaris</i> accession		66.4	36.0	100.0
G 12952 Arc4	Susceptible wild <i>P. vulgaris</i> accession		60.0	47.6	100.0
G 40168	Susceptible <i>P. acutifolius</i> accession		65.2	43.4	100.0
G 25410	Susceptible <i>P. lunatus</i> accession		90.4	42.4	100.0
ICA Pijao	Susceptible <i>P. vulgaris</i> cultivar		93.9	30.6	100.0
G 40199	Resistant <i>P. acutifolius</i> accession		16.3	58.5	39.0
G 25042	Resistant <i>P. lunatus</i> accession		1.5	62.0	7.1

We also tested three interspecific hybrids with *P. vulgaris* cytoplasm (all susceptible) and eight with *P. acutifolius* cytoplasm, three of which (BWG-5N F₃, BWG-6Y F₃, and BWG-1F F₃) showed resistance (Table 24). After multiplication of selected seeds, replicated reconfirmation tests revealed intermediate resistance (20-50% adult emergence) in some of these hybrids (Table 25).

Table 24. Resistance to *Acanthoscelides obtectus* in selected segregating F₃ hybrid progenies derived from *Phaseolus vulgaris* - *P. acutifolius* crosses

Code and generation	Type of material	Percentage adult emergence	Days to adult emergence	Percentage seeds damaged
Hybrids				
TZT – 4A3 F ₄	Interspecific <i>P. vulgaris</i> - <i>P. acutifolius</i> hybrid with <i>P. vulgaris</i> cytoplasm	82.2	35.9	73.3
TZT – 4A1 F ₄	“ “	73.3	42.1	80.0
TZT – 1E F ₄	“ “	96.0	40.0	100.0
BWG – 5M F ₃	“ “	52.6	45.9	78.1
BWG – 5N F ₃	Interspecific <i>P. vulgaris</i> - <i>P. acutifolius</i> hybrid with <i>P. acutifolius</i> cytoplasm	11.3	58.5	31.1
BWG – 5S F ₃	“ “	80.0	50.2	96.7
BWG – 6Y F ₃	“ “	48.8	52.8	85.0
BWG – 6W F ₃	“ “	94.5	41.9	100.0
BWG – 1F F ₃	“ “	39.8	49.3	67.0
BWG – 1A F ₃	“ “	64.4	46.3	76.7
BWG – 1G F ₃	“ “	95.6	39.2	93.3
Checks				
G 12882 arc 1	Susceptible wild <i>P. vulgaris</i> accession	78.3	35.8	100.0
G 12952 arc 4	“ “	75.0	46.3	100.0
G 40168	Susceptible <i>P. acutifolius</i> accession	88.3	41.8	100.0
G 25410	Susceptible <i>P. lunatus</i> accession	93.3	42.7	100.0
RAZ 44	Susceptible <i>P. vulgaris</i> line	98.3	36.9	100.0
ICA Pijao	Susceptible <i>P. vulgaris</i> cultivar	96.6	31.7	100.0
G 40199	Resistant <i>P. acutifolius</i> accession	3.3	85.7	12.2
G 25042	Resistant <i>P. lunatus</i> accession	1.6	80.0	5.3

Table 25. Resistance to *Acanthoscelides obtectus* in selected segregating F₄ hybrid progenies derived from *Phaseolus vulgaris* - *P. acutifolius* crosses

Cross Code	Hybrid number	Percentage adult emergence	Days to adult emergence	Percentage seeds damaged
Hybrids				
BWG	1F7 F4	43.2	43.4	70.1
BWG	1F13 F4	45.4	46.4	90.5
BWG	1F14 F4	44.4	43.4	73.0
BWG	1F18 F4	25.6	43.7	53.8
BWG	5N1 F4	33.8	49.9	64.1
BWG	5N4 F4	24.4	55.3	55.1
BWG	6Y6 F4	29.5	50.7	64.8
BWG	6Y15 F4	17.5	51.4	35.1
Checks				
G 12882 Arc 1	Susceptible wild <i>P. vulgaris</i>	66.4	36.0	100.0
G 12952 Arc 4	“ “	60.0	47.6	100.0
G 40168	Susceptible <i>P. acutifolius</i>	65.2	43.4	100.0
G 25410	Susceptible <i>P. lunatus</i> accession	90.4	42.4	100.0
ICA Pijao	Susceptible <i>P. vulgaris</i> cultivar	93.9	30.6	100.0
G 40199	Resistant <i>P. acutifolius</i> accession	16.3	58.5	39.0
G 25042	Resistant <i>P. lunatus</i> accession	1.5	62.0	7.1

The tedious but important process of testing individual seeds to detect segregation in interspecific hybrids continued in 2004 (Table 26). Those selected for resistance were multiplied but the seed did not germinate. One intraspecific *P. lunatus* hybrid that did germinate (coded V5) showed a very high level of resistance comparable to that of the resistant accession G 25042. Two double congruent hybrids with *P. acutifolius* cytoplasm (GKVGAG 1B 4D F₅ and GKVGAG 1E 2C F₅) were selected for further testing (Table 27).

Table 26. Reconfirmation of resistance to *Acanthoscelides obtectus* in pre-selected segregating hybrid progenies derived from interspecific *Phaseolus vulgaris* x *P. acutifolius* crosses and intraspecific *Phaseolus lunatus* crosses

Code and generation	Type of material	Number of seeds evaluated	Number of resistant seeds	Days to adult emergence
Hybrids				
GNVAV-21 F ₃	Interspecific <i>P. vulgaris</i> - <i>P. acutifolius</i> hybrid with <i>P. acutifolius</i> cytoplasm	4	3	N.E ^a
GKA 11 F ₂	“ “	15	3	N.E
Z99ZX6 F ₂	Double congruent hybrid with <i>P. acutifolius</i> cytoplasm	6	1	N.E
Z99ZX-1A F ₃	Double congruent hybrid with <i>P. acutifolius</i> cytoplasm	20	8	N.E ¹
Z99ZX-11A F ₃	“ “	7	1	N.E
ZX99-15 F ₃	“ “	7	3	N.E
ZXTG31-4-10 F ₄	“ “	12	5	N.E
GKVGAG-1A F ₃	“ “	31	31	N.E
A6 F ₂	Intraspecific <i>P. lunatus</i> hybrid	9	7	N.E
VS42-14 F ₂	“ “	5	4	N.E
V5 F ₂	“ “	31	31	N.E.
VS42-7 F ₂	“ “	6	6	N.E
Checks				
G 40168	Susceptible <i>P. acutifolius</i> accession	15	0	42.6
G 25410	Susceptible <i>P. lunatus</i> accession	15	0	44.4
RAZ 44	Susceptible <i>P. vulgaris</i> line	15	0	38.0
ICA Pijao	Susceptible <i>P. vulgaris</i> cultivar	15	0	31.9
G 40199	Resistant <i>P. acutifolius</i> accession	15	9	N.E
G 25042	Resistant <i>P. lunatus</i> accession	15	9	N.E
G 25713	Resistant <i>P. lunatus</i> accession	26	24	N.E

^a N.E., no adult emergence from resistant seeds

Table 27. Reconfirmation of resistance to *Acanthoscelides obtectus* in pre-selected segregating F₅ hybrid progenies derived from interspecific *Phaseolus vulgaris* x *P. acutifolius* crosses

Code and generation	Type of material	Number of seeds evaluated	Number of resistant seeds	Days to adult emergence
Hybrids				
GKVGAG 1B 4D F ₅	Double congruent hybrid with <i>P. acutifolius</i> cytoplasm	25	22	N.E ^a
GKVGAG 1E 2C F ₅	“ “	59	58	N.E
Checks				
G 12882 ARC1	Susceptible wild <i>P. vulgaris</i> accession	20	0	37.5
G 12952 ARC 4	“ “	20	0	53.3
G 40168	Susceptible <i>P. acutifolius</i> accession	20	0	45.2
G 25410	Susceptible <i>P. lunatus</i> accession	19	0	43.7
RAZ 44	Susceptible <i>P. vulgaris</i> line	20	0	37.3
ICA Pijao	Susceptible <i>P. vulgaris</i> cultivar	20	0	30.5
G 40199	Resistant <i>P. acutifolius</i> accession	19	19	N.E
G 25042	Resistant <i>P. lunatus</i> accession	20	20	N.E

^aN.E., no adult emergence from resistant seeds

Contributors: C. Cardona, J. F. Valor, A. Mejía, S. Beebe, and J. Tohme

Pod weevil (*Apion godmani*)

Rationale: The pod weevil is one of the most important pests of beans in Mexico and Central America. As indicated in previous reports, we are attempting to develop a molecular marker for *Apion* resistance. This work has been conducted in close collaboration with Dr. Ramón Garza from INIFAP. In order to support the molecular work, new phenotypic data were obtained by testing for resistance in the field a set of 54 recombinant inbred lines (RILs) developed in 2002. The lines are derived from a cross between Jamapa (a susceptible cultivar) and J-117 (a highly resistant Mexican landrace). The materials were tested at two locations (Santa Lucía de Prías in Mexico State and Atotonilco in Hidalgo State) in replicated nurseries using three replications per material in a randomized complete block design. The infestation in Santa Lucía was low and unreliable for proper resistance evaluation. That in Atotonilco was high and reliable to discriminate between susceptible and resistance genotypes.

The population of RILs was normally distributed for *Apion* resistance (Figure 23), suggesting that the inheritance of resistance to the pod weevil may be governed by more than a single major resistance gene. Even though overall levels of infestation in 2003 were higher than in 2002, there was a significant correlation ($r = 0.423$; $P < 0.01$) between damage scores obtained in 2002 and in 2003 (Figure 24). The phenotypic data obtained in 2003 is being used in the development of a molecular marker for pod weevil resistance (for details see SB-2 report).

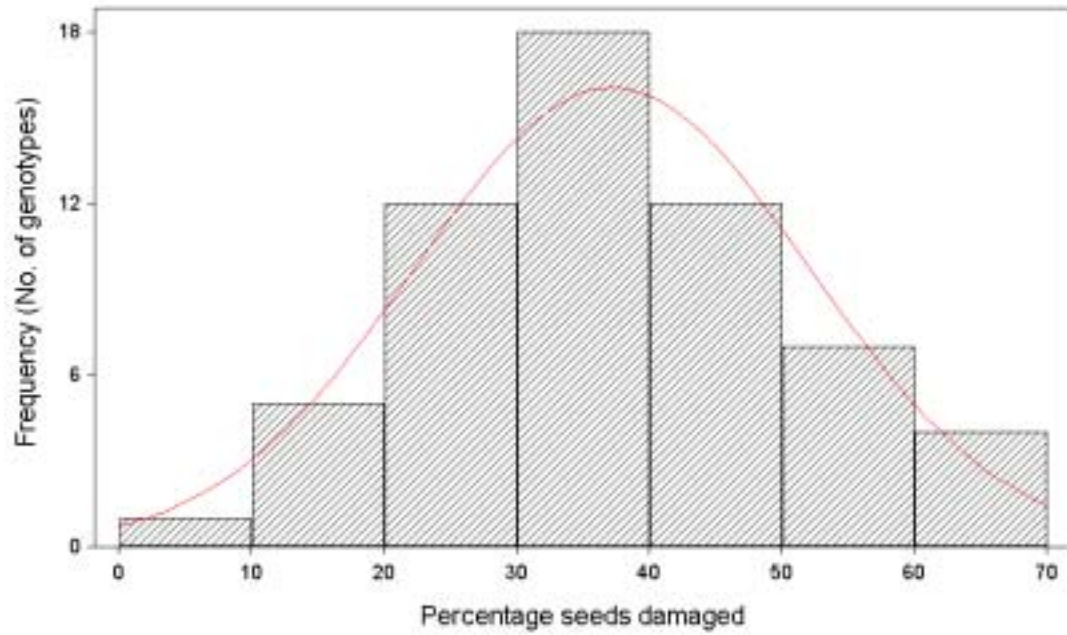


Figure 23. Frequency histogram of percentage seeds damaged by the pod weevil (*Apion godmani*) in a population of 54 recombinant inbred lines derived from a cross between Jamapa (a highly susceptible cultivar) and J-117 (a highly resistant Mexican landrace). The lines were screened under field conditions and high insect populations in a replicated nursery. Atotonilco, Hidalgo State, Mexico, 2003B.

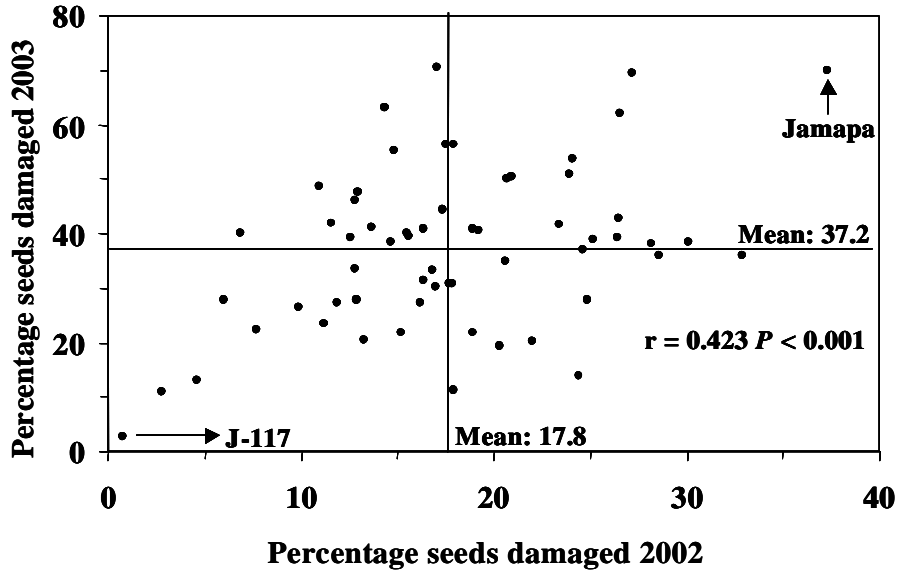


Figure 24. Percentage seed damage in 54 recombinant inbred lines (RILs) tested for resistance to the pod weevil (*Apion godmani*) in two consecutive trials. RILs derived from a cross between Jamapa (a susceptible cultivar) and the resistance source J-117 (a Mexican landrace). Tests

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Leafhopper (*Empoasca kraemeri*)

In 2004 we screened a total of 549 bean germplasm accessions for resistance to the leafhopper. Those selected in 2003 (33) were reconfirmed in replicated nurseries. Of these, 21 were selected for further testing in 2004. We also gave support to the mainstream breeding activities of the Bean Project by screening a series of nurseries. These included 29 selections made in 2003 individual plant selections in Andean crosses performed with selected EMP lines as parents. Thirteen were yield-tested in 2004. Other yield tests included 13 lines derived from crosses with EMP 250 and lines from crosses with Saladin and 16 Andean lines.

We will highlight the work on evaluation of interspecific *P. vulgaris* - *P. acutifolius* hybrids. Similar to the work with bruchids these progenies were obtained by means of the Double Congruity Backcross technique developed at CIAT. We tested 189 progenies (F₂ and F₃) of crosses made with the tepary sources of resistance to leafhopper G 40019 and G 40036. Selected progenies and their reaction to leafhopper are shown in Tables 28-30. In general, the best lines show an intermediate level of resistance comparable to that found in the tolerant check, ICA Pijao. It can also be said that resistance to leafhopper in interspecific hybrids is not as good as the resistance found in *P. acutifolius* accessions G 40036, G40019, and G 40019.

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Table 28. Resistance to *Empoasca kraemeri* in selected F_{2.5} progenies derived from interspecific *Phaseolus vulgaris* - *P. acutifolius* crosses

Code	Pedigree ^a	Damage scores ^b	Reproductive adaptation scores ^c	Overall rating
Hybrids				
KKQ-11 F ₅	V-DCBC x V-DCBC	6.8	3.8	Intermediate
A99Y-15 F ₄	V-DCBC x (G40199 X A-DCBC)	6.0	5.3	Resistant
A19Y-103 F ₅	V-DCBC x (G40019 X A-DCBC)	6.3	4.0	Intermediate
A19Y-117 F ₄	V-DCBC x (G40019 X A-DCBC)	6.4	4.8	Intermediate
A36Y-42 F ₅	V-DCBC x (G40036 X A-DCBC)	6.1	4.3	Intermediate
A99Y-86 F ₄	V-DCBC x (G40199 X A-DCBC)	6.4	4.8	Intermediate
A99Y-90 F ₄	V-DCBC x (G40199 X A-DCBC)	5.9	5.0	Resistant
A99Y-91 F ₄	V-DCBC x (G40199 X A-DCBC)	6.3	4.3	Intermediate
ANIY-101 F ₄	V-DCBC x A-DCBC	6.9	4.0	Intermediate
A36Y-42 F ₄	T-6FB x G36NGP-3FL	6.5	-	Intermediate
EMPZ-2 F ₃	A99Y-90 x ZXTGS21-9	6.2	-	Intermediate
EMPZ-5 F ₃	A36Y-42 x ZXTGS-21-11	6.7	-	Intermediate
EMPZ-8 F ₃	A99Y-103 x ZXTGS49-8	7.0	-	Intermediate
EMPZ-9 F ₃	A99Y-103 x ZXTGS49-8	7.0	-	Intermediate
TZTE - 9F F ₂	TZT-12FL x EMPZ-3FB	7.0	-	Intermediate
TZTE - 11F ₂	TZT-3FL x EMPZ-2FB	7.0	-	Intermediate
TZTE - 20B F ₂	TZT-3FL x EMPZ-3FB	6.5	-	Intermediate
TZTE - 71B F ₂	TZT-4FL x EMPZ-3FB	5.7	-	Intermediate
Checks				
BAT 41	Susceptible <i>P. vulgaris</i> line	8.8	3.5	Susceptible
EMP 250	Tolerant <i>P. vulgaris</i> line	6.4	6.0	Intermediate
EMP 508	Tolerant <i>P. vulgaris</i> line	6.2	6.3	Intermediate
EMP 512	Tolerant <i>P. vulgaris</i> line	6.0	5.8	Resistant
G40016	Susceptible <i>P. acutifolius</i> accession	8.6	3.0	Susceptible
G40019	Resistant <i>P. acutifolius</i> accession	5.6	5.5	Resistant
G40036	Resistant <i>P. acutifolius</i> accession	5.3	6.0	Resistant
G40056	Susceptible <i>P. acutifolius</i> accession	8.8	2.5	Susceptible
G40065	Susceptible <i>P. acutifolius</i> accession	8.1	4.8	Susceptible
G40119	Resistant <i>P. acutifolius</i> accession	5.1	6.0	Resistant
ICA Pijao	Tolerant <i>P. vulgaris</i> cultivar	7.3	6.0	Intermediate
NI576	Susceptible <i>P. acutifolius</i> line	8.8	2.0	Susceptible

^aV-DCBC = Double congruent hybrid with *P. vulgaris* cytoplasm; A-DCBC = Double congruent hybrid with *P. acutifolius* cytoplasm

^bOn a 1-9 visual scale (1, no damage; 9, severe damage)

^cOn a 1-9 visual scale (1, no yield, no pod formation; 9, excellent pod formation and filling, excellent yield).

Table 29. Resistance to *Empoasca kraemeri* in selected F_{3,6} progenies derived from interspecific *Phaseolus vulgaris* - *P. acutifolius* crosses

Code	Pedigree ^a	Damage scores ^b	Reproductive adaptation scores ^c	Overall rating
Hybrids				
A99Y-15 F ₅	V-DCBC x (G40199 X A-DCBC)	6.8	4.5	Intermediate
A19Y-103 F ₆	V-DCBC x (G40019 X A-DCBC)	6.8	4.0	Intermediate
A19Y-117 F ₅	V-DCBC x (G40019 X A-DCBC)	7.2	4.0	Intermediate
A99Y-86 F ₅	V-DCBC x (G40199 X A-DCBC)	6.8	4.5	Intermediate
A99Y-90 F ₅	V-DCBC x (G40199 X A-DCBC)	6.6	4.5	Intermediate
A99Y-91 F ₅	V-DCBC x (G40199 X A-DCBC)	6.8	4.3	Intermediate
ANIY-101 F ₅	V-DCBC x A-DCBC	7.2	3.5	Intermediate
A36Y-42 F ₅	T-6FB x G36NGP-3FL	7.0	4.5	Intermediate
EMPZ-8 F ₄	A99Y-103 x ZXTGS49-8	7.2	3.5	Intermediate
EMPZ-9 F ₄	A99Y-103 x ZXTGS49-8	7.0	3.8	Intermediate
TZTE - 20B F ₃	TZT-3FL x EMPZ-3FB	7.4	3.8	Intermediate
EMPZ-2 F ₄	A99Y-90 x ZXTGS21-9	6.4	5.0	Resistant
EMPZ-5 F ₄	A36Y-42 x ZXTGS-21-11	6.8	4.5	Intermediate
TZTE - 71B F ₃	TZT-4FL x EMPZ-3FB	6.5	4.0	Intermediate
Checks				
G40019	Resistant <i>P. acutifolius</i> accession	5.6	5.5	Resistant
G40036	Resistant <i>P. acutifolius</i> accession	5.6	5.8	Resistant
NI576	Susceptible <i>P. acutifolius</i> line	7.8	2.8	Susceptible
G40033	Susceptible <i>P. acutifolius</i> accession	8.8	2.3	Susceptible
G40119	Resistant <i>P. acutifolius</i> accession	5.7	5.0	Resistant
EMP 512	Tolerant <i>P. vulgaris</i> line	6.1	5.3	Resistant
EMP 508	Tolerant <i>P. vulgaris</i> line	6.5	4.3	Intermediate
EMP 250	Tolerant <i>P. vulgaris</i> line	6.8	4.3	Intermediate
BAT 41	Susceptible <i>P. vulgaris</i> line	9.0	2.0	Susceptible
ICA Pijao	Tolerant <i>P. vulgaris</i> cultivar	6.8	4.3	Intermediate

^a V-DCBC = Double congruent hybrid with *P. vulgaris* cytoplasm; A-DCBC = Double congruent hybrid with *P. acutifolius* cytoplasm

^b On a 1-9 visual scale (1, no damage; 9, severe damage)

^c On a 1-9 visual scale (1, no yield, no pod formation; 9, excellent pod formation and filling, excellent yield)

Table 30. Resistance to *Empoasca kraemeri* in selected F_{3.6} progenies derived from interspecific *Phaseolus vulgaris* - *P. acutifolius* crosses

Code ^a	Pedigree	Damage scores ^b	Reproductive adaptation scores ^c	Overall rating
Hybrids				
TSC	TZTA-1A2L FB x Row 3 FB (A36Y 42)	6.3	4.0	Intermediate
TSC	TZTA-1A2L FB x Row 3 FB (A36Y 42)	6.0	4.3	Intermediate
TSC	TZTA-1A2N FB x Row 3 FB (A36Y 42)	6.3	4.3	Intermediate
TSC	TZTA-1A2N FB x Row 3 FB (A36Y 42)	6.3	4.3	Intermediate
TSC	TZTA-1A2N FB x Row 3 FB (A36Y 42)	6.3	4.3	Intermediate
TSC	TZTA-1A2N FB x Row 3 FB (A36Y 42)	6.3	4.3	Intermediate
TSC	TZTA-1A2L FB x Row 3 FB (A36Y 42)	6.3	4.3	Intermediate
TSC	TZTTZ-85R FB x Row 10 FB (EMPZ2)	6.3	4.3	Intermediate
TSC	TZTTZ78M FB x Row 30 FB (TZTE-71)	6.3	4.3	Intermediate
ZXTGS	ZXTG6FB x Row 49 Entry 70FL	6.3	4.3	Intermediate
ZXTGS	ZXTG6FB x Row 49 Entry 70FL	6.3	4.3	Intermediate
ZXTGS	ZXTG6FB x Row 21 FLG36NGP-3F ₂	5.7	4.3	Resistant
SCO	ZXTG6FB x Row 49 Entry 70FL	6.3	4.7	Intermediate
SCO	ZXTG6FB x Row 21 FLG36NGP-3F ₂	5.7	4.7	Resistant
TSC	TZTA-1A2L FB	6.3	5.5	Resistant
TSC	TZTTZ-98B FL	6.0	5.0	Resistant
Checks				
G40019	Resistant <i>P. acutifolius</i> accession	4.5	6.0	Resistant
G40036	Resistant <i>P. acutifolius</i> accession	4.3	6.1	Resistant
NI576	Susceptible <i>P. acutifolius</i> line	8.0	2.8	Susceptible
G40033	Susceptible <i>P. acutifolius</i> accession	8.8	2.3	Susceptible
G40119	Resistant <i>P. acutifolius</i> accession	4.6	5.6	Resistant
EMP 512	Tolerant <i>P. vulgaris</i> line	5.9	6.0	Resistant
EMP 508	Tolerant <i>P. vulgaris</i> line	6.5	4.3	Intermediate
EMP 250	Tolerant <i>P. vulgaris</i> line	6.2	6.0	Intermediate
BAT 41	Susceptible <i>P. vulgaris</i> line	8.3	2.6	Susceptible
ICA Pijao	Tolerant <i>P. vulgaris</i> cultivar	6.7	5.3	Intermediate

^a TSC = Double congruent hybrid with *P. vulgaris* cytoplasm; A-DCBC = Double congruent hybrid with *P. acutifolius* cytoplasm; both ZXTGS and SCO possess *P. acutifolius* cytoplasm

^b On a 1-9 visual scale (1, no damage; 9, severe damage)

^c On a 1-9 visual scale (1, no yield, no pod formation; 9, excellent pod formation and filling, excellent yield)

1.3.2 Studies on progress in tolerance to leafhopper

In 2004 we finished our studies on progress in incorporating tolerance to leafhopper. We performed the combined analysis of variance for the five consecutive trials aimed at measuring the response of EMP lines (bred for leafhopper resistance) and checks to two levels of infestation (3 and 6 nymphs per leaf). These were obtained by exercising chemical control at pre-established action levels. There was not a significant interaction between trials and treatments. At all levels of infestation, EMP 250, EMP 542, EMP 544, and EMP 588 yielded significantly better than the susceptible check BAT 41 and EMP 124. None performed better than ICA Pijao, the tolerant check (Figure 25). However, in terms of percentage yield losses, new lines (the EMP 500 series) performed better at all levels of infestation than the improved checks EMP 124 and EMP 250, and, in some cases, better than the standard tolerant check, ICA Pijao. At very high levels of infestation (6 nymphs per leaf) average yield losses in EMP lines was above the 30% level, meaning that even tolerant materials would benefit from integration with chemical control exercised at pre-established action levels.

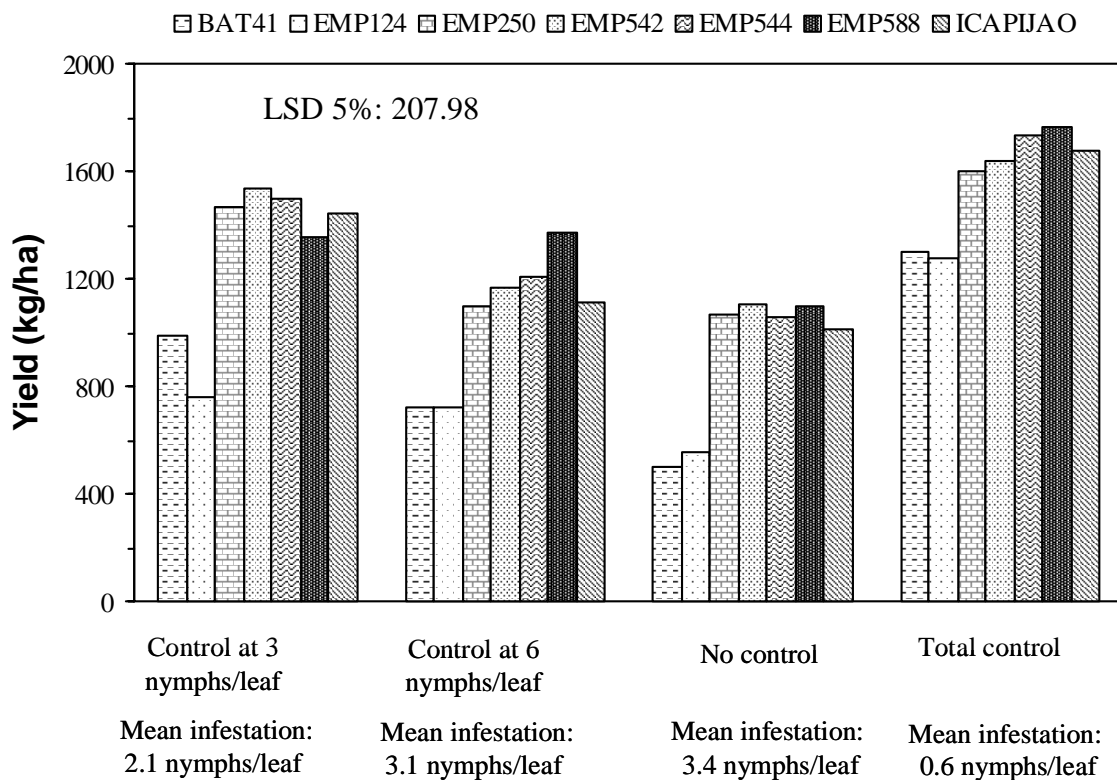


Figure 25. Yields of selected EMP lines and checks (BAT 41, ICA Pijao) at different levels of Infestation with the leafhopper *Empoasca kraemeri*. Means of five trials

Contributors: J.M. Bueno, C. Cardona

Progress toward achieving output milestones:

- The identification of resistant progeny from interspecific crosses between *P. vulgaris* and *P. acutifolius* suggests that resistance is a heritable trait, although most resistant lines carry cytoplasm of *P. acutifolius*.
- Obtaining a second year of phenotypic data for the reaction of RILs to the pod weevil will permit gene tagging. The development of molecular markers for pod weevil, thrips, and bruchids should facilitate breeding for resistance.

Activity 1.4 Developing more nutritious small seeded bean varieties

Highlights:

- Lines combining a moderate level of drought tolerance with 50% higher level of iron have been recovered. These are still deficient in grain type and other agronomic traits but will form the basis for another cycle of recurrent selection.
- A study of G x E across CIAT's research sites suggests that some factor associated with low pH results in low seed iron concentration.
- Two varieties (Gofta and Roba-1) show high levels of iron and zinc concentration across locations and seasons
- Significant interaction of genotypes, soil conditions and P application can be exploited to enhance grain iron and zinc concentration
- Accessions of *Phaseolus coccineus* and *Phaseolus polyanthus* present levels of iron as much as 60% above checks and zinc only narrowly above checks in this trial. Confirmation of a wider advantage is necessary to justify interspecific crosses to improve iron concentration.
- New bean lines high in iron and zinc concentration identified in Eastern Africa and evaluated for agronomic characteristics by more than 20 farmers.

1.4.1 Evaluation of F₃-derived F₅ families to combine high iron with agronomic traits

Rationale: Improvement of nutritional quality must go hand in hand with improvement of agronomic characters. Eventual adoption and cultivation by farmers will depend on some visible advantage in terms of yield, market value, or some other trait that induces farmers to grow beans. Past advances must be maintained and additional agronomic traits must be added. For many bean growing areas, drought tolerance is a trait that is needed for food security and will be very attractive to farmers. Combining drought tolerance with higher mineral concentration will serve to accelerate the diffusion of varieties with improved nutritional value.

Materials and Methods: Multiple crosses were created among parents with diverse traits: resistance to BGYMV, which is now a requisite for varietal release in most areas of Central America; resistance to angular leaf spot, which is important in both Central America and Africa; drought tolerance; and high iron concentration. Multiple parents of high iron were employed to combine genes for this trait from various sources. In the F₂ generation about 1500 F₁-derived F₂ families were evaluated under drought, and 250 were advanced and selected under pressure of anthracnose and angular leaf spot in successive generations. Twenty-seven F₃-derived F₅ families were again tested under drought pressure in 2004. This group represents a sub-set of those reported in section 1.1.1 above.

Results and Discussion: Our short term goal (i.e., in year 1 of the HarvestPlus program) for the improvement of iron and zinc concentration calls for an increase of 50% in mineral content in some ten F₃-derived F₅ families with tolerance to drought. This would be the equivalent of about 65-70 mg/kg⁻¹ iron in the conditions of this particular trial in Quilichao in which the checks presented less than 45 mg kg⁻¹ of iron. A few families meet this criterion (Table 31) when the standard against which drought tolerance is compared is Tio Canela, a widely used commercial

variety in Central America, although their advantage in drought tolerance is modest. However, no improvement in zinc concentration of the selected lines was detected. Nonetheless, the recovery of even this small number of lines with a positive combination of traits suggests that higher mineral concentration can be obtained in agronomically superior materials. For example, MDSF 14729-23-MC-4Q-MQ presented a 17% yield advantage over the check in a replicated trial, and from 74 mg kg⁻¹ iron in an unreplicated assay to 80 mg kg⁻¹ in a replicated trial. This bodes well for future work, and a second round of populations with high mineral parents appears to be more promising in its adaptation to drought conditions.

Table 31. Lines derived from crosses to combine superior mineral concentration with drought tolerance.

Cross / Line	Yield as % checks ¹	Yield checks	[Fe] in F ₄ families (mg kg ⁻¹)	[Zn] in F ₄ families (mg kg ⁻¹)
(SXB 111 x (INB35 x G23834E)) x (MAB 85 x EAP9653-16B-1)				
MDSF 14729-23-MC-2Q-MQ	140	1191	70	31
MDSF 14729-23-MC-3Q-MQ	113	1191	75	31
MDSF 14729-23-MC-4Q-MQ	117	1191	74	33
(SXB 127 x (MIB 81 x G23823E)) x (MAB 87 x EAP9653-16B-1)				
MDSF 14734-31-MC-35Q-MQ	123	1191	75	23
MDSF 14734-31-MC-22Q-MQ	98	1191	83	23
MDSF 14734-31-MC-37Q-MQ	89	1191	97	22
(SXB 124 x (INB 35 x G23834E)) x (SXB 123 x RIB 68)				
MDSF 14742-3-MC-12Q-MQ	157	1191	65	32
MDSF 14742-3-MC-27Q-MQ	113	1191	65	28
(SXB 122 x (INB 36 x G23818B)) x (MAB 95 x EAP9653-16B-1)				
MDSF 14743-27-MC-23Q-MQ	106	1191	75	30
MDSF 14743-51-MC-3Q-MQ	129	1191	75	29
(SXB 122 x (INB 36 x G23818B)) x BFB 146				
MDSF 14744-15-MC-2Q-MQ	145	1191	87	30
DOR 500			42	28
CAL 96			44	24

¹ Yields of lines were calculated as a per cent of the yield of commercial check Tio Canela.

Conclusion: Combining higher mineral concentration with acceptable agronomic type is a particular challenge for the warmer tropical environments in which the sources of higher mineral concentration are poorly adapted. However, progress in this regard indicates that this is possible.

Contributors: S. Beebe, C. Cajiao, M.A. Grajales (IP-1);
O. Mosquera (Analytical Laboratory)

1.4.2 A study of G x E interaction across CIAT's research sites with lines bred for high mineral content

Rationale: Genotype x Environment interaction confounds the expected performance of selected materials over seasons or in environments other than the selection sites *per se*. Our original evaluation of gene bank accessions in the core collection was carried out in Popayán and in Darién where most landrace germplasm adapts reasonably well. However, breeding for warm tropical environments requires selection at other sites, and in the case of CIAT, this implies selection at Palmira and/or Santander de Quilichao, both of which have soils that contrast with the those at Popayán or Darién.

Materials and Methods: A nursery of 31 lines and sources was composed of original sources (gene bank accessions) and lines selected from crosses among sources. This was planted at three sites with contrasting soil characteristics: Popayán (inceptisol with high organic matter and a modified pH of 5.6); Quilichao (oxisol with a modified pH of 4.5-5.0); and Palmira (molisol with a pH of 7.2). Single row plots were used in three replications. The primary purpose was to verify the effect of G x E on mineral concentration, but yield was measured as well.

Results and Discussion: Mineral content was strongly affected by location, genotype and genotype x location interaction (Tables 32 and 33). Palmira gave the highest levels of iron, while Popayán gave the highest levels of zinc. The effect of location could have been due to several factors. Palmira and Quilichao have similar temperatures but resulted in widely differing mineral concentrations in grain. On the other hand Quilichao and Popayán have very different temperatures but both present relatively low mineral concentrations. Thus, temperature differences do not appear to explain differences in mineral concentration over sites. The most obvious common factor that Quilichao and Popayán have in common and that distinguishes both from Palmira is an acid soil pH and other possibly associated soil characteristics such as manganese toxicity. However, an acid soil would not be expected to give lower iron concentration. Quite the contrary, an acid soil should have more available iron than a neutral to alkaline soil like that in Palmira. However, another trial with a partial set of genotypes in Quilichao in a lot with pH of 6.2 presented higher levels of iron than the Quilichao soil at pH 4.5 – 5.0, thus tending to confirm that more iron is accumulated in grain at higher soil pH. Hypotheses to explain this behavior include a pH-sensitive plant response to activate uptake mechanisms at higher pH; or interference of manganese with iron absorption at low pH. Both Quilichao and Popayán have high manganese content in the soil. In spite of G x E effects, correlations across sites for iron concentration were high, ranging from $r = 0.71$ to 0.86 , whereas correlations with zinc ranged from 0.47 to 0.74 . Thus, selection would still be effective across sites, especially for iron.

Table 32. Significance of effects in ANOVA for mineral concentration and yield of 31 genotypes over three sites.

Source	Df	[Fe]	[Zn]	Yield
Locality	2	***	***	***
Genotype	30	***	***	***
Locality x Genotype	60	***	***	***
Rep (Locality)	6	**	NS	***

Table 33. Iron and zinc concentrations in selected lines, gene bank accessions and controls in three sites and under different soil pH values.

Tmt.	Identification	Iron					Zinc				
		Pal. pH 7.2	Pop. pH 5.6	Quil. pH 4.5	Ave.	Quil. pH 6.2	Pal. pH 7.2	Pop. pH 5.6	Quil. pH 4.5	Ave.	Quil. pH 6.2
4	MIB 151	87	68	75	77	94	27	42	34	34	43
5	MIB 152	90	59	81	77	89	26	37	31	32	42
6	MIB 153	82	60	72	71	92	30	34	31	32	40
8	MIB 154	82	68	63	71	89	30	35	29	31	38
10	MIB 155	105	66	70	80	97	35	33	32	33	38
11	MIB 156	81	50	51	60	77	27	30	25	27	35
12	MIB 157	105	72	77	85	93	40	32	29	34	38
13	MIB 158	104	78	77	86	93	37	33	28	33	38
23	G23818B	92	87	79	86		35	38	36	36	
24	G23823E	95	96	92	94		36	35	30	33	
25	G23834E	119	91	87	99		30	32	29	30	
26	DICTA 17	58	45	48	50		23	28	28	26	
27	DOR 500	58	48	52	53	53	24	29	24	26	27
28	CAL 96	50	51	50	50	46	19	23	23	22	22
	Trial mean	78	61	64	68	82	27	31	28	29	36

Compared to mineral concentration of local checks DOR 500 and CAL 96, the advantage of the lines bred for high minerals was reduced by about 50% under pH 5.6 and lower. However, implications for targeting of high iron materials and the effect of G x E on mineral content may not be serious for many bean growing areas. The bred lines maintained a broad advantage over checks at pH 6.2 in Quilichao, and this pH would more typical of most soils in Central America and the Caribbean. Very low pH soils would be a greater concern for Costa Rica, southern Mexico and Central Africa, especially Congo and western Rwanda.

Although yield was measured on single row plots, highly significant effects were detected for materials, locations, and materials x locations. A tendency emerged of a negative correlation between yield and mineral concentration, reflecting the poor adaptation of the original sources. Among the gene bank accessions, all performed very poorly at Palmira and Quilichao, but much better in Popayán under cooler temperatures, where G23834E produced 3428 kg/ha. This highlights the difficulty of breeding high mineral beans for warmer environments with these sources, and the need for recurrent selection.

Conclusion: The effect of pH on mineral content of bean seed requires additional study. But in spite of G x E effects, ranking of genotypes across sites tends to be similar and to permit selection of high mineral cultivars.

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1.4.3 Influence of P application on grain iron, zinc and protein concentration

Rationale: Micronutrient deficiency is a world-wide health problem affecting more than 1 billion people. Major deficiencies occur in iron, zinc and vitamin A. Alternative strategies of reducing micronutrient deficiencies such as supplementation and fortification have had limited success in the developing world, where the problem is most acute, because of limited coverage, underdeveloped food industry and difficulties in patient compliance and access. Dietary improvement is probably the most effective and sustainable strategy for reducing micronutrient deficiencies in Africa. This approach aims to increase dietary availability, regular access and consumption of mineral-rich foods in at - risk and micronutrient-deficient groups of populations. It involves development and promoting enhanced consumption of culturally acceptable, mineral rich grains and vegetables. Common bean offers unique opportunities for improved micronutrient nutrition and food security because it is widely grown (3.7 million ha annually in Africa) and consumed; it is rich in protein (>20%), minerals and calories, and is relatively cheap and highly marketable. We previously reported that genetic variation exists in common bean to facilitate improvement of the grain iron concentration by 80% and zinc level by 50%. However, the stability of expression of this trait may be influenced by environmental factors and interactions with genotypes. Rengel (1999) in an extensive review of literature concluded that fertilization with inorganic and organic forms of micronutrients has potential to increase their concentration in the grain. Effectiveness of various agricultural measures in increasing micronutrient density depends on soil type, crop, cultivar, and rotation, and environmental and other factors, thus necessitating development of a specific set of measures for individual regions. However, little is known on the role applying macronutrients such as P, N and K on the grain iron and zinc concentration in common bean and other staple crops. In this report we highlight results of a study on the effect of P application on seed iron, zinc and protein.

Materials and Methods: Four trials were conducted to evaluate the effect of levels of P application on seed iron, zinc and protein in 27 bean lines. The trials were conducted at Kabete (1860m) and Thika (1500m) for two seasons. The seasons were the long rain season (April-August) of 2002 and short rain season (November 2002 to February 2003). Soil at Kabete and Thika are acidic to slightly acidic nitosols (pH between 4.7 and 6). However, Kabete soils are of medium fertility. Soils at Thika are deficient in P and N. A basal rate of 100 kg calcium ammonium nitrate (21% N) was applied at the two sites. P was applied at 0, 50 and 100 kg ha⁻¹. Source of P was triple super phosphate (45% P₂O₅). A plot had four, 5 m rows. Spacing was 10 cm within rows and 45 cm between rows. The experimental design was a split plot with three replicates. P levels were the main plots and bean lines as the subplots. Seed for mineral analysis was harvested from the inner two rows. Mineral concentration was determined with atomic absorption following standard procedures at CIAT, Colombia. Data was analyzed using SAS statistical software. Some plots were lost due susceptibility to diseases (especially root rot, black root) and therefore were excluded from the analysis.

Results and Discussion: Combined analysis of the data showed that there were highly significant differences in grain iron concentration (P<0.01) due to season, location, and genotypic effects. Significant season x P level, season x location and location x season x P levels were also detected (Table 34). There were significant interactions between genotypes and locations, genotypes and seasons and genotypes with P application levels. Significant second

order interactions were detected among genotypes, locations, seasons and P levels for grain iron concentration. Mean grain iron concentration varied with seasons. It was higher during the short rain season (76.8 mg kg⁻¹) compared to long rain season (68.4 mg kg⁻¹). Mean iron concentration was higher at Thika (75 mg kg⁻¹) than Kabete (70.1 mg kg⁻¹). Grain iron concentration increased modestly with P application. The average concentration was 72, 72 and 73.6 mg kg⁻¹ at 0, 50 and 100 kg P ha⁻¹, respectively over the two locations, seasons and genotypes. However, iron concentration varied with locations and P levels. Mean iron concentration was highest at 50 kg P ha⁻¹ at Thika (77 mg kg⁻¹) and lowest at same P level at Kabete (66.7 mg kg⁻¹). Gofta had the highest seed iron concentration (79.7 mg kg⁻¹) across sites, seasons and P levels, confirming previous reports. It was followed by Roba-1 (78 mg kg⁻¹). Genotypic responses were influenced by location, season and P level. The highest iron concentration was for Zebra at 50 kg P ha⁻¹ (90 mg kg⁻¹), Gofta and MCM 2001 at 100 kg P ha⁻¹ at Thika (89 mg kg⁻¹) during the 2002 long rain season. Red Wolaita (66 mg kg⁻¹) and Ranjonoby (64 mg kg⁻¹) had the lowest seed iron concentration at 0 kg P ha⁻¹ in the same site and season. These results suggest that P application enhances seed iron concentration. The seasonal effect may be due to moisture availability, since P is a relatively immobile element, and translocation efficiency of individual genotypes.

Table 34. Mean squares for seed iron, zinc and protein concentration of 15 bean lines grown at Kabete and Thika (Kenya) over two seasons under different P treatments.

Source	Df	Mean Squares		
		Iron (mg kg ⁻¹)	Zinc (mg kg ⁻¹)	Protein (%)
Seasons (S)	1	9423.68**	1822.48**	508.99**
Locations (L)	1	3318.22**	575.93**	1565.56**
Locations x Seasons	1	21667.01**	65.06**	744.94**
Reps (L x S)	8	360.23**	57.46**	57.31**
P levels	2	166.57NS	117.89**	305.92**
S x P levels	2	1937.69**	322.29**	469.99**
L x P levels	2	1173.53**	22.77NS	85.17**
L x S x P levels	2	3387.87**	105.47**	99.66**
Reps x P levels(L x S)	16	122.96**	16.43*	74.53**
Genotypes (G)	14	590.46**	78.80**	41.33**
G x S	14	261.83**	41.40**	22.20**
G x L	14	234.52**	40.74**	18.06**
G x S x L	14	104.98NS	22.64**	8.60NS
G x P levels	28	103.84*	10.86NS	5.57NS
G x S x P levels	28	127.80**	10.81NS	5.14NS
G x P levels x L	28	137.46**	8.31NS	9.18*
G x P levels x S x L	28	137.46**	6.52NS	4.5NS
Pooled error	536	66.76	8.60	5.38

*, **= Significant at 5% and 1% probability levels, respectively; NS= not significant.

There were highly significant season, location, P level and genotypic effects on the seed zinc concentration (Table 34). Zinc concentration was higher during the short rain season (37.4 mg kg⁻¹) compared with the long rain season (33.4 mg kg⁻¹). In contrast with iron, grain zinc concentration was higher at Kabete (36.6 mg kg⁻¹) than at Thika (34.5 mg kg⁻¹). Zinc concentration varied with P levels. The concentrations were 34.7, 36.3 and 35.6 mg kg⁻¹ with application of 0, 50 and 100 kg P ha⁻¹, respectively. Mean zinc concentration varied from 33 mg kg⁻¹ for TY 3396, Ranjonoby and K131 to 38.8 mg kg⁻¹ for ICA Pijao (Table 35). However, the genotypic responses varied with locations and P levels. The highest Zn levels were recorded at Kabete with application of 50 kg P ha⁻¹. Gofta had the highest Zn concentration (35.5 mg kg⁻¹) at Thika. ICA Pijao (42.7 mg kg⁻¹) and Ituri matata (42.5 mg kg⁻¹) had the highest zinc concentration at 100 kg P ha⁻¹. Gofta had a mean Zn concentration of 36.8 mg kg⁻¹ at 100 kg ha⁻¹ across sites.

Table 35. Mean seed iron, zinc and protein concentration of 15 bean lines grown at Kabete and Thika (Kenya) for two seasons.

Line	Iron (mg kg ⁻¹)	Zinc (mg kg ⁻¹)	Protein (%)
Atndaba	69.1	35.7	20.1
Gofta	79.7	35.3	21.2
ICA Pijao	73.8	38.8	20.7
Ituri Matata	70.6	36.7	20.7
K131	69.0	33.8	19.8
Lingot Blanc	71.5	35.1	21.6
Maasai Red	71.3	37.3	21.4
MCM 2001	71.5	35.7	20.4
Mexican 142	74.6	37.3	21.8
Ranjonoby	63.8	33.8	20.6
Red Wolaita	70.6	36.0	21.5
Roba-1	78.5	34.6	21.1
Simama	73.8	34.1	19.9
TY 3396-12	73.8	33.8	20.1
Zebra	77.1	35.2	19.9
Mean	72.6	35.6	20.7
CV (%)	19.2	12.6	13.1

There were significant season, location, P level and genotypic effects on the seed protein. Seed protein concentration was higher during the short rain season (21.3%) compared with long rain season (20.1%). Seed protein was higher at Kabete (21.8%) compared to Thika (19.6%). Seed protein increased with levels of P application. The mean protein concentration across sites, season and genotypes was 19.9, 20.6 and 21.6% with 0, 50 and 100 kg P application, respectively. Mexican 142, Maasai Red and Lingot Blanc had the highest mean protein concentration (21.8 %) across sites and seasons. K131 and TY 3396-12 (both carioca grain type) had the lowest seed protein concentration (19.9%). Gofta had the highest seed protein concentration at Thika (20.2%).

These results suggest that application of P may be enhance the seed iron, zinc and protein concentration. However, the magnitude of the effect will vary with locations and seasonal factors.

Contribution: P. Kimani, S. Beebe

Collaborators: E. Tovar, D. Macharia and Kabete Bean Team.

1.4.4 Identification of high mineral accessions in sister species of common bean

Rationale: Common bean, *Phaseolus vulgaris*, is one of five domesticated species in the genus *Phaseolus*, and is readily crossed with *P. coccineus* and *P. polyanthus*. Several years ago a core collection was designed to represent the eco-geographical variability in the sites of origin of the accessions of *P. coccineus* and *P. polyanthus* held in the CIAT gene bank. Core collections offer a rapid assessment of the potential of a species for any given trait about which little is known for that species.

Materials and Methods: The core collection of approximately 160 accessions was planted and harvested in Popayán, and evaluated for iron and zinc concentration. Promising accessions were planted again in Popayán for the evaluation of single plant harvest. Both species are allogamous and accessions are likely to be variable from plant to plant. The harvest of individual plants was likewise analyzed for iron and zinc.

Results and Discussion: In both the initial evaluation and in the validation based on individual plants, *P. polyanthus* tended to express higher levels of iron than *P. coccineus* (Table 36). Both species presented values higher than those normally found in *P. vulgaris*, although the values for the common bean checks, DOR 390 and CAL 96, were somewhat higher than normal. Although in the initial evaluation some high values of zinc were found, in the subsequent evaluation these fell within values that have been observed in better common bean lines.

Conclusion: While interspecific crosses are a long-term solution to any problem, in some cases they can offer significant genetic gain. It is important to verify how wide an advantage the sister species enjoy over the common bean to determine if interspecific crosses are warranted for the improvement of mineral content. However, both species could have value in and of themselves in moist highland areas where they would be expected to adapt.

Contributors: S. Beebe, C. Cajiao (IP-1); O. Mosquera (Analytical Laboratory)

Table 36. Concentration of iron and zinc in accessions of *P. polyanthus* and *P. coccineus* in two successive evaluations of seed harvested in Popayán.

G number	Origin	Species*	Core evaluation values (mg kg ⁻¹)		Individual plant values (mg kg ⁻¹)			
			Fe	Zn	Fe		Zn	
					Ave	Range	Ave	Range
G 35155	GBR	COCC	82	50	76	69-99	36	24-44
G 35243	PRT	COCC	80	52	93	69-115	41	30-56
G 35382	MEX	COCC	86	52	83	73-124	35	30-43
G 35573	CRI	PLAN	99	52	121	107-134	38	37-38
G 35575	MEX	PLAN	95	54	111	90-142	41	35-44
G 35595	GTM	PLAN	94	50	104	78-131	40	28-49
G 35597	GTM	COCC	104	54	106	94-119	39	35-44
G 35623	YUG	COCC	66	52	96	86-110	49	38-55
G 35755	GTM	PLAN	114	50	92	70-131	46	41-54
G 35999	COL	COCC	87	63	103	71-128	42	32-48
G 36011	YUG	COCC	70	51	75	57-84	36	27-41
DOR 390	Check				74		37	
CAL 96	Check				80		32	

* COCC = *P. coccineus*; PLAN = *P. polyanthus*

Progress towards achieving output milestones:

- Mid-term milestones call for an increase of 50% iron concentration in bred materials. This level has been attained in several bred lines with a moderate level of drought tolerance but agronomic quality for other traits is still deficient. These materials will be used to create another cycle of crosses, to improve both mineral concentration and agronomic value.
- Studies of G x E demonstrate that environmental and agronomic effects influence mineral content greatly, but that ranking of materials is similar in spite of G x E.

Output 2: Improved, large-seeded, bean germplasm resistant to major biotic and abiotic stresses with greater nutritional and market value

Activity 2.1 Developing germplasm resistant to diseases

Highlights:

- Over 1000 populations of different generations F₃-F₆ in various market classes were selected during this reporting period.
- Several lines were selected from the large red kidney and sugar bean market classes nurseries, which combined more than one attribute such as high yield, resistance to diseases (ALS and FLS) and tolerance to low soil fertility. These will be available for distribution to NARIs partners in SABRN.
- Four advanced lines (HGA 24, HGA 25, HGA 26, and HGA 27) were identified that combined resistance to rust, common bacterial blight, anthracnose and the angular leaf spot.
- The recessive *bc-3* gene is being successfully incorporated in climbing bean genotypes to control the increasing incidence of bean common mosaic in the American highlands. This gene confers total resistance to the causal viruses (BCMV and BCMNV), and facilitates the selection of virus resistant common bean genotypes possessing seed colors that exhibit genetic linkage problems (e.g. cranberry and red-seeded types).
- Several common bean genotypes possessing resistance to Bean leaf crumple virus, a begomovirus transmitted by the whitefly *Bemisia tabaci*, have been identified in field screening plots planted in the Cauca Valley. The resistance sources identified are already present in many advanced common bean lines.
- Over 39 resistant and potential parental materials were evaluated under greenhouse conditions against nine isolates representing 6 *Pythium* species pathogenic to beans in eastern Africa. Thirty remained resistant.
- Over 500, F₂-derived F₅ lines and populations from simple, double and backcrosses were selected for *Pythium* and angular leaf spot resistance.
- Marker assisted selection for BCMV resistance continued this year in Andean bush and climbing beans with wide application of the SCAR markers ROC11 for the *bc-3* gene and SW13 for the *I* gene. This work was expanded to collaboration with additional partners in the Andean region: CORPOICA, Universidad Nacional–Bogotá and PROMPEX-Peru.
- New heat tolerant, BCMV-resistant, red and cream mottled Andean climbing beans were produced. Peruvian varieties from the Alubia, Bayo, and Canario seed classes were also improved for BCMV resistance. Based on successes in marker assisted selection, a new project will begin next year for incorporating BCMV resistance into East African varieties with partners from Kenya, Rwanda and Uganda including ISAR, KARI, NARO, University of Nairobi and University of Rwanda.
- Marker assisted selection for anthracnose resistance genes was implemented in yellow, white and red seeded climbing beans using the SCAR markers SAS13 for the *Co-4²* gene and SAB3 for the *Co-5* gene. The SAB3 marker was found to work well under a range of PCR conditions while SAS13 marker amplification was improved. The anthracnose resistance genes are being pyramided into lines with BCMV resistance and commercial

seed type. This project is important goal for breeding of Andean beans in both Africa and Latin America.

2.1.1 Breeding for specific bean market classes in Southern Africa Bean Research Network (SABRN)

Rationale: The bean breeding strategy for Africa, focusing on specific bean market classes, has been going on since 2001. In this strategy, national scientists within the network share responsibilities in generating multiple constraint crosses, for specific market classes where they have comparative advantages. Within SABRN the responsibilities for breeding programs are assigned by countries: program 1 Red Mottled (Malawi); program 2a Dark Red Kidney (Zimbabwe); program 2b Small Red (Tanzania); program 3 Brown Yellow and Tan (Zambia); program 4 Cream and Sugar (South Africa); program, 5a Small-white or Navy (South Africa); program 5b. Large White (South Africa); and program 6 Purples (Tanzania). Other countries that have interest in specific market classes collaborate in evaluation of fixed lines and cultivars, of the preferred types. The CIAT-SABRN regional breeding program, based in Malawi continued to provide backstopping support to the national scientists in 4 market classes: red mottled, brown/tan, dark red kidney and sugar. This section of the report covers activities of the regional breeding program in Malawi, capturing evaluation of segregating populations and nurseries in various market classes.

a) Segregating populations

Materials and Methods: The segregating populations (F4-6) evaluated here, were derived from crosses that were initiated a few years ago. The crosses were made for 4 different market classes (red mottled, brown/tan, dark red kidney and sugar), which are preferred by farmers and consumers in more than 2 countries in the SADC region. Good parents for the market classes and parental lines to serve as sources of resistance to various biotic and abiotic constraints were chosen. The parents for good biotic and abiotic attributes were: Mexico 54, AND 277 and AND 279 for angular leaf spot (ALS); VAX 5 and VAX 6 for common bacterial blight (CBB); RAO 55 and UBR (92) 25, for low P, low N and low pH complex and G52201 and Mlama 127 for bean stem maggot (BSM). The evaluation was done at Chitedze (1200 masl) and Bembeke (1650 masl).

Results and Discussion: The disease pressure for CBB at Chitedze (CTZ), was over-masked by widespread virus symptoms with similar appearance, making it difficult to screen for CBB resistance. However, the ALS pressure at Bembeke (BBK) was predominant, which made it easy for the program to screen for resistance to ALS at this site. The soils at Bembeke continued to provide a stressful environment, suitable to screen genotypes for adaptation to low soil fertility. A total of 1123 populations (Table 37) were selected, 856 at Chitedze and 267 at Bembeke. More seed of these populations has been multiplied using surface irrigation facilities at Bwanje in Malawi. These populations will be available for distribution to interested NARS partners within the SABRN network in the next season.

Table 37. Summary of segregating populations in various colors evaluated under fertility stress at Chitedze (CTZ) and Bembeke (BBK), Malawi, 2004.

Families Evaluated	Populations				
	Evaluated		Selected		Total
	CTZ	BBK	CTZ	BBK	
Normal soil fertility:					
F ₃ Climbers	621		149		149
F ₄ Khaki Bulk	25	57	7	13	20
F ₄ Khaki Selections	57	24	19	4	23
F ₄ Sugars Selections	454	454	50	117	167
F ₄ Sugars Bulk	142		12		12
F ₄ Red Kidney Selection	58	58	29	10	39
F ₄ Red Kidney Bulk	33	31	4	7	11
F ₄ General Selections	130	130	59	23	82
F ₄ General Bulk	47	47	55	23	78
F ₄ Red Mottled Selection	139	139	99	54	153
F ₄ Red Mottled Bulk	85	84	25	16	41
F ₅ Red Mottled	742		188		188
F ₆ Red Mottled	521		160		160
Total	3054	1024	856	267	1123

b) Evaluation of bean germplasm developed for specific market classes for adaptation, yield and reaction to biotic and abiotic stresses in Malawi

In addition to evaluating the segregating populations for various attributes, the program evaluated fixed lines of various market classes for adaptation, yield and reaction to diseases at Chitedze and Bembeke, and for tolerance to low soil fertility stress at Bembeke.

Materials and Methods: Nurseries for specific market classes included: sugars (76 lines), red mottled (70 lines), red kidney (67 lines), carioca (50 lines) and small reds (44 lines). At Bembeke, a set of sugar and red kidney lines were also planted in a low soil fertility stress block. The soil fertility stress block has been used over years to identify potential bean lines, which can perform well under low P, low N and low pH complex conditions. The nurseries were planted during the second week of January, in single row plots without replication. Data were collected on yield and reaction to diseases in both sets of nurseries, under with and without low soil fertility stress conditions.

Results and Discussion: The crop at Chitedze was adversely affected by the wide spread of virus-like symptoms, which appeared at early pod formation stage. This affected both, the expression of other diseases and the yield performance. As such the data from Chitedze were excluded from this report. This section therefore focused at data from Bembeke, a site, which continued to offer considerable disease pressure for ALS and floury leaf spot (FLS), but less of CBB, ascochyta (ASC) and anthracnose (ANT). This pattern was consistent across all nurseries. The data presented in the subsequent tables capture only the top 10 lines in each market class, which are compared to a control cultivar.

i. Large red kidney lines

Among the top 10 lines out of the 70 that were evaluated, all originated from CIAT derived segregating populations coded VTTT. These have gone through a series of selections in Malawi, such that the fixed lines are now being evaluated for yield, tolerance to low soil fertility and reaction to diseases. Some of the top-yielding lines like VTTT 917/6-1, VTTT 924/19-8-1, VTTT 928/9-1 and VTTT 918/15-4-4 have resistance to moderate resistance levels to ALS, (scores ranging from 3-6). These lines also have good grain yield levels ranging from 2900 to 3200 kg ha⁻¹, which is much more than the control RWR 1946, 1900 kg ha⁻¹ (Table 38). The site mean is very low, 467 kg ha⁻¹, because some lines were very poorly adapted, such that their grain yields were very low, and sometimes 0.

Table 38. Yield performance and reaction to diseases of top 10 large red kidney lines evaluated at Bembeke, 2004.

Identity	Disease Scores					Grain Yield (kg ha ⁻¹)
	ALS	CBB	ASC	ANT	FLS	
VTTT 917/6-1	4	1	2	1	7	3219
VTTT 924/19-8-1	5	1	4	1	6	3108
VTTT 916/8-3	7	1	2	1	7	3108
VTTT 928/9-1	6	1	2	1	6	2914
VTTT 918/15-4-4	3	2	2	1	7	2914
VTTT 918/15-2	3	1	3	1	7	2886
VTTT 918/15-4-5	4	1	2	2	7	2886
VTTT 925/7-8-1	4	2	2	1	7	2775
VTTT 918/15-4-2	4	2	4	2	7	2775
VTTT 924/12-5-1	6	2	3	1	7	2775
RWR 1946 (control)	3	1	2	1	7	1915
Mean						467

A similar set of lines was planted in the low soil fertility block at Bembeke where a similar pattern of disease pressure was observed. However the grain yields were very low, almost 10% of those without soil fertility stress. The severe soil fertility pressure restricted the number of lines that were selected, because some of them had no yield data. Most of the selected lines had good levels of resistance to ALS, with scores ranging from 2-4 (Table 39). Among the 10 top lines selected under low soil fertility conditions, 2 of them (VTTT924/19/8-1 and VTTT18/15-2) were also among the top 10 lines selected in the block without soil fertility stress. This suggested that some lines combine good disease resistance, tolerance to low soil fertility and high grain yield potential.

Table 39. Yield performance and reaction to diseases of top 10 large red kidney lines evaluated under low soil fertility stress, Bembeke 2004.

Identity	Disease Score					Grain Yield (kg ha ⁻¹)
	ALS	CBB	FLS	ASC	ANT	
VTTT 923/7-2	4	1	4	2	1	333
VTTT 918/15-4	2	1	2	1	1	333
VTTT 916/8-3	3	1	4	1	1	333
VTTT 924/6-3-3	4	1	1	1	1	305
VTTT 925/7-8-1	4	2	5	2	2	278
VTTT 920/24-3	3	1	6	3	1	250
VTTT 924/19-8-1	3	1	4	1	1	250
VTTT 918/15-2	3	1	4	2	1	250
VTTT 915/14-2	4	1	5	2	1	250
VTTT 923/9-1	3	2	6	1	1	222
RWR 1946 (Control)	5	1	4	2	2	28
Mean						128

ii. Sugar lines

Among the 76 sugar lines that were evaluated at Bembeke, only VTTT lines emerged in the top 10 category (Table 40). They all had medium to susceptible rating for disease resistance for ALS and FLS. However, their yield performance was satisfactory, ranging from 2600 to 3000 kg ha⁻¹, which were well above the control cultivar SUG 131 (250 kg ha⁻¹), which was even below the site mean (374 kg ha⁻¹). The same set of lines was also planted in a low soil fertility block at Bembeke. Like the large red lines, the yield level under the low soil fertility conditions were also only 10% of the yields realized in the block that was not stressed (Table 41). Two of the lines, VTTT925/7-6 and VTTT924/15-2, were among the top 10 in both Tables 40 and 41, indicating again that some lines combined such attributes as disease resistance, tolerance to low soil fertility and high yield potential.

Table 40. Yield performance and reaction to diseases of top 10 sugar lines evaluated at Bembeke, 2004.

Identity	Disease score					Grain Yield (kg ha ⁻¹)
	ALS	CBB	ASC	ANT	FLS	
VTTT 923/10-6-2	6	2	3	2	6	3025
VTTT 924/15-2	5	2	3	1	7	2969
VTTT 924/19-3	6	1	2	1	7	2886
VTTT 925/7-6	6	1	3	1	5	2858
VTTT 924/10-7	7	1	2	1	7	2831
VTTT 923/10-2	5	2	2	1	6	2775
VTTT 924/2-4-2-1	7	2	5	1	7	2775
VTTT 925/7-5	7	1	2	1	7	2720
VTTT 925/9-3	6	1	2	1	6	2664
VTTT 924/12-5-3	6	1	4	1	7	2664
SUG 131 (control)	5	2	2	1	4	250
Mean						374

Table 41. Yield performance and reactions to diseases of sugar lines under low soil fertility stress at Bembeke, 2004.

Identity	Disease Score					Grain Yield (kg ha ⁻¹)
	ALS	CBB	FLS	ASC	ANT	
VTTT 925/7-6	2	1	3	1	1	333
VTTT 925/1-4	2	1	5	1	1	333
VTTT 925/1-2-1	3	1	4	2	1	222
VTTT 925/2-5-2-2	3	1	3	1	2	194
VTTT 925/2-7-1	2	1	4	2	1	194
VTTT 924/15-2	2	1	5	1	1	167
VTTT 924/2-4-1	2	1	4	2	1	139
VTTT 924/18-6	3	1	3	1	1	111
VTTT 925/4-3-3	4	1	3	1	1	111
VTTT 923/12-4	3	1	2	2	1	83
Sugar 131 (Control)						0
Mean						75

iii. Red mottled lines

The background of the lines that appeared among the top 10, within the red mottled market at Bembeke were varied, including such lines as RA 13170-5-1-3, BOA 1-5/34, RMA 21 and VTTT 925/6-4-1. Among the group, only RA 13170-5-1-3 showed a good level of resistance to ALS, the rest were mildly resistant to susceptible. Others like BOA 1-5/34 and VTTT 925/6-4-1 had good levels of resistance to FLS. The yield levels among the top 10 lines were reasonable, above 2000 kg ha⁻¹, which were better than the control variety CAL 143, 1305 kg ha⁻¹, (Table 42).

Table 42. Yield performance and reaction to diseases of top 10 red mottled lines at Bembeke, 2004.

Identity	Disease Score					Grain Yield (kg ha ⁻¹)
	ALS	CBB	ASC	ANT	FLS	
RA 13170-5-1-3	3	1	3	1	5	2831
BOA 1-5/34	6	2	2	1	1	2775
RMA 21	6	2	2	1	7	2609
VTTT 925/6-4-1	6	1	2	2	5	2553
RMA 12	7	2	2		5	2553
RMA 18	6	2	3	1	5	2553
AND 1064	6	2	2	1	2	2553
VTTT 915/7-3-2	5	2	2	1	7	2498
VTTT 916/14-4-3	5	1	2	1	6	2442
RMA 44	7	2	3	2	7	2387
CAL 143 (Control)	3	2	3	1	5	1305
Mean						368

Conclusion: The regional breeding program continued to make progress in creating and screening populations for multiple attributes, combining grain yield, preferred grain color and resistance to biotic and abiotic constraints. Over 1000 populations of different generations F₃-F₆ in various market classes were selected during this reporting period. In addition further progress has been achieved this season in selecting high yielding genotypes of various grain market classes that combine more than one attribute. For example, some genotypes in large red kidney and sugar bean market classes combined good grain yield, resistance to diseases (ALS and FLS) and tolerance to low soil fertility. More seed for all selected populations and fixed lines is under multiplication for further distribution to NARS partners.

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2.1.2 Identifying Andean genotypes with multiple disease resistance

Rationale: The increase in the importance and distribution of anthracnose and angular leaf spot of beans means that simultaneous incorporation of resistance genes against the two pathogens is a good breeding strategy. However, this is complicated by the high pathogenic variability found in both pathogens that makes the development and use of resistance to manage this disease difficult. Validating the usefulness and effectiveness of potential sources of resistance and breeding lines against multiple pathotypes of these pathogens and defining the deployment strategies of such varieties is a major activity in our program. With this in mind, we evaluated breeding lines developed through multiple crosses designed to pyramid resistance genes to anthracnose, common bacterial blight, angular leaf spot, and bean common mosaic virus (BCMV) for their effectiveness against several races of these pathogens under greenhouse conditions. These lines were developed to specifically target the Andean zone and taking into account the preferred grain types.

Materials and Methods: Forty genotypes were evaluated for resistance to anthracnose under greenhouse conditions. Thirty-three were advanced breeding lines (F₅-F₈) derived from multiple crosses involving 10 parents with resistance to a total of six factors (Table 43). These were inoculated with Andean and Mesoamerican pathotypes of *C. lindemuthianum*, *P. griseola*, one isolate of *Xanthomonas campestris* pv. *phaseoli*, and an Andean rust (*Puccinia appendiculatus*) isolate (Table 43). Plant handling, inoculum production, inoculations and disease evaluations were done as described previously (CIAT 2003).

Results and Discussion: Four lines, HGA 24, HGA 25, HGA 26, and HGA 27 were resistant to the four pathogens evaluated in this study (anthracnose, angular leaf spot, rust and common bacterial blight pathogens) (Table 43). The lines HGA4 and HGA 8 were resistant to three of the four pathogens (all races of anthracnose, anthracnose and rust used in this study). The majority of the lines were resistant to either one or two pathogens, and these lines can be deployed, depending on the distribution, prevalence and importance of the pathogens for which they lack resistance.

Table 43. Response of advanced lines to inoculation with anthracnose, angular leaf spot, rust and common bacterial blight pathogens.

Genotype	<i>Colletotrichum lindemuthianum</i>			<i>Phaeoisariopsis griseola</i>			Rust	CBB-123	
	1	7	3481	1	15-0	31-0			7-55
CHOCHO	1.0	9.0	1.0	1.0	8.0	8.0	4.1	1.0	5.3
CATRACHITA	1.0	1.0	9.0	1.0	1.0	1.0	8.0	1.0	5.7
G 5686	1.0	1.0	1.0	1.0	1.0	1.0	2.3	9.0	7.0
VAX 3	5.3	2.4	9.0	6.0	1.0	1.0	8.0	1.0	1.0
HGA 1	1.0	1.0	9.0	1.0	1.6	1.6	8.0	1.0	7.0
HGA 2	1.0	1.2	7.0	1.0	1.0	1.0	8.0	9.0	2.7
HGA 3	4.9	1.9	8.0	1.0	2.0	2.0	8.0	5.0	1.3
HGA 4	1.1	1.0	4.5	1.0	6.2	6.2	8.0	1.0	1.0
HGA 5	4.6	9.0	3.6	7.2	6.4	6.4	8.0	9.0	5.3
HGA 6	2.0	1.4	3.3	2.6	8.0	8.0	8.0	1.0	3.3
HGA 7	1.0	1.0	1.0	1.0	1.0	1.0	6.0	9.0	4.0
HGA 8	1.0	1.0	4.4	1.0	1.0	1.0	8.0	1.0	1.0
HGA 9	4.5	9.0	9.0	7.4	2.2	2.2	8.0	4.5	4.0
HGA 10	1.0	9.0	1.3	1.0	1.0	1.0	7.2	1.0	6.3
HGA 11		2.0	5.6	2.6	1.2	1.2	4.9	9.0	1.0
HGA 12	1.0	1.0	1.0	1.0	1.0	1.0	5.7	5.0	1.3
HGA 13	1.9	6.0	6.1	5.3	1.0	1.0	6.0	1.0	1.3
HGA 14	1.0	1.0	9.0	1.0	1.0	1.0	8.0	1.0	4.3
HGA 15	2.8	4.3	9.0	1.0	1.0	1.0	8.0	9.0	1.7
HGA 16	1.0	1.0	8.2	1.0	1.0	1.0	8.0	1.0	1.7
HGA 17	1.0	1.0	9.0	1.0	2.2	2.2	8.0	1.0	7.0
HGA 18	1.0	1.0	9.0	1.0	1.0	1.0	8.0	1.0	3.7
HGA 19	1.0	1.9	9.0	1.1	1.2	1.2	8.0	9.0	6.3
HGA 20	1.0	1.0	9.0	1.0	1.0	1.0	8.0	1.0	2.0
CALIMA	1.0	9.0	1.0	1.0	1.0	1.0	4.7	5.0	9.0
VAX 6	6.4	9.0	9.0	3.1	1.0	1.0	8.0	1.0	1.0
A 193	1.0	1.0	1.0	1.0	3.3	3.3	8.0	5.0	6.7
HGA 21	1.0	1.0	9.0	2.0	1.0	1.0	8.0	5.0	2.7
HGA 22	9.0	7.4	1.0	9.0	1.3	1.3	1.8	9.0	2.3
HGA 23	1.0	1.0	1.0	3.7	1.3	1.3	8.0	9.0	1.0
HGA 24	1.0	1.0	1.0	1.0	1.3	1.3	3.2	1.0	1.3
HGA 25	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0	1.7
HGA 26	1.0	1.0	1.0	1.0	1.0	1.0	5.7	1.0	1.0
HGA 27	1.0	1.0	1.0	1.0	1.2	1.2	3.3	1.0	1.3
A 483	1.0	1.0	1.0	1.0	2.7	2.7	8.0	9.0	9.0
TALASH	9.0	9.0	9.0	9.0	8.0	8.0	8.0	8.0	9.0
WILKINSON 2			9.0	5.6			8.0		1.0
HGA 28	9.0	3.4	9.0	6.7	2.4	2.4	8.0	9.0	6.5
HGA 29	9.0	9.0	9.0	9.0	2.0	2.0	3.4	9.0	6.3
HGA 30	1.0	1.0	3.3	1.0	8.0	8.0	8.0	9.0	8.3
HGA 31	1.0	1.0	1.0	2.0	1.0	1.0	8.0	1.0	6.3
HGA 32	1.0	1.0	1.4	1.0	8.0	8.0	7.0	9.0	8.3
HGA 33	1.0	7.8	9.0	9.0	3.0	3.0	8.0	9.0	4.3
VAX 1	1.0	1.0	9.0	1.0	1.0	1.0	2.0	1.0	1.0
DICTA 17	1.0	1.0	9.0	1.0	1.8	1.8	8.0	1.0	7.7
MAR 1	2.7	1.0	9.0	2.9	1.0	1.0	2.0	1.0	3.0
NIC 159	9.0	1.0	9.0	3.1	1.0	1.0	2.0	1.0	7.7
ICA PIJAO	9.0	4.0	9.0	9.0	1.0	1.0	8.0	1.0	8.0
G 17198	1.0	2.7	1.0	1.0	5.0	5.0	8.0	9.0	6.7

Conclusion: The lines that combine resistance to all four pathogens in this study form a valuable group that can be deployed in those areas where the respective pathogens are important. In addition, these lines can serve as sources of resistance in breeding programs tasked with simultaneously developing resistance to several bean diseases. Some of the parents used in this study, e.g. VAX 1, has been shown to be adapted to low soil fertility conditions including aluminum toxicity, and has resistance to several root rot causing pathogens. These materials need to be tested for other pathogens such as several root rot causing pathogens, abiotic constraints (e.g. tolerance to aluminum and drought) and nutritional quality (iron and zinc).

References

CIAT 2003. Bean Annual Report, Bean Program 2003. CIAT, Cali, Colombia .

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2.1.3 Incorporation of recessive resistance to BCMV/BCMNV

A SCAR marker, ROC11, and mechanical inoculation tests conducted at CIAT with a combination of mosaic- and necrosis-inducing strains of BCMV (NL4) and BCMNV (NL3) showed that the recessive *bc-3* gene can be transferred to common bean genotypes possessing seed colors known to be genetically linked to recessive traits conditioning susceptibility to these viruses in *Phaseolus vulgaris*. In a study conducted by Biol. Gloria Santana of CORPOICA, Rionegro, Antioquia, in collaboration with CIAT, the *bc-3* gene was incorporated into 14 Cargamanto lines. This highly commercial grain type had become increasingly affected by common mosaic in northwestern Colombia. This technology is also applicable to Africa, where the *bc-3* gene could be used to protect common bean cultivars against necrosis-inducing strains of BCMV and BCMNV.

The screening of common bean breeding materials for the presence of the *bc-3* gene has increased gradually in recent years, particularly in the case of climbing bean genotypes. This year, a total of 1,443 climbing lines for the Andean region and Africa were evaluated for their reaction to BCMNV and presence of the *bc-3* gene.

2.1.4 Search for sources of resistance to begomoviruses affecting common bean

Last year, we reported on the emergence of a new disease of common bean in the Cauca Valley of Colombia, caused by a new begomovirus transmitted by the whitefly *Bemisia tabaci*. Snap beans are severely attacked by whitefly-transmitted viruses because they are mostly climbing types not bred for the lowland regions affected by whitefly-borne viruses. Approximately 240 common bean genotypes consisting of advanced bush and climbing bean types, and potential sources of resistance, were planted and evaluated in the municipality of Pradera, Cauca Valley, Colombia. Two of three plantings (each having three replications), showed a high incidence of bean leaf crumple (Figure 26), and were used to score the selected genotypes for their reaction to the virus. Figure 27 shows the grouping and frequency distribution of the materials evaluated, based on their reaction to the virus expressed as an average score using a scale of 1 (symptomless) to 5 (severely affected) Table 44. As shown, only three bean genotypes: EMP

496, DICTA 113, and a breeding material (TLP35XG21212)F1 X ICTA Ligerero, remained symptomless. Eight entries, mostly materials developed for their resistance to begomoviruses, had scores lower than 2. These materials included BAT 304, Tio Canela, DOR 390 and DOR476.



Figure 26. Bean leaf crumple disease in the Cauca Valley of Colombia.

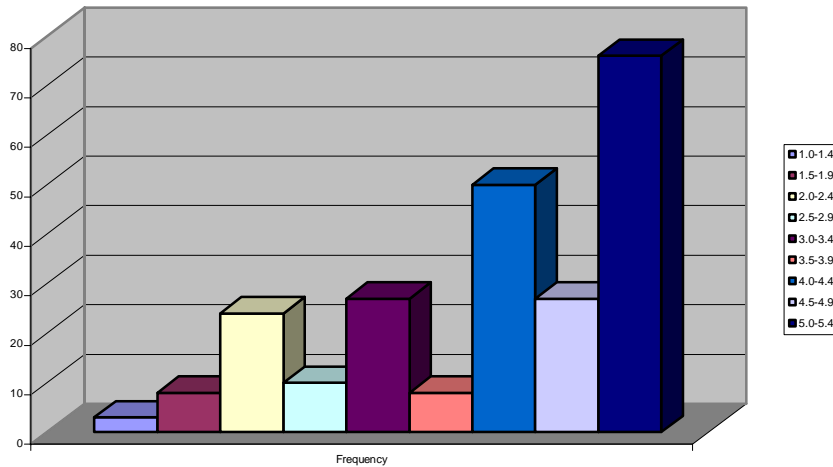


Figure 27. BLCrV score frequencies-La Tupia, September 2004

Table 44. Sources of resistance to begomoviruses

Ent	Code	Cross Number	#BGMV	Identification	Fn	BGMV Res. genes	First trial (2003A)				Second trial (2004A)			
							R1	R2	R3	Media	R1	R2	R3	Media
1	DOR 476	.	.	DOR 476	.	bgm1 + W12	1	1	1	1.0	1	2	2	1.7
2	DOR 482	.	.	DOR 482	.	bgm1 + W12	1	2	2	1.7	1	2	4	2.3
3	EAP 9504-30B	.	.	EAP 9504-30B	.	bgm1 + W12	1	1	1	1.0	1	2	3	2.0
4	EAP 9510-77	.	.	EAP 9510-77	.	bgm1 + W12	2	1	1	1.3	1	4	4	3.0
5	9653-16B-1	.	.	9653-16B-1	.	bgm1 + W12	1	1	1	1.0	2	2	3	2.3
6	9653-16B-3	.	.	9653-16B-3	.	bgm1 + W12	1	1	1	1.0	2	1	3	2.0
7	9824-47-1/F7	.	.	9824-47-1/F7	.	bgm1 + W12	1	2	1	1.3	3	4	3	3.3
8	9824-56-2/F7	.	.	9824-56-2/F7	.	bgm1 + W12	1	1	2	1.3	3	5	5	4.3
9	9825-46-1/F6	.	.	9825-46-1/F6	.	bgm1 + W12	1	2	1	1.3	2	4	3	3.0
10	RAB 609	.	.	RAB 609	.	bgm1 + W12	1	1	1	1.0	2	2	3	2.3
11	SAM 1	.	.	SAM 1	.	bgm1 + W12	1	4	2	2.3	4	5	5	4.7
12	TIO CANELA 75	.	.	TIO CANELA 75	.	bgm1 + W12	1	2	1	1.3	1	2	2	1.7
13	A 429	.	.	A 429	.	bgm1	1	1	1	1.0	1	2	3	2.0
14	DOR 714	.	.	DOR 714	.	bgm1	1	1	1	1.0	1	4	2	2.3
15	EMP 496	.	.	EMP 496	.	bgm1	2	1	1	1.3	1	1	2	1.3
16	FEB 212	.	.	FEB 212	.	bgm1	1	1	1	1.0	1	3	3	2.3
17	G 2402 [GARRAPATO]	.	.	G 2402 [GARRAPATO]	.	bgm1	1	4	3	2.7	4	5	5	4.7
18	ICTA LIGERO	.	.	ICTA LIGERO	.	bgm1	3	1	2	2.0	1	3	3	2.3
19	DOR 390	.	.	DOR 390	.	bgm1	1	2	1	1.3	1	1	3	1.7
20	RAB 608	.	.	RAB 608	.	bgm1	1	1	1	1.0	1	3	3	2.3
21	RAB 612	.	.	RAB 612	.	bgm1	1	2	1	1.3	1	4	4	3.0
22	RAB 619	.	.	RAB 619	.	bgm1	3	3	4	3.3	3	5	5	4.3
23	RAB 623	.	.	RAB 623	.	bgm1	4	3	3	3.3	3	4	5	4.0
24	RAB 630	.	.	RAB 630	.	bgm1	2	4	2	2.7	2	5	5	4.0
26	RJB 10	.	.	RJB 10	.	bgm1	1	1	1	1.0	2	2	3	2.3
27	ICA PIJAO	.	.	ICA PIJAO	.	W12	1	2	1	1.3	2	3	4	3.0
28	PORRILLO SINTETICO	.	.	PORRILLO SINTETICO	.	W12	1	1	1	1.0	1	4	3	2.7
29	BAT 304	.	.	BAT 304	.	W12	1	1	1	1.0	1	2	2	1.7
30	DOR 364	.	.	DOR 364	.	W12	1	1	1	1.0	1	3	4	2.7
31	DOR 582	.	.	DOR 582	.	W12	1	2	1	1.3	1	5	4	3.3
32	DICTA 113	.	.	DICTA 113	.	W12	1	1	1	1.0	1	1	2	1.3
33	EAP 9020-14	.	.	EAP 9020-14	.	W12	1	1	1	1.0	1	2	2	1.7
34	FEB 115	.	.	FEB 115	.	W12	1	1	1	1.0	3	5	5	4.3
35	G 17341	.	.	G 17341	.	W12	2	1	2	1.7	2	5	5	4.0
36	ICTA OSTUA	.	.	ICTA OSTUA	.	W12	1	1	1	1.0	1	2	4	2.3
37	MD 23-24	.	.	MD 23-24	.	W12	2	1	2	1.7	1	5	4	3.3
38	NEGRO COAXTLA 91	.	.	NEGRO COAXTLA 91	.	W12	1	1	2	1.3	1	3	4	2.7
39	RAVEN	.	.	RAVEN	.	W12	3	4	3	3.3	3	5	5	4.3
40	SAM 3	.	.	SAM 3	.	W12	3	2	3	2.7	2	4	3	3.0
41	TLP 35	.	.	TLP 35	.	W12	2	1	1	1.3	2	4	4	3.3
42	GMR 5	.	.	GMR 5	.	?	1	1	1	1.0	2	4	2	2.7
44	ASC 72 [Pv x Pc]	.	.	ASC 72 [Pv x Pc]	.	?	1	1	1	1.0	2	3	2	2.3
45	ASC 74 [Pv x Pc]	.	.	ASC 74 [Pv x Pc]	.	?	4	2	1	2.3	4	5	5	4.7

Table 44. Sources of resistance to begomoviruses

Ent	Code	Cross Number	#BGMV	Identification	Fn	BGMV Res. genes	First trial (2003A)				Second trial (2004A)			
							R1	R2	R3	Media	R1	R2	R3	Media
46	ASC 75 [Pv x Pc]		.	ASC 75 [Pv x Pc]	?		1	2	2	1.7	5	5	5	5.0
47	G 35171 [P coce]		.	G 35171 [P coce]	?		1	1	1	1.0	4	2	4	3.3
48	G 35172 [P coce]		.	G 35172 [P coce]	?		1	2	2	1.7	2	2	2	2.0
49	G 35252 [P coce]		.	G 35252 [P coce]	?		1	1	1	1.0	2	3	3	2.7
50	MR	13937-15	BGMV 550	MD 23-24 x (RAB 655 x G 21212)F1/-MC-3P-MQ-MC-2C-MC-MC	W12		3	3	1	2.3	1	4	4	3.0
51	MR	13937-21	BGMV 550	MD 23-24 x (RAB 655 x G 21212)F1/-MC-7P-MQ-MC-9C-MC-MC	W12		2	1	2	1.7	3	4	5	4.0
52	MR	14000-2	BGMV 551	RAB 651 x (MD 23-24xG 21212)F1/-MC-1P-MQ-MC-15C-MC-MC	bgm1		3	2	4	3.0	5	4	5	4.7
53	MR	14000-2	BGMV 551	RAB 651 x (MD 23-24xG 21212)F1/-MC-1P-MQ-MC-21C-MC-MC	bgm1		2	3	4	3.0	5	5	5	5.0
54	MR	14000-2	BGMV 551	RAB 651 x (MD 23-24xG 21212)F1/-MC-10P-MQ-MC-1C-MC-MC	bgm1+W12		2	3	2	2.3	5	5	5	5.0
55	MR	14000-2	BGMV 551	RAB 651 x (MD 23-24xG 21212)F1/-MC-10P-MQ-MC-13C-MC-MC	bgm1		1	3	3	2.3	5	5	5	5.0
56	MR	14000-2	BGMV 551	RAB 651 x (MD 23-24xG 21212)F1/-MC-10P-MQ-MC-21C-MC-MC	bgm1+W12		1	2	3	2.0	5	5	5	5.0
57	MR	14143-28	BGMV 451	(RAB 651 x TIO CANELA 75)F1 X (RAB 608 x SEA 15)F1/-MC-2P-MQ-MC-3C-MC-MC	bgm1		1	1	1	1.0	1	3	2	2.0
58	MR	14143-28	BGMV 451	(RAB 651 x TIO CANELA 75)F1 X (RAB 608 x SEA 15)F1/-MC-2P-MQ-MC-4C-MC-MC	bgm1		1	2	1	1.3	1	2	3	2.0
59	MR	14143-28	BGMV 451	(RAB 651 x TIO CANELA 75)F1 X (RAB 608 x SEA 15)F1/-MC-2P-MQ-MC-6C-MC-MC	bgm1		2	2	1	1.7	1	2	2	1.7
60	MR	14143-28	BGMV 451	(RAB 651 x TIO CANELA 75)F1 X (RAB 608 x SEA 15)F1/-MC-2P-MQ-MC-8C-MC-MC	bgm1		1	1	1	1.0	1	5	4	3.3
61	MR	14143-28	BGMV 451	(RAB 651 x TIO CANELA 75)F1 X (RAB 608 x SEA 15)F1/-MC-2P-MQ-MC-15C-MC-MC	bgm1		1	1	1	1.0	3	3	2	2.7
62	MR	14143-28	BGMV 451	(RAB 651 x TIO CANELA 75)F1 X (RAB 608 x SEA 15)F1/-MC-2P-MQ-MC-17C-MC-MC	bgm1		1	1	1	1.0	3	4	3	3.3
63	MR	14143-28	BGMV 451	(RAB 651 x TIO CANELA 75)F1 X (RAB 608 x SEA 15)F1/-MC-2P-MQ-MC-20C-MC-MC	bgm1		1	2	1	1.3	3	4	3	3.3
64	MR	14143-28	BGMV 451	(RAB 651 x TIO CANELA 75)F1 X (RAB 608 x SEA 15)F1/-MC-2P-MQ-MC-25C-MC-MC	bgm1		1	1	1	1.0	3	3	3	3.0

Table 44. Sources of resistance to begomoviruses

Ent	Code	Cross Number	#BGMV	Identification	Fn	BGMV Res. genes	First trial (2003A)				Second trial (2004A)			
							R1	R2	R3	Media	R1	R2	R3	Media
65	MR	14143-28	BGMV 451	(RAB 651 x TIO CANELA 75)F1 X (RAB 608 x SEA 15)F1/-MC-2P-MQ-MC-27C-MC-MC		bgm1	1	2	1	1.3	2	4	3	3.0
66	MR	14148-54	BGMV 453	(SEA 21 x RAB 623)F1 X 9653-16 B-1/-MC-3P-MQ-MC-13C-MC-MC		W12	1	2	2	1.7	4	5	5	4.7
68	MR	14148-80	BGMV 453	(SEA 21 x RAB 623)F1 X 9653-16 B-1/-MC-2P-MQ-MC-2C-MC-MC		bgm1+W12	1	2	1	1.3	3	4	5	4.0
69	MR	14148-80	BGMV 453	(SEA 21 x RAB 623)F1 X 9653-16 B-1/-MC-2P-MQ-MC-3C-MC-MC		W12	2	3	2	2.3	3	5	5	4.3
70	MR	14152-14	BGMV 561	(SEA 22 x (TLP 35 x G 21212)F1)F1 X EAP 9504-30 B/-MC-3P-MQ-MC-1C-MC-MC		W12	1	1	1	1.0	3	4	3	3.3
71	MR	14153-3	BGMV 562	(SEA 22 x (A 774 x G 21212)F1)F1X(RAB619xTIO CANELA 75)F1/-MC-2P-MQ-MC-4C-MC-MC		bgm1	1	2	1	1.3	5	5	5	5.0
72	MR	14153-3	BGMV 562	(SEA 22 x (A 774 x G 21212)F1)F1X(RAB619xTIO CANELA 75)F1/-MC-3P-MQ-MC-17C-MC-MC		W12	2	2	2	2.0	5	5	5	5.0
73	MR	14153-3	BGMV 562	(SEA 22 x (A 774 x G 21212)F1)F1X(RAB619xTIO CANELA 75)F1/-MC-3P-MQ-MC-21C-MC-MC		W12	3	3	3	3.0	5	5	5	5.0
74	MR	14198-13	BGMV 291	(RAB 618x(DOR 364x(DOR 364x(DOR 364xSAM 1)F1)F2)F3)F1 X ((RAB 655xG 21212)F1xSEA 21)F1/-MC-1P-MQ-MC-11C-MC-MC		W12	1	3	1	1.7	5	5	5	5.0
75	MR	14198-13	BGMV 291	(RAB 618x(DOR 364x(DOR 364x(DOR 364xSAM 1)F1)F2)F3)F1 X ((RAB 655xG 21212)F1xSEA 21)F1/-MC-1P-MQ-MC-23C-MC-MC		bgm1+W12	1	3	2	2.0	5	5	5	5.0
76	MR	14215-9	BGMV 308	(SEA 15 x MD 23-24)F1 X (TIO CANELA 75 x G 21212)F1/-MC-6P-MQ-MC-11C-MC-MC		W12	1	1	1	1.0	4	3	3	3.3
77	MR	14258-7	BGMV 351	(DICTA 122x(DICTA 122x(DICTA 122xSAM 1)F1)F3-1)F1 X (MD 23-24x(RAB 655xG 21212)F1)F1/-MC-9P-MQ-MC-4C-MC-MC		W12	2	2	2	2.0	3	3	4	3.3
78	MR	14258-7	BGMV 351	(DICTA 122x(DICTA 122x(DICTA 122xSAM 1)F1)F3-1)F1 X (MD 23-24x(RAB 655xG 21212)F1)F1/-MC-9P-MQ-MC-8C-MC-MC		W12	2	1	2	1.7	2	4	3	3.0
79	MR	14273-4	BGMV 366	(RAB 623 x DICTA 17)F1 X (RAB 630 x SEA 21)F1/-MC-3P-MQ-MC-6C-MC-MC		W12	3	2	3	2.7	5	5	5	5.0

Table 44. Sources of resistance to begomoviruses

Ent	Code	Cross Number	#BGMV	Identification	Fn	BGMV Res. genes	First trial (2003A)				Second trial (2004A)			
							R1	R2	R3	Media	R1	R2	R3	Media
80	MR	14273-4	BGMV 366	(RAB 623 x DICTA 17)F1 X (RAB 630 x SEA 21)F1/-MC-3P-MQ-MC-11C-MC-MC		W12	2	4	4	3.3	5	5	5	5.0
81	MR	14292-63	BGMV 385	(DICTA 122x(DICTA 122x(DICTA 122xSAM 1)F1)F3-1)F1 X (RAB 651x(VAX 1xRAB 655)F1)F1/-MC-2P-MQ-MC-11C-MC-MC		W12?	1	2	2	1.7	4	4	4	4.0
82	MN	14059-8	BGMV 448	(FEB 192 x G 21212)F1 x ICTA LIGERO/-MC-4P-MQ-MC-4C-MC-MC		bgm1	1	2	1	1.3	5	5	4	4.7
83	MN	13934-63	BGMV 570	(FEB 192xG 21212)F1x(DOR500x(DOR390x(DOR390xSAM1)F1)F2)F3/-MC-2P-MQ-MC-9C-MC-MC		W12	2	1	1	1.3	3	4	5	4.0
84	MN	13934-63	BGMV 570	(FEB 192xG21212)F1x(DOR500x(DOR390x(DOR390xSAM1)F1)F2)F3/-MC-2P-MQ-MC-15C-M-MC		W12	2	1	1	1.3	4	5	4	4.3
85	MN	13942-22	BGMV 575	(TLP 35xG 21212)F1 x ICTA LIGERO/-MC-1P-MQ-MC-1C-MC-MC		bgm1	1	1	1	1.0	2	2	2	2.0
86	MN	13942-22	BGMV 575	(TLP 35xG 21212)F1 x ICTA LIGERO/-MC-1P-MQ-MC-3C-MC-MC		bgm1	1	1	1	1.0	1	2	1	1.3
87	MN	13942-22	BGMV 575	(TLP 35xG 21212)F1 x ICTA LIGERO/-MC-1P-MQ-MC-5C-MC-MC		bgm1	1	1	1	1.0	1	2	3	2.0
88	MN	13942-22	BGMV 575	(TLP 35xG 21212)F1 x ICTA LIGERO/-MC-1P-MQ-MC-11C-MC-MC		bgm1	1	1	1	1.0	1	2	2	1.7
90	MN	13942-33	BGMV 575	(TLP 35xG 21212)F1 x ICTA LIGERO/-MC-7P-MQ-MC-6C-MC-MC		W12	2	2	1	1.7	5	5	5	5.0
91	MR	14144-11	BGMV 578	(SEA 18 x (FEB 192 x G 21212)F1)F1 X EAP 9020-14/-MC-1P-MQ-MC-2C-MC-MC		W12	1	1	1	1.0	4	4	5	4.3
92	MR	14144-11	BGMV 578	(SEA 18 x (FEB 192 x G 21212)F1)F1 X EAP 9020-14/-MC-1P-MQ-MC-8C-MC-MC		W12	2	2	1	1.7	4	4	4	4.0
93	MR	14144-15	BGMV 578	(SEA 18 x (FEB 192 x G 21212)F1)F1 X EAP 9020-14/-MC-1P-MQ-MC-1C-MC-MC		W12	1	1	1	1.0	4	4	3	3.7
94	MN	14154-10	BGMV 579	(RIB 68 x G 21212)F1 X ICTA LIGERO/-MC-4P-MQ-MC-11C-MC-MC		bgm1	1	1	2	1.3	4	4	3	3.7
95	MN	14154-31	BGMV 579	(RIB 68 x G 21212)F1 X ICTA LIGERO/-MC-9P-MQ-MC-4C-MC-MC		bgm1?	3	1	2	2.0	4	4	5	4.3
96	MN	14154-31	BGMV 579	(RIB 68 x G 21212)F1 X ICTA LIGERO/-MC-9P-MQ-MC-5C-MC-MC		bgm1	3	3	2	2.7	4	4	5	4.3

Table 44. Sources of resistance to begomoviruses

Ent	Code	Cross Number	#BGMV	Identification	Fn	BGMV Res. genes	First trial (2003A)				Second trial (2004A)			
							R1	R2	R3	Media	R1	R2	R3	Media
97	MN	14154-31	BGMV 579	(RIB 68 x G 21212)F1 X ICTA LIGERO/-MC-9P-MQ-MC-9C-MC-MC		bgml	2	3	2	2.3	5	4	5	4.7
98	MN	14154-31	BGMV 579	(RIB 68 x G 21212)F1 X ICTA LIGERO/-MC-9P-MQ-MC-14C-MC-MC		bgml	2	2	3	2.3	5	5	5	5.0
99	MN	14154-36	BGMV 579	(RIB 68 x G 21212)F1 X ICTA LIGERO/-MC-12P-MQ-MC-2C-MC-MC		bgml+W12?	1	1	1	1.0	4	2	3	3.0
100	MR	14194-19	BGMV 287	((A 774xG 21212)F1xRAB 609)F1x((DOR 500x(DOR 390x(DOR 390xSAM 1)F1)F2)F3xSEA 18)F1/- MC-3P-MQ-MC-6C-MC-MC		bgml	1	3	2	2.0	4	3	4	3.7
101	MR	14212-4	BGMV 305	(SEA 15x(G 18479x(G 18479x(G 18479xSAM 1)F1)F2)F3)F1 X (TIO CANELA 75x(FEB 192xG 21212)F1)F1/-MC-2P-MQ-MC-4C-MC- MC		W12?	1	2	2	1.7	4	4	4	4.0
102	MR	14212-12	BGMV 305	(SEA 15x(G 18479x(G 18479x(G 18479xSAM 1)F1)F2)F3)F1 X (TIO CANELA 75x(FEB 192xG 21212)F1)F1/-MC-5P-MQ-MC-3C-MC- MC		bgml	1	3	2	2.0	4	5	5	4.7
103	MR	14212-12	BGMV 305	(SEA 15x(G 18479x(G 18479x(G 18479xSAM 1)F1)F2)F3)F1 X (TIO CANELA 75x(FEB 192xG 21212)F1)F1/-MC-5P-MQ-MC-4C-MC- MC		bgml	2	1	1	1.3	5	5	5	5.0
104	MR	14212-12	BGMV 305	(SEA 15x(G 18479x(G 18479x(G 18479xSAM 1)F1)F2)F3)F1 X (TIO CANELA 75x(FEB 192xG 21212)F1)F1/-MC-5P-MQ-MC-7C-MC- MC		bgml	3	4	3	3.3	4	4	5	4.3
105	MR	14215-5	BGMV 308	(SEA 15 x MD 23-24)F1 X (TIO CANELA 75 x G 21212)F1/-MC-9P-MQ- MC-4C-MC-MC		bgml[H]?	2	1	2	1.7	5	5	5	5.0
106	MN	13856-6	BGMV 252	LORE 24 x ((VAX 1xA 774)F1x(G 18479x(G 18479x(G 18479xSAM 1)F1)F2)F1)F1/-MQ-3P-MQ-MC-2C-MC- MC		bgml	2	2	2	2.0	4	4	5	4.3
107	MN	13856-35	BGMV 252	LORE 24 x ((VAX 1xA 774)F1x(G 18479x(G 18479x(G 18479xSAM 1)F1)F2)F1)F1/-MQ-3P-MQ-MC-3C-MC- MC		bgml	2	2	1	1.7	4	3	4	3.7

Table 44. Sources of resistance to begomoviruses

Ent	Code	Cross Number	#BGMV	Identification	Fn	BGMV Res. genes	First trial (2003A)				Second trial (2004A)			
							R1	R2	R3	Media	R1	R2	R3	Media
108	MN	13862-44	BGMV 258	LORE 87 x ((VAX 1xIPA 7)F1x(G 18479x(G 18479x(G 18479xSAM 1)F1)F2)F1)F1/-MQ-1P-MQ-MC-2C-MC-MC		bgm1+W12	1	2	1	1.3	5	3	2	3.3
109	MR	14202-4	BGMV 295	(RAB 623 x MD 23-24)F1 X (SEA 15 x (RAB 655 x G 21212)F1)F1/-MC-3P-MQ-MC-9C-MC-MC		W12	3	4	3	3.3	5	5	5	5.0
110	MR	14202-4	BGMV 295	(RAB 623 x MD 23-24)F1 X (SEA 15 x (RAB 655 x G 21212)F1)F1/-MC-3P-MQ-MC-12C-MC-MC		W12	2	1	1	1.3	5	5	4	4.7
111	MR	14216-3	BGMV 309	(SEA 15x(DOR 364x(DOR 364x(DOR 364xSAM 1)F1)F2)F3)F1 X (RAB 651x(MD 23-24xG 21212)F1)F1/-MC-7P-MQ-MC-1C-MC-MC		bgm1+W12	2	2	1	1.7	5	5	5	5.0
112	MR	14216-3	BGMV 309	(SEA 15x(DOR 364x(DOR 364x(DOR 364xSAM 1)F1)F2)F3)F1 X (RAB 651x(MD 23-24xG 21212)F1)F1/-MC-7P-MQ-MC-9C-MC-MC		bgm1+W12	2	3	3	2.7	5	5	5	5.0
113	MR	14000-20	BGMV 551	RAB 651 x (MD 23-24xG 21212)F1/-MC-6P-MQ-MC-1C-MC-MC		bgm1	3	3	2	2.7	4	5	5	4.7
115	MR	14000-20	BGMV 551	RAB 651 x (MD 23-24xG 21212)F1/-MC-6P-MQ-MC-10C-MC-MC		bgm1	3	3	4	3.3	5	5	5	5.0
116	MR	14215-5	BGMV 308	(SEA 15 x MD 23-24)F1 X (TIO CANELA 75 x G 21212)F1/-MC-4P-MQ-MC-8C-MC-MC		bgm1	3	2	3	2.7	5	5	5	5.0
117	MR	14215-5	BGMV 308	(SEA 15 x MD 23-24)F1 X (TIO CANELA 75 x G 21212)F1/-MC-5P-MQ-MC-1C-MC-MC		bgm1	4	2	1	2.3	5	5	5	5.0
118	MR	14215-5	BGMV 308	(SEA 15 x MD 23-24)F1 X (TIO CANELA 75 x G 21212)F1/-MC-5P-MQ-MC-10C-MC-MC		bgm1+W12	4	2	3	3.0	5	5	5	5.0
119	MR	14215-6	BGMV 308	(SEA 15 x MD 23-24)F1 X (TIO CANELA 75 x G 21212)F1/-MC-4P-MQ-MC-12C-MC-MC		bgm1+W12	2	3	2	2.3	5	5	5	5.0
121	.	.	.	BAT 338 x G35252	F11	Interesp	1	1	1	1.0	4	4	5	4.3
122	.	.	.	BAT 338 x G35252	F10	Interesp	2	2	2	2.0	4	3	5	4.0
123	.	.	.	((G35649 x G 3807)x G35023	F7	Interesp	2	2	1	1.7	1	2	3	2.0
124	.	.	.	((G35876 x G 3807)x G35182)x A 114	F9	Interesp	1	1	1	1.0	3	3	3	3.0
126	.	.	.	BAT 338 x G35252	F11	Interesp	2	2	2	2.0	5	4	5	4.7
127	.	.	.	BAT 338 x G35252	F11	Interesp	3	3	4	3.3	5	4	4	4.3
129	.	.	.	BAT 338 x G35252	F11	Interesp	2	3	2	2.3	5	5	5	5.0
130	.	.	.	BAT 338 x G35252	F11	Interesp	1	2	1	1.3	1	2	3	2.0
132	.	.	.	BAT 338 x G35252	F11	Interesp	2	2	1	1.7	5	5	4	4.7

Table 44. Sources of resistance to begomoviruses

Ent	Code	Cross Number	#BGMV	Identification	Fn	BGMV Res. genes	First trial (2003A)				Second trial (2004A)			
							R1	R2	R3	Media	R1	R2	R3	Media
133	.	.	.	BAT 338 x G35252	F10	Interesp	1	3	1	1.7	5	4	5	4.7
134	.	.	.	AND 107 x Piloy	F4	Interesp	2	3	4	3.0	5	5	4	4.7
135	.	.	.	BAT 338 x G35252	F11	Interesp	2	1	1	1.3	5	4	4	4.3
136	.	.	.	BAT 338 x G35252	F11	Interesp	3	3	4	3.3	5	5	5	5.0
137	.	.	.	BAT 338 x G35252	F10	Interesp	2	2	1	1.7	2	3	2	2.3
138	.	.	.	Pasto x G35122	F11	Interesp	3	3	2	2.7	4	4	4	4.0
139	.	.	.	BAT 338 x G35252	F11	Interesp	2	2	1	1.7	2	3	4	3.0
140	.	.	.	BAT 338 x G35252	F11	Interesp	3	2	4	3.0	4	5	4	4.3
141	.	.	.	Pasto x G35122	F10	Interesp	1	2	2	1.7	4	5	5	4.7
142	.	.	.	(ICA PIJAO X G 35171)F1 X ICA PIJAO)F1/-(NN)P-(NN)P(F8)-(NN)P-(NN)D	F10	Interesp	3	3	4	3.3	5	5	5	5.0
143	.	.	.	(ICA PIJAO X G 35171)F1 X ICA PIJAO)F1/-(NN)P-(NN)P(F8)-(NN)P-(NN)D	F10	Interesp	1	1	1	1.0	3	3	2	2.7
144	.	.	.	(ICA PIJAO X G 35172) X ICA PIJAO)F1/-4P-(NN)P(F8)-(NN)P-(NN)D	F10	Interesp	1	1	1	1.0	2	3	3	2.7
145	.	.	.	(ICA PIJAO X G 35172) X ICA PIJAO)F1/-19P-(NN)P(F8)-(NN)P-(NN)D	F10	Interesp	1	1	2	1.3	2	1	3	2.0
146	.	.	.	ICA PIJAO X (ICA PIJAO X G 35877)F1/-(NN)P-(NN)Q-(NN)P-(NN)D	F6	Interesp	2	2	1	1.7	4	4	5	4.3
147	.	.	.	ICA PIJAO X (ICA PIJAO X G 35877)F1/-(NN)P-(NN)Q-(NN)P-(NN)D	F6	Interesp	1	2	1	1.3	3	2	2	2.3
148	.	.	.	ICA PIJAO X (ICA PIJAO X G 35877)F1/-(NN)P-(NN)Q-(NN)P-(NN)D	F6	Interesp	1	1	1	1.0	3	2	3	2.7
149	.	.	.	ICA PIJAO X (ICA PIJAO X G 35877)F1/-(NN)P-(NN)Q-(NN)P-(NN)D	F6	Interesp	2	1	1	1.3	1	2	2	1.7
150	.	.	.	ICA PIJAO X (ICA PIJAO X G 35877)F1/-(NN)P-(NN)Q-(NN)P-(NN)D	F6	Interesp	2	2	2	2.0	3	3	5	3.7
151	.	.	.	ICA PIJAO X (ICA PIJAO X G 35877)F1/-(NN)P-(NN)Q-(NN)P-(NN)D	F6	Interesp	1	2	2	1.7	3	2	3	2.7
152	.	.	.	ICA PIJAO X (ICA PIJAO X G 35877)F1/-(NN)P-(NN)Q-(NN)P-(NN)D	F6	Interesp	1	1	2	1.3	2	3	4	3.0
153	.	.	.	ICA PIJAO X (ICA PIJAO X G 35877)F1/-(NN)P-(NN)Q-(NN)P-(NN)D	F6	Interesp	1	2	1	1.3	2	2	2	2.0
154	.	.	.	RMC 2			3	2	2	2.3	5	5	5	5.0
155	.	.	.	RMC 3			2	2	2	2.0	5	5	5	5.0
156	.	.	.	RMC 4			2	3	4	3.0	5	5	5	5.0
157	.	.	.	RMC 5			2	2	1	1.7	5	5	5	5.0
158	.	.	.	RMC 6			2	3	4	3.0	5	5	5	5.0
159	.	.	.	RMC 7			1	4	1	2.0	5	5	5	5.0
160	.	.	.	RMC 9			1	2	1	1.3	5	4	4	4.3
161	.	.	.	RMC 10			4	3	3	3.3	5	5	5	5.0

Table 44. Sources of resistance to begomoviruses

Ent	Code	Cross Number	#BGMV	Identification	Fn	BGMV Res. genes	First trial (2003A)				Second trial (2004A)			
							R1	R2	R3	Media	R1	R2	R3	Media
162		.	.	RMC 11			4	3	4	3.7	5	5	5	5.0
163		.	.	RMC 12			5	2	2	3.0	5	5	5	5.0
164		.	.	RMC 14			3	4	3	3.3	5	4	5	4.7
165		.	.	RMC 16			4	3	2	3.0	5	5	5	5.0
168		.	.	RMC 25			4	3	1	2.7	5	5	5	5.0
169		.	.	RMC 26			4	4	4	4.0	5	5	5	5.0
170		.	.	RMC 27			4	4	4	4.0	5	5	5	5.0
171		.	.	RMC 29			4	4	4	4.0	5	4	5	4.7
172		.	.	RMC 30			4	4	4	4.0	5	5	5	5.0
173		.	.	RMC 33			4	4	3	3.7	5	5	5	5.0
174		.	.	RMC 34			4	3	3	3.3	5	5	5	5.0
175		.	.	RMC 35			3	1	1	1.7	5	5	5	5.0
176	. 21598 -(M)W F2-(CM)W-CM(6)W- 7W-CM(8)W	.	.	UPR9745-138 X SEL 1446			4	4	4	4.0	5	4	5	4.7
178	. 21605 -(M)W F2-(CM)W-CM(30)W- 6W-CM(2)W	.	.	UPR9745-226 X SEL 1447			4	2	2	2.7	5	5	5	5.0
179	. 21605 -(M)W F2-(CM)W-CM(30)W- 9W-CM(6)W	.	.	UPR9745-226 X SEL 1447			3	3	1	2.3	4	5	4	4.3
181	. 21605 -(M)W F2-(CM)W-CM(30)W-12W-CM(8)W	.	.	UPR9745-226 X SEL 1447			2	2	3	2.3	5	5	5	5.0
183	. 21605 -(M)W F2-(CM)W-CM(30)W-16W-CM(5)W	.	.	UPR9745-226 X SEL 1447			2	2	2	2.0	5	4	5	4.7
184	. 21608 -(M)W F2-(CM)W-CM(25)W- 4W-CM(10)W	.	.	UPR9745-226 X S 31465			2	2	3	2.3	5	2	5	4.0
185	. 21609 -(M)W F2-(CM)W-CM(18)W-11W-CM(3)W	.	.	UPR9745-226 X CALIMA DAR			3	3	3	3.0	5	5	5	5.0
187	. 21609 -(M)W F2-(CM)W-CM(18)W-22W-CM(10)W	.	.	UPR9745-226 X CALIMA DAR			3	4	2	3.0	5	5	5	5.0
188	. 21609 -(M)W F2-(CM)W-CM(18)W-23W-CM(13)W	.	.	UPR9745-226 X CALIMA DAR			4	2	3	3.0	5	5	5	5.0
191	. 21597R-(M)W F2-(CM)W-CM(25)W-17W-CM(3)W	.	.	SEL 1445 X UPR9745-138			3	4	3	3.3	5	5	5	5.0
193	. 21607R-(M)W F2-(CM)W-CM(22)W- 1W-CM(6)W	.	.	SEL 1448 X UPR9745-226			2	2	3	2.3	5	5	5	5.0
195	. 21609R-(M)W F2-(CM)W-CM(50)W- 2W-CM(11)W	.	.	CALIMA DAR X UPR9745-226			3	3	4	3.3	5	5	5	5.0
196	. 21661 -(M)W F2-(CM)W-(CM)W-4W-CM(16)W	.	.	TIO CANELA X G 2333			1	1	1	1.0	4	4	3	3.7
197	. 21661 -(M)W F2-(CM)W-(CM)W-6W-CM(4)W	.	.	TIO CANELA X G 2333			2	1	1	1.3	4	4	5	4.3
198	. 21661 -(M)W F2-(CM)W-(CM)W-7W-CM(15)W	.	.	TIO CANELA X G 2333			1	2	1	1.3	4	3	3	3.3

Table 44. Sources of resistance to begomoviruses

Ent	Code	Cross Number	#BGMV	Identification	Fn	BGMV Res. genes	First trial (2003A)				Second trial (2004A)			
							R1	R2	R3	Media	R1	R2	R3	Media
199	. 21661 -(M)W F2-(CM)W-(CM)W-15W-CM(15)W			TIO CANELA X G 2333			1	1	1	1.0	4	2	3	3.0
200	. 21662 -(M)W F2-(CM)W-(CM)W-2W-CM(10)W			G 685 X TIO CANELA			2	3	2	2.3	4	3	5	4.0
201	. 21662 -(M)W F2-(CM)W-(CM)W-3W-CM(15)W			G 685 X TIO CANELA			3	2	1	2.0	3	4	5	4.0
202	. 21662 -(M)W F2-(CM)W-(CM)W-4W-CM(7)W			G 685 X TIO CANELA			1	2	3	2.0	3	4	4	3.7
203	. 21662 -(M)W F2-(CM)W-(CM)W-6W-CM(17)W			G 685 X TIO CANELA			3	3	3	3.0	4	4	4	4.0
205	. 21662 -(M)W F2-(CM)W-(CM)W-13W-CM(24)W			TIO CANELA X G 685			1	2	1	1.3	3	3	3	3.0
206	. 21662 -(M)W F2-(CM)W-(CM)W-4W-CM(14)W			TIO CANELA X G 685			3	4	2	3.0	4	4	5	4.3
207	. 21662 -(M)W F2-(CM)W-(CM)W-5W-CM(2)W			TIO CANELA X G 685			1	1	1	1.0	4	5	4	4.3
208	. 21662 -(M)W F2-(CM)W-(CM)W-9W-CM(14)W			TIO CANELA X G 685			1	2	1	1.3	4	4	4	4.0
209	. 21662 -(M)W F2-(CM)W-(CM)W-14W-CM(8)W			TIO CANELA X G 685			3	3	3	3.0	4	5	5	4.7
210	. 21662 -(M)W F2-(CM)W-(CM)W-15W-CM(21)W			TIO CANELA X G 685			2	2	1	1.7	4	4	4	4.0
211	. 21662 -(M)W F2-(CM)W-(CM)W-15W-CM(21)W			TIO CANELA X G 685			3	2	3	2.7	4	4	5	4.3
212	. 21662 -(M)W F2-(CM)W-(CM)W-16W-CM(20)W			TIO CANELA X G 685			2	2	2	2.0	4	4	5	4.3
213	. 21661R-(M)W F2-(CM)W-(CM)W- 4W-CM(16)W			G 2333 X TIO CANELA			3	3	4	3.3	4	4	4	4.0
214	. 21661R-(M)W F2-(CM)W-(CM)W- 4W-CM(12)W			G 2333 X TIO CANELA			3	2	2	2.3	4	5	5	4.7
215	. 21661R-(M)W F2-(CM)W-(CM)W- 6W-CM(13)W			G 2333 X TIO CANELA			2	2	2	2.0	4	4	4	4.0
216	. 21661R-(M)W F2-(CM)W-(CM)W- 8W-CM(10)W			G 2333 X TIO CANELA			1	2	1	1.3	3	3	3	3.0
217	. 21661R-(M)W F2-(CM)W-(CM)W-12W-CM(12)W			G 2333 X TIO CANELA			3	3	2	2.7	4	4	5	4.3
218	. 21661R-(M)W F2-(CM)W-(CM)W-14W-CM(11)W			G 2333 X TIO CANELA			3	4	1	2.7	5	4	4	4.3
219	. 21661 -(M)W F2-(CM)W-(CM)W-7W-CM(11)W			TIO CANELA X G 2333			2	2	2	2.0	5	5	5	5.0
220	. 21662 -(M)W F2-(CM)W-(CM)W-6W-CM(5)W			G 685 X TIO CANELA			2	2	2	2.0	4	5	4	4.3

Table 44. Sources of resistance to begomoviruses

Ent	Code	Cross Number	#BGMV	Identification	Fn	BGMV Res. genes	First trial (2003A)				Second trial (2004A)			
							R1	R2	R3	Media	R1	R2	R3	Media
221	. 21662 -(M)W F2-(CM)W-(CM)W-7W-CM(7)W	.	.	G 685 X TIO CANELA	.		1	1	1	1.0	4	4	3	3.7
222	. 21662 -(M)W F2-(CM)W-(CM)W-9W-CM(15)W	.	.	G 685 X TIO CANELA	.		2	3	3	2.7	5	5	5	5.0
223	. 21662 -(M)W F2-(CM)W-(CM)W-10W-CM(4)W	.	.	G 685 X TIO CANELA	.		1	2	1	1.3	3	2	4	3.0
224	. 21662 -(M)W F2-(CM)W-(CM)W-13W-CM(4)W	.	.	G 685 X TIO CANELA	.		1	2	1	1.3	3	3	4	3.3
225	. 21662 -(M)W F2-(CM)W-(CM)W-17W-CM(7)W	.	.	G 685 X TIO CANELA	.		2	1	1	1.3	4	5	5	4.7
226	. 21662 -(M)W F2-(CM)W-(CM)W-20W-CM(10)W	.	.	G 685 X TIO CANELA	.		2	2	2	2.0	5	5	4	4.7
227	. 21662 -(M)W F2-(CM)W-(CM)W-22W-CM(4)W	.	.	G 685 X TIO CANELA	.		2	1	1	1.3	3	4	3	3.3
228	. 21662 -(M)W F2-(CM)W-(CM)W-1W-CM(11)W	.	.	G 685 X TIO CANELA	.		1	1	1	1.0	3	2	5	3.3
229	. 21662 -(M)W F2-(CM)W-(CM)W-1W-CM(14)W	.	.	TIO CANELA X G 685	.		1	1	2	1.3	3	5	5	4.3
230	. 21661R-(M)W F2-(CM)W-(CM)W-6W-CM(17)W	.	.	G 2333 X TIO CANELA	.		2	1	1	1.3	5	5	4	4.7
231	. 21661R-(M)W F2-(CM)W-(CM)W-7W-CM(12)W	.	.	G 2333 X TIO CANELA	.		3	3	2	2.7	5	5	5	5.0
233	.	.	.	G 685	.		2	3	2	2.3	4	5	5	4.7
235	.	.	.	RM - 35	.		1	-	-	1.0	5	5	5	5.0
236	.	.	.	G5746 (RGL - C)	.		3	3	3	3.0	5	5	5	5.0
237	.	.	.	Rojo Brasil	.		3	2	2	2.3	5	5	5	5.0
114*	MR	14000-20	BGMV 551	RAB 651 x (MD 23-24xG 21212)F1/-MC-6P-MQ-MC-4C-MC-MC	.	bgm1	4	4	4	4.0	-	-	-	
120*	MR	14215-9	BGMV 308	(SEA 15 x MD 23-24)F1 X (TIO CANELA 75 x G 21212)F1/-MC-8P-MQ-MC-1C-MC-MC	.	bgm1+W12	4	4	4	4.0	-	-	-	
125*	.	.	.	BAT 338 x G35252	F11	Interesp	5	4	5	4.7	-	-	-	
128*	.	.	.	AND 279 x G35337	F4	Interesp	3	4	4	3.7	-	-	-	
131*	.	.	.	BAT 338 x G35252	F10	Interesp	3	4	4	3.7	-	-	-	
166*	.	.	.	RMC 22	.		4	4	4	4.0	-	-	-	
167*	.	.	.	RMC 23	.		4	4	3	3.7	-	-	-	
177*	. 21602 -(M)W F2-(CM)W-CM(20)W-16W-CM(12)W	.	.	UPR9745-138 X CALIMA DAR	.		4	4	4	4.0	-	-	-	
180*	. 21605 -(M)W F2-(CM)W-CM(30)W-12W-CM(8)W	.	.	UPR9745-226 X SEL 1447	.		4	4	2	3.3	-	-	-	
182*	. 21605 -(M)W F2-(CM)W-CM(30)W-15W-CM(8)W	.	.	UPR9745-226 X SEL 1447	.		4	4	4	4.0	-	-	-	

Table 44. Sources of resistance to begomoviruses

Ent	Code	Cross Number	#BGMV	Identification	Fn	BGMV Res. genes	First trial (2003A)				Second trial (2004A)			
							R1	R2	R3	Media	R1	R2	R3	Media
186*	. 21609 -(M)W F2-(CM)W-CM(18)W-16W-CM(9)W	.	.	UPR9745-226 X CALIMA DAR	.		4	4	4	4.0	-	-	-	-
189*	. 21609 -(M)W F2-(CM)W-CM(18)W-25W-CM(8)W	.	.	UPR9745-226 X CALIMA DAR	.		4	4	4	4.0	-	-	-	-
190*	. 21597R-(M)W F2-(CM)W-CM(25)W- 2W-CM(4)W	.	.	SEL 1445 X UPR9745-138	.		4	4	2	3.3	-	-	-	-
192*	. 21597R-(M)W F2-(CM)W-CM(25)W-20W-CM(5)W	.	.	SEL 1445 X UPR9745-138	.		3	4	4	3.7	-	-	-	-
194*	. 21607R-(M)W F2-(CM)W-CM(22)W- 4W-CM(8)W	.	.	SEL 1448 X UPR9745-226	.		3	4	4	3.7	-	-	-	-
204*	. 21662 -(M)W F2-(CM)W-(CM)W-8W-CM(11)W	.	.	G 685 X TIO CANELA	.		4	4	3	3.7	-	-	-	-
232*		.	.	. SEL 1445	.		4	4	4	4.0	-	-	-	-
234*		.	.	GN - 31	.		4	4	-	4.0	-	-	-	-
238*		.	.	G - 76 (RED KLOUD)	.		4	4	3	3.7	-	-	-	-
25*	RAB 651	.	.	RAB 651	.	bgm1	3	4	4	3.7	-	-	-	-
43*	G 4090	.	.	G 4090 [ROJO DE SEDA]	.	Susceptible	4	4	3	3.7	-	-	-	-
67*	MR	14148-72	BGMV 453	(SEA 21 x RAB 623)F1 X 9653-16 B-1/-MC-3P-MQ-MC-3C-MC-MC	.	W12	3	4	4	3.7	-	-	-	-
89*	MN	13942-31	BGMV 575	(TLP 35xG 21212)F1 x ICTA LIGERO/-MC-1P-MQ-MC-4C-MC-MC	.	bgm1+W12	4	4	2	3.3	-	-	-	-
10H	SB 14565-4	14		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-1P-1P-4T	F5		-	-	-		5	5	-	5.0
11H	SB 14565-4	13		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-1P-1P-3T	F5		-	-	-		5	5	5	5.0
12H	SB 14565-4	12		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-1P-1P-2T	F5		-	-	-		5	5	5	5.0
13H	SB 14565-4	11		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-1P-1P-1T	F5		-	-	-		5	5	5	5.0
14H	SB 14565-3	10		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-1P-1P-2T	F5		-	-	-		5	5	5	5.0
15H	SB 14565-3	9		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-1P-1P-1T	F5		-	-	-		5	5	5	5.0
16H	SB 14565-1	8		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-4P-5P-4T	F5	bgm1+W12	-	-	-		5	5	5	5.0
17H	SB 14565-1	7		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-4P-5P-3T	F5	Susceptible	-	-	-		5	5	5	5.0
18H	SB 14565-1	6		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-4P-5P-2T	F5		-	-	-		5	5	5	5.0
19H	SB 14565-1	5		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-4P-5P-1T	F5		-	-	-		4	5	-	4.5
1H	SB 14565-7	23		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-2P-1P-2T	F5	Interesp	-	-	-		5	5	5	5.0

Table 44. Sources of resistance to begomoviruses

Ent	Code	Cross Number	#BGMV	Identification	Fn	BGMV Res. genes	First trial (2003A)				Second trial (2004A)			
							R1	R2	R3	Media	R1	R2	R3	Media
20H	SB 14565-1	4		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-4P-3P-1T	F5	Interesp	-	-	-		5	5	5	5.0
21H	SB 14565-1	3		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-4P-1P-3T	F5	Interesp	-	-	-		5	5	5	5.0
22H	SB 14565-1	2		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-4P-1P-2T	F5	W12	-	-	-		5	5	5	5.0
23H	SB 14565-1	1		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-4P-1P-1T	F5	bgm1	-	-	-		4	5	5	4.7
2H	SB 14565-7	22		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-2P-1P-1T	F5		-	-	-		5	5	5	5.0
3H	SB 14565-4	21		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-3P-2P-2T	F5		-	-	-		5	5	5	5.0
4H	SB 14565-4	20		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-3P-2P-1T	F5		-	-	-		5	5	5	5.0
5H	SB 14565-4	19		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-1P-2P-3T	F5		-	-	-		5	5	5	5.0
6H	SB 14565-4	18		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-1P-2P-2T	F5		-	-	-		5	5	5	5.0
7H	SB 14565-4	17		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-1P-2P-1T	F5		-	-	-		5	5	5	5.0
8H	SB 14565-4	16		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-1P-1P-6T	F5	bgm1+W12	-	-	-		5	5	5	5.0
9H	SB 14565-4	15		HAV 129 X (G 17723 x (G 685 x (ASC 73 x ICTA HUNAPU)F1)F1)F5/-1P-1P-5T	F5	bgm1	-	-	-		5	5	5	5.0

A screening of selected sources of begomovirus resistance was also conducted under glasshouse conditions to determine the efficiency of transmission of the virus by *B. tabaci*. Table 45 shows the average incidence of two inoculations of seven day old seedlings using eight whitefly adults per plant.

Table 45. Bean leaf crumple incidence in selected bean genotypes artificially inoculated using eight *B. tabaci* individuals per test plant.

Bean Genotype	Bean leaf crumple Incidence (%)
Topcrop	100
Red Kloud	100
Redlands Greenleaf-C	83.3
Garrapato	54.2
Great Northern 31	33.3
EAP-9510-77	16.7
Rojo Brasil	16.7
Red Mexican 35	4.5
ICTA Ligeró	0
Porrillo Sintetico	0
BAT 304	0

The field and glasshouse inoculations of selected sources of resistance and the susceptible control (Topcrop), showed that the genetics of resistance to Bean leaf crumple is similar to that reported for other begomoviruses of common bean. Basically, the best common bean genotypes identified, are either virus-resistant genotypes or have virus-resistant parents of different racial origin. However, the best sources of virus resistance are found in the black-seeded genotypes (e.g. BAT 304, Porrillo Sintetico, and ICTA Ligeró). Unfortunately, although the black-seeded genotypes have been widely used as sources of resistance to begomoviruses in bush types, the climbers and most snap bean varieties have not been previously bred for resistance to these emerging virus problems. This requires a concerted effort to improve snap beans for their resistance to begomoviruses.

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2.1.5 Resistance to different pathogenic species of *Pythium*

Rationale: In screenhouse evaluations of germplasm and potential sources of resistance against *Pythium* root rots, we have in the past used *P. aphanidermatum*. As a result we identified and confirmed a number of resistance sources. However, our recent pathogen characterization studies showed that over nine *Pythium* species (*Pythium ultimum*, *P. salpingophorum*, *P. irregulare*, *P. aphanidermatum*, *P. nodosum*, *P. spinosum*, *P. tulosum*, *P. chamaehyphon* and *P. pachycaule*) from east and central African countries infect beans, with *P. ultimum* being the most widespread species (found in 25-30% of samples collected). Besides, some of the genotypes observed to be

resistant in the screenhouse against *P. aphanidermatum* were susceptible under field conditions, while resistance in some varieties (RWR 221) varied with location (e.g. resistant in Rwanda but susceptible in Western Kenya). It is therefore vital to subject the resistant germplasm or potential parental materials against the different characterized *Pythium* species, so as to ensure that the resistance identified and used for introgression into commercial varieties is broad and durable.

Materials and Methods: Thirty-nine genotypes, previously screened and found to be resistant to *P. aphanidermatum* were evaluated against nine isolates representing six *Pythium* species (*Pythium ultimum*, *P. salpingophorum*, *P. spinosum*, *P. tulosum*, *P. chamaeophon* and *P. pachycaule*) pathogenic to beans. Plants were grown in wooden trays containing soil artificially infested with each of the six species. Soil conditions favoring pathogen establishment and disease development (high soil moisture) were provided and plants were evaluated three weeks after germination. Seedlings were gently uprooted, washed in tap water, and severity of lesions on the root system scored using a CIAT severity rating scale of 1 (resistant) to 9 (susceptible). Twelve plants per entry were evaluated in two replications. CAL 96 and RWR 719 were used as susceptible and resistant checks respectively.

Results and Discussion: Thirty out of thirty-nine genotypes maintained their resistance against the different species of *Pythium* (Table 46), a demonstration of their potential value in genetic improvement of commercial varieties. Of interest and probably influenced by species was the susceptible reactions of DOR 708, VAX 2, DOR 622, RWR 1058 and RWR 1059 which were previously considered resistant (using *P. aphanidermatum*). However, there was no differential reaction of the bean genotypes to different *Pythium* species used in the current study, implying that the genes responsible for resistance might have a similar mode of action. Some of the small seeded varieties (Mex 54, 217/2, GLP 585 and GLP X 92) had intermediate reactions implying that they possibly have some levels of resistance but distinct from that in resistant varieties. This is consistent with observations under field conditions where some of these entries (e.g. GLP X92) are more tolerant to *Pythium* root rot than the susceptible ones (GLP 2). Mex 54, resistant to most races of angular leaf spot pathogen (*Phaeoisariopsis griseola*) found in Africa has been used in crosses to improve resistance against the disease. Its medium to susceptible reactions against *Pythium* species, demonstrates the need to pyramid ALS and *Pythium* root rot resistances. The large or medium seeded Andean varieties like CAL 96, GLP 2, GLP 24, RWR 1058, RWR 1092, and Urugezi were susceptible (reaction score of 9) and died 21 days after planting. Varietal improvement is targeting these materials some of which are important commercial varieties in east and central Africa.

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Table 46. Reaction of common bean genotypes to artificial inoculation with six *Pythium* species causing bean root rots. Kawanda, 2004

Entry	<i>Pythium</i> species / isolates								
	<i>P. ultimum</i>		<i>P. salpingophorum</i>		<i>P. sp.</i>	<i>P. chamaeophyon</i>	<i>P. pachycaule</i>	<i>P. spinosum</i>	<i>P. torulosum</i>
	JIM 85A	JIM 7HI	JM 84	JM 65A	KAK 5B	VIH 2A	JIM 29A	JM70H1	JM 65A
MLB-49-89A	1	1	1	1	1	1	1	1	1
MLB-40-89A	1	1	1	1	1	1	1	1	1
MLB-48-89A	4	4	3	3	1	3	3	2	1
MLB-39-89A	1	1	1	1	1	1	1	1	1
MLB-17-89A	1	1	1	1	1	1	1	1	1
MLB-36-89A	1	1	1	1	1	1	1	1	1
MLB-22-88B	2	2	1	1	1	1	1	1	1
MLB-68-89A	1	1	1	1	1	1	1	1	1
RWR 719	1	1	1	1	1	1	1	1	1
RWR 1873	2	2	2	2	1	1	1	1	1
RWR 2075	2	2	2	2	1	1	1	1	1
RWR 1946	2	2	2	2	1	1	1	1	1
RWR 221	1	1	1	1	1	1	1	1	1
RWR 1092	1	1	2	2	2	2	1	1	1
RWR 1091	1	1	1	1	1	1	1	1	1
Ihumure	1	1	1	1	1	2	1	1	1
SCAM80-CM/15	1	1	1	1	1	1	1	1	1
SCAM80-CM/5	1	1	1	1	1	1	1	1	1
MCD 221	3	3	1	1	1	1	1	1	1
AND 1064	1	1	1	1	1	1	1	1	1
AND1055	1	1	1	1	1	1	1	1	1
AND 1062	1	1	1	1	1	1	1	1	1
MAM 38	3	3	2	3	1	1	1	1	1
UBR (95) 2	1	1	1	1	1	1	1	1	1
CIM 9314-1	1	1	1	1	1	1	1	1	1
CIM 9313-1	1	1	1	1	1	1	1	1	1
EC-DE-HAR	2	2	2	2	2	2	1	1	1
DFA 54	3	3	2	2	1	1	1	1	1
FEB 181	3	3	2	2	1	1	1	1	1
311/7	2	1	2	1	1	1	1	1	1
Mexico 54	6	6	6	7	7	7	7	8	7
217/2	5	5	7	7	7	7	7	7	7
GLP 585	7	7	7	7	7	7	7	7	7
GLP X 92	7	7	7	7	6	6	7	6	6
DOR 708	9	9	9	9	9	9	9	9	9
VAX 2	9	9	9	9	6	6	6	7	7
DOR 622	9	8	8	8	9	9	8	9	9
RWR 1059	9	9	9	9	9	9	6	9	9
RWR 1058	9	9	9	9	9	9	9	9	9
GLP 24	9	9	9	9	9	9	9	9	9
GLP2	9	9	9	9	9	9	9	9	9
URUGEZI	9	9	9	9	9	9	9	9	9
CAL 96	9	9	9	9	9	9	9	9	9

2.1.6 Evaluation and selection among segregating populations for resistance to *Pythium* root rot and angular leaf spot.

Rationale: In efforts to increase bean production through genetic improvement in Africa, and reduce yield losses caused by two major bean diseases; angular leaf spot (ALS) and bean root rots, several populations designed to transfer, combine and pyramid resistance against the diseases, into major commercial and adapted bush and climbing bean cultivars were generated. Some of the parents used (see Section 2.1.1 above) are resistant to several species of *Pythium* and important races of *Phaeoisariopsis griseola* in Africa. Selections from segregating populations and lines focused on seed types and resistance to *Pythium* root rot and ALS.

Materials and Methods: Several F₂ derived F₄ populations, lines and families were grown at Rubaya in southwest Uganda and at Kawanda. At Kawanda, populations were grown in the field and evaluated for ALS, common bacterial blight and bean common mosaic virus. At Rubaya, populations were evaluated for root rots and resistance to other foliar diseases. Some lines were evaluated in the screenhouse using artificial inoculation with *P. ultimum* as described under 2.1.1.

Evaluation for angular leaf spot resistance was done by artificially inoculating populations with a mixture of local Andean and Mesoamerican races. Three week-old seedlings were spray-inoculated with a spore suspension from 14 day-old cultures at a concentration of 2×10^4 conidia ml⁻¹. Inoculated plants were incubated in a humid chamber for 4 days and thereafter in the open, inside the screen house. Assessment of disease reaction was done every third day over a three-week period using a CIAT severity scale of 1 (resistant) to 9 (susceptible).

Results and Discussion:

Selection of recombinant inbred lines (RILs) for improved resistance to *Pythium* root rot:

The F₄ single plants evaluated had been derived from two selection pathways of F₂ populations. The first set of F₂ population had been evaluated in soil artificially infested with *P. ultimum* in the screen house. F₂ resistant plants were selected and planted in single row progenies in the field at Kawanda. Resulting F₃ families were advanced to F₄ by single seed descent. The F₄ superior single plants were grown this year in Rubaya and Senge and selected for their resistance to root rots and for other agronomic traits. About 170 F₅ single plant progenies were selected (Table 47) and will be made available to partners in both ECBREN and SABRN countries for multi-ecology evaluations with farmer participation.

Another set of F₂ populations were screened in the field in Rubaya (a root rot hotspot) and advanced by selecting best individual plants to get F₃ families (pedigree selection). The best F₄ plants were selected from best rows within each family to produce F₅ families. These were evaluated in the screen house against *P. ultimum*. The best resistant entries (≤ 3.9 in a CIAT scale of 1-9) and also representing a range of seed types (e.g. red mottle, red, black, beige, cream etc) are shown on Table 48. Seed multiplication is underway and the materials will be available for multi-location evaluation with farmer participation.

Table 47. F₅ recombinant inbred lines (RILs) derived by single seed descent from F₂ resistant progenies.

Pedigree	Lines			
	Evaluated			Selected
	F ₃ at Senge 2003B	F ₄ at Senge 2004A	F ₄ at Rubaya 2004A	F ₅ at Rubaya 2004A
GLP 2 x RWR 719	5	2	2	1
GLP2 x AND 1055	103	63	22	21
GLP2 x AND 1062	35	23	(under evaluation)	
GLP 585 x RWR 719	40	20	3	3
GLP 585 x MLB-49-89A	456	205	124	114
GLP 585 x SCAM 80- CM/15	7	3	3	1
GLP 585 x AND 1062	8	7	(under evaluation)	
CAL 96 x MLB-49-89A	5	10	5	5
BCr ₁ GLP 585 x MLB-49- 89A	30	20	36	21
BCr ₁ CAL 96 x MLB-49- 89A	11	10	5	4
Total	684	363	200	170

Table 48. F₅ lines resistant against *P. ultimum* (score of less than ≤ 3.9) derived from F₂ resistant progenies by pedigree method. Kawanda, screen house, 2004

Pedigree	Line codes	No. of lines with resistant disease severity scores ^x		
		1	(1.1-2)	(2.1-3.9)
GLP 2 x MLB-49-89A	RF RO2-12	4	2	8
GLP 2 x SCAM 80-CM/15	RF RO2-13	5	2	6
GLP 2 x AND 1055	RF RO2-14	3		6
GLP 2 x AND 1062	RF RO2-15	3		5
GLP 585 x RWR 719	RF RO2-21	2	1	
GLP 585 x SCAM 80-CM/15	RF RO2-23			1
GLP 585 x AND 1062	RF RO2-25	1	2	1
CAL 96 x MLB-49-89A	RF RO2-32			1
Total		18	7	28

^x - Based on a CIAT scale of 1 to 9 where 1 is resistant and 9 susceptible

Development of backcross (BC) populations with *Pythium* root rot resistance

Parallel to the development of RILs, a backcrossing program initiated to transfer resistance into popular market class types grown in Kenya, Rwanda and Uganda has generated 20 backcross populations (Table 49). Two and five populations are at BC₅ and BC₄ respectively. The latter is being advanced to BC₅. The BC₅ will be available for heterogeneity test by partners in different countries for selecting lines of interest (resistance and farmer preferences) under different environments.

Table 49. Developed backcross (BCs) populations by 2004

Population codes	No. of populations	Generation
BC _{s1} RFR O2-1-11	2	BC ₅
BC _{s1} RFR O2-1-12, 13, 15, 22, 24	5	BC ₄
BC _{s1} RFR O2-1-14, 21, 23, 25, 31, 32, 33, 34, 35, 40, 42, 43, 44-45.	13	BC ₃
Total	20	BC₂₋₅

Selection from families combining ALS and *Pythium* root rot resistance

Out of 31 F₂ families (Table 50) designed to combine ALS and *Pythium* root rot resistant in different seed background and evaluated at Kabale for root rot and at Kawanda for angular leaf spot resistance, 205 F₅ families were selected by bulk breeding method. The families generated are heterogeneous for agronomic traits and seed types. They will be distributed to national program partners for further selection.

Table 50. F₅ Families combining resistance for bean root rot and angular leaf spot, Kawanda, 2004.

Cross	F ₅ Families selected
F ₁ (CAL 96 x RW 719) x F ₁ (CAL 96 x MEX 54)	17
F ₁ (CAL 96 x RWR 719) x F ₁ (CAL 96 x BAT 332)	38
F ₁ (CAL 96 x MLB-49-89A) x F ₁ (CAL 96 x MEX 54)	16
F ₁ (CAL 96 x SCAM 80- CM/15) x F ₁ (CAL 96 x BAT 32)	68
F ₁ (CAL 96 x MLB-49-89A) x F ₁ (CAL 96 x BAT 332)	50
F ₁ (CAL 96 x SCAM 80CM/15) x F ₁ CAL 96 x MEX 54)	16
Total	205

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Collaborators: S. Beebe and M. Blair.

2.1.7 Use of the RAPD marker OPE -04 to select for angular leaf spot resistance gene contributed by Mex 54

Rationale: Marker-assisted selection (MAS) is considered a useful biotechnology tool in speeding and improving effectiveness of breeding and in pyramiding desired genes into commercial backgrounds. Mex 54, a good source of resistance to most races of *Phaeoisariopsis griseola* found in Africa, has been extensively used in simple and complex crosses to transfer resistance into commercial but susceptible varieties. Last year we showed that a RAPD primer OPE-04 is associated and segregates with a single resistant dominant gene in Mex 54 (detected when using race 63-39 of *P. griseola*) and therefore offers potential for use in selecting resistant progenies. The objective of this study was to develop and adapt a protocol for evaluating and selecting resistant progenies.

Materials and Methods: Segregating populations (F₁, F₂ and F₅) derived from simple and double crosses and several lines and varieties were inoculated with race 63-39 of *P. griseola* and evaluated as described under section 2.1.2. DNA was extracted from leaves of the same populations and lines according to Doyle and Doyle (1990), with some modification and by the alkaline method (Warner *et al* 2001). DNA samples were amplified by RAPD technique according to Williams *et al.* (1990) with a decamer primer OPE-04 (GTGACATGCC) (Sigma Genosys). Each amplification reaction of 25µl contained 1X PCR buffer, 3mM of MgCl₂, 0.2mM of each dNTP, 1µM of primer, 1 unit of *Taq* DNA polymerase, 10ng of DNA and 0.1 mg of BSA (Bovine serum albumin). The amplification conditions used are as follows: DNA denaturation (94°C for 15 seconds), primer annealing (35°C for 30 seconds) and extension by *Taq* DNA polymerase (72°C for 1 min). After 40 cycles, samples are subjected to a final extension of 7 minutes at 72°C and finally kept at 4°C. Amplification products were separated on a 2% agarose gel containing 5µg/ml ethidium bromide.

Results and Discussions: A modification of the DNA extraction method by Doyle and Doyle (1990) yielded more polymorphism than the alkaline method (Warner *et. al.* 2001) and we therefore opted to use the former to evaluate progenies and lines for the presence or absence of the marker associated with the resistance gene in Mex54. Primer OPE-04 amplified a 700bp DNA fragment that was present in individuals scored as resistant based on virulence data and absent in susceptible individuals. Results of some of the progenies/lines are shown on Figure 28 and clearly demonstrate the possibility of using the method and primer to select for the resistance gene associated with the RAPD primer. Efforts are underway to design protocols that will facilitate the efficient use of this method and to enhance effectiveness of selecting for ALS resistance. Similarly, collaborating arrangements and procedures are being developed to enable bean network partners in different countries to make use of these tools at selected laboratories.



Figure 28. Identification of F₂ plants with a marker associated with ALS resistant gene in Mex 54 and detected by an OPE4, RAPD primer. Lane 1=100bp ladder, Lane 2 = Mex54; Lane 3 = GLP 585; Lane 4 = K132; Lane 5 = GLP2; Lane 6 = SCAM80-CM/15, Lane 7 - 14 = with the marker (resistant), Lane 15 - 19 = without marker (susceptible).

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2.1.8 Yield testing of BCMV resistant, heat tolerant Andean climbing beans developed with marker assisted selection and virus screening

Rationale: Climbing beans are grown in both intensive (trellised/staked monoculture) and extensive (inter-cropping with corn) farming systems. In either system the need to protect the crop from diseases is great, especially against seed borne or easily transmitted viral diseases such as bean common mosaic virus (BCMV or BCMNV). Bean common mosaic virus is found worldwide and is an aphid transmitted Potyvirus. A number of BCMNV resistance genes have been tagged including the *I* gene, *bc3*, *bc2* and *bc1*². The genes can be distinguished by inoculation with different viral isolates. BCMNV resistance is very important in Africa where necrotic strains are prevalent and has become a renewed priority for parts of Latin America where necrotic strains have been discovered. Very few climbing beans have been bred for resistance to bean common mosaic virus. Therefore it has been our goal to incorporate recessive resistance based on the *bc-3* gene into a series of climbing beans. One initial target of the breeding effort has been the MAC lines that we have recently developed and distributed to East Africa. These are mid-altitude climbing bean (MAC) lines, which are more heat tolerant, and higher yielding than many traditional climbing bean varieties and have great promise for the region. We have started this program with a series of backcrosses and simple crosses between MAC lines and sources of BCMV resistance. During the breeding program we used marker-assisted selection extensively based on the SCAR marker for *bc3* and combined this with virus screening to select resistant progeny. The objective of this report is to summarize yield testing of the most advanced climbing bean lines with BCMV resistance that are coming out of this breeding effort.

Materials and Methods: A total of 40 advanced F_{5,7} lines were selected for yield testing. These represented the best selections from simple crosses between virus resistant bush bean parents and susceptible climbing bean parents which had been evaluated with marker-assisted selection using the SCAR marker for *bc3* resistance, ROC11, evaluated on the F₅ single plant selection and with virus inoculations performed on the F_{5,6} progeny. MAS procedures and viral inoculations were as described in last year's annual report. Selections were also made based on agronomic performance, climbing bean architecture and large red mottled seed type. Parents involved in the crosses included a series of mid-altitude climbing (MAC) bean advanced lines (SEL1445, 1446, 1447, 1448 and 1449), as well as the local landrace Calima Voluble Darien (selected for its long grain and straight pods) crossed with three sources of *bc3* resistance, BRB29, BRB32 and BRB191. The trial was planted in Palmira in the 2003B season in a randomized complete block design with three repetitions. The genotypes were grown in 3m long single row plots with a trellis system. Agronomic management was as described previously in annual reports. Check varieties included three of the heat tolerant MAC lines (SEL1445, 1446 and 1449) as well as the heat susceptible genotype, Calima Voluble Darien, all of which had been used as parents.

Results and Discussion: BCMV resistance was predicted to occur in all of the advanced lines based on virus screening¹ (for those lines with BRB191 in their pedigrees) or based on marker assisted selection (for those lines with BRB29 or BRB32 in their pedigrees). Some lines still segregated for BCMV resistance as shown by either +/- signals for marker results or S/R, susceptible-resistant, segregation for virus inoculation results (Table 51). However, BCMV was prevalent in the border rows but not within the trial showing that the selections were indeed resistant to field pressure of the disease even in high temperatures that favor symptom development.

Heat tolerance was found in over half of the genotypes tested, as shown by their high yields (ranging from 1694 to 2746 kg ha⁻¹) which were comparable or surpassed the yields of the heat tolerant checks SEL1445, 1446 and 1449 (1371 to 2212 kg ha⁻¹) (Table 51). The heat susceptible genotype, Calima Voluble Darien, and the lines derived from this parent were the lowest yielding of the checks and of the lines, respectively. The two highest yielding lines, both from the cross BRB191 x SEL1447, produced 2746 and 2632 kg ha⁻¹, respectively, which were significantly higher than the yield for two of the heat tolerant checks, SEL1445 and SEL1449, based on LSD comparisons (P=0.05). Lines derived from crosses between BRB29 or BRB32 and SEL1448 or SEL1449 tended to perform less well than those between BRB191 and SEL1447 or SEL1445, indicating which may be the most favorable parents for further crosses. Days to flowering ranged from 31.5 to 46 while days to maturity ranged from 65.5 to 90 days, a range which surpassed that of the checks. This was as expected, since we selected both early maturing and late maturing climbing beans to see if there was an effect on yield due to growth cycle, which was not borne out by phenotypic correlations between days to flowering and productivity (r=-0.122 and -0.121, for plant and plot yields respectively) or days to maturity and productivity (r=0.058 and 0.032, respectively) all of which were not significant. Significant correlation was observed between days to flowering and days to maturity (r=0.877) and plant (g pl⁻¹) and plot (kg ha⁻¹) productivity (r=0.869).

Conclusions and Future Plans: We will begin to implement marker assisted selection for the I gene in these populations and compare BCMV resistance and yield capacity of the lines selected with this SCAR marker.

Collaborators: M.W. Blair, H.F. Buendia, A. Hoyos (IP-1)
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¹ Viral inoculations using a necrotic strain of BCMNV to evaluate viral resistance or susceptibility reactions were evaluated after approximately 10 days, the plants were scored for necrotic hypersensitivity I gene resistance (N), susceptible mosaic symptoms (M) or immune resistance response indicating presence of the bc3 gene (0).

Table 51. Best yielding BCMNV resistant heat tolerant climbing bean F₇ advanced lines developed through marker assisted selection and progeny testing.

Entry no.	Pedigree	Cross no.	F _{5,7} sel. no.	ROC11 SCAR	BCMV			DF	DM	g/pl	Yield kg ha ⁻¹	
					N	S	R					
1	BRB 29 X SEL 1445	21614	5W	+	-	-	-	39.5	76	13.7	712.0	
2	BRB 29 X SEL 1445	21614	8W	+	-	-	-	36	71.5	20.3	1699.5	
3	BRB 29 X SEL 1445	21614	11W	+	-	-	-	36.5	73.5	21.3	1566.8	
4	BRB 29 X SEL 1446	21615	5W	+	-	-	-	35.5	71.5	25.4	1853.6	
5	BRB 29 X SEL 1449	21617	6W	+	-	-	-	39.5	79	21.2	1444.8	
6	BRB 29 X SEL 1448	21618	4W	+	-	-	-	46	90	21.2	1697.1	
7	BRB 29 X SEL 1448	21618	7W	+	-	-	-	38.5	74	14.9	1244.2	
8	BRB 29 X CALIMA DAR	21620	3W	+	-	-	-	40.5	78	26.0	1224.3	
9	BRB 29 X CALIMA DAR	21620	5W	+/-	-	-	-	37.5	77	13.1	997.2	
10	BRB 29 X CALIMA DAR	21620	6W	+	-	-	-	38	74	24.0	1607.4	
11	BRB 32 X SEL 1446	21622	11W	+	-	-	-	35	69	19.2	1463.1	
12	BRB 32 X SEL 1446	21622	14W	+/-	-	-	-	37	71.5	27.4	1990.1	
13	BRB 32 X SEL 1446	21622	17W	+/-	-	-	-	35	69.5	19.5	1481.3	
14	BRB 32 X SEL 1449	21624	1W	+	-	-	-	32	65.5	18.2	1301.0	
15	BRB 32 X SEL 1449	21624	4W	+/-	-	-	-	35.5	67	21.5	1740.7	
16	BRB 32 X SEL 1449	21624	7W	+	-	-	-	39	73	24.0	1695.7	
17	BRB 32 X SEL 1449	21624	10W	+	-	-	-	35	68	18.5	1519.4	
18	BRB 32 X SEL 1449	21624	13W	+	-	-	-	39	74	24.7	1508.1	
19	BRB 32 X SEL 1449	21624	16W	+/-	-	-	-	31.5	67	22.7	1636.7	
20	BRB 32 X SEL 1449	21624	18W	+	-	-	-	35	68	20.3	1625.8	
21	BRB 32 X SEL 1449	21624	19W	+/-	-	-	-	34	70	33.9	2131.0	
22	BRB 32 X S 31465	21626	3W	+/-	-	-	-	38	71	23.4	1755.8	
23	BRB 32 X CALIMA DAR	21627	4W	+	-	-	-	39	79.5	18.7	1036.4	
24	BRB 32 X CALIMA DAR	21627	5W	+	-	-	-	38.5	75	14.7	1180.7	
25	BRB 191 X SEL 1445	21628	2W	+/-	-	-	-	32.5	69	25.4	1878.9	
26	BRB 191 X SEL 1445	21628	3W	NA	0	3	12	39	76	28.9	2195.9	
27	BRB 191 X SEL 1445	21628	4W	NA	0	9	5	33.5	66.5	21.2	1645.6	
28	BRB 191 X SEL 1445	21628	6W	NA	0	8	4	38.5	77.5	26.6	1533.4	
29	BRB 191 X SEL 1445	21628	8W	NA	0	0	15	34.5	69	29.3	2129.8	
30	BRB 191 X SEL 1445	21628	9W	NA	0	0	15	38.5	76.5	23.3	1560.5	
31	BRB 191 X SEL 1445	21628	10W	NA	0	0	15	38	76.5	23.1	1758.7	
32	BRB 191 X SEL 1445	21628	11W	NA	0	4	11	39.5	76	22.5	1709.4	
33	BRB 191 X SEL 1449	21631	10W	NA	0	0	14	34.5	69.5	25.5	1526.3	
34	BRB 191 X SEL 1447	21630	2W	NA	0	0	13	41.5	83.5	26.9	2157.8	
35	BRB 191 X SEL 1447	21630	4W	NA	0	3	12	36	71	25.6	2131.2	
36	BRB 191 X SEL 1447	21630	7W	NA	5	0	8	36.5	75.5	23.8	1999.1	
37	BRB 191 X SEL 1447	21630	8W	NA	0	0	14	36.5	76.5	21.6	1694.7	
38	BRB 191 X SEL 1447	21630	9W	NA	0	3	12	33	72.5	37.1	2175.2	
39	BRB 191 X SEL 1447	21630	11W	NA	0	0	12	37.5	80	33.5	2631.9	
40	BRB 191 X SEL 1447	21630	12W	NA	0	0	15	39	79.5	37.0	2746.5	
41	SEL 1445	--	--	-	-	-	-	36.5	69	24.9	1918.8	
42	CALIMA VOL DE DARIEN	--	--	-	-	-	-	39.5	77.5	12.2	1009.5	
43	SEL 1446	--	--	-	-	-	-	38	75.5	28.7	2212.1	
44	SEL 1449	--	--	-	-	-	-	37	72.5	19.1	1371.6	
								LSD	4.7	4.1	27.3	752.8
								CV (%)	3.5	6.0	12.8	22.2

2.1.9 Adaptation and use of SCAR markers for marker assisted selection of two anthracnose resistance genes in Andean bean breeding

Rationale: Anthracnose, caused by the fungal pathogen *Colletotrichum lindemuthianum*, is a serious biotic constraint on common bean (*Phaseolus vulgaris*) in many areas of East Africa, and South America where Andean beans are grown. A set of differentials and mapping population have been used to identify over a dozen genes and QTLs affecting resistance/ susceptibility reactions of different races of the pathogen to different common bean genotypes. Co-evolution is known to have occurred between fungal pathotypes and the two common bean gene pools – such that Andean races attack Andean genotypes and Mesoamerican races attack Mesoamerican genotypes, while Andean genotypes resist Mesoamerican races and Mesoamerican genotypes resist Andean races. Therefore the best sources of resistance for breeding programs is often found in the complementary gene pool and genes for resistance must be introgressed through wide crosses and recurrent selection or backcrossing between Andean and Mesoamerican genotypes. In this case marker assisted selection (MAS) is a good option for rapidly breeding resistant varieties especially in the case of climbing beans which are longer season and more expensive to produce than bush beans. Our objective in this study was to introgress two important resistance genes against Andean races of anthracnose into Andean climbing bean breeding lines from their Mesoamerican sources. The principal source used for this work was G2333, a climbing bean landrace from Mexico that is known to have several target genes, namely *Co-4²* and *Co-5* (Young et al., 1998).

Materials and Methods:

DNA extraction and Plant Material: Two extraction techniques were used: 1) Alkaline Extraction (a high-throughput “microprep”, 96-well format method based on alkaline lysis of fresh leaf tissue disks) and 2) Miniprep (ammonium acetate based method using liquid N2 ground tissue from newly-emerging trifoliates). Both techniques have been described before. A total of 574 genotypes were extracted with the first method and 140 genotypes were extracted with the second method. The first group consisted in F₅ advanced lines from simple crosses and from backcross derived families that are part of the Andean bean breeding program, while the second group consisted of inbreeding lines and anthracnose differentials as controls. Alkaline extraction DNA after the neutralizing step was diluted 1:1, 1:5, 1:10, 1:20, 1:30 and 1:50 with sterile water to determine the optimum concentration for amplification. Resuspended miniprep DNA was diluted 1:10.

SCAR markers: A set of four SCAR markers were used in this study to target *Co-4²* and *Co-5* resistance genes: SAS13 (Young et al., 1998), SH18 and SBB14 (Awale and Kelly, 2000) for *Co-4²* and SAB3 (Vallejo and Kelly, 2000) for *Co-5*. PCR amplification conditions were tested with a gradient cycler to find the annealing temperature that worked best with the diluted alkaline extraction DNA. PCR products were visualized on 30 well, 1.5% agarose gels run in 0.5X TBE buffer for 45 minutes at 220 volts, with up to two loadings per comb. Gels were photographed for scoring. The presence or absence of PCR products and the size of these were evaluated for each genotype to determine if the genotype was likely to contain the resistance allele or the susceptible allele.

Results and Discussion:

Genotyping: All four SCAR markers worked well with miniprep DNA diluted 1:10 and presented the expected size band (Table 52) in the correct source genotype (G2333) and other sources of the same gene or alternate allele of the same gene. In the case of SAS13 a band was amplified in the genotypes containing *Co-4*: G-2333, TO, PI, Widusa. This agrees with the results of Young et al. (1998) who found that the marker was not specific to G2333 and other *Co-4*² containing genotypes but also amplified a band in several genotypes that have the *Co-4* allele. Meanwhile in the case of the co-dominant marker SBB14 which was reported to only produce the expected band in G2333 and derived genotypes according to Awale and Kelly (2001) there was also amplification of the resistance-associated allele in the genotypes AB136, Cornell 47-292 and TO, in addition to G2333. The other specific marker from Awale and Kelly (2001), SH18, behaved as expected and amplified a band exclusively in G2333. The *Co-5* marker, SAB3 amplified in both G2333 and TU, as expected from the report of Vallejo and Kelly, (2000).

Table 52. Results of dilution series tests on SCAR marker amplification in the 12 Anthracnose differential genotypes.

Marker	Size bp	Gene	MP		Alkaline	
			Dil. 1:10	Dil. 1:5	Dil. 1:10	Dil. 1:20
SAB-3 (5.9cM) ²	400	<i>Co-5</i> (dominant)	+	+	+	+
SAS-13 (0cM) ³	950	<i>Co-4</i> <i>Co-4</i> ² (dominant)	+	(Tu only) -	(Tu, G2333) -	(Tu, G2333) +
SBB-14 (5.89cM) ¹	1150-1050	<i>Co-4</i> ² (co-dominant)	+	-	-	(G2333) +/-
SH-18 (4.2cM) ¹	1100	<i>Co-4</i> ² (dominant)	+	-	-	(G2333,AB136) -

Alkaline extraction DNA at 1:1 or 1:5 dilutions as template for PCR reactions, was not as reliable as miniprep DNA for SAS13, SBB14 or SH18 amplification but was for SAB3 amplification, which produced the expected bands for the genotypes G2333 and TU at this concentration (Table 52). Increasing the dilution to 1:20 was effective for the amplification of the correct band in G2333 by the markers SAS13 and SBB14 although band intensity was still low (Figure 29). The SAS13 marker which was reported by Young et al. (1998) to amplify in a number of genotypes containing *Co-4* and which did so when miniprep DNA was used, only produced a band for G2333. The SBB14 marker which was reported by Awale and Kelly (2001) to be co-dominant became a dominant marker when alkaline extraction DNA was used but still amplified the correct resistance-associated band in G2333 and AB136. Other dilutions were also tried, including 1:30 and 1:50, but only SAB-3 was observed to amplify the correct genotypes (G-2333 and TU) under all dilutions (data not shown). With alkaline extraction DNA, the most effective annealing temperature for SAS13 was 68°C rather than the 72°C as previously reported (Young et al., 1998).

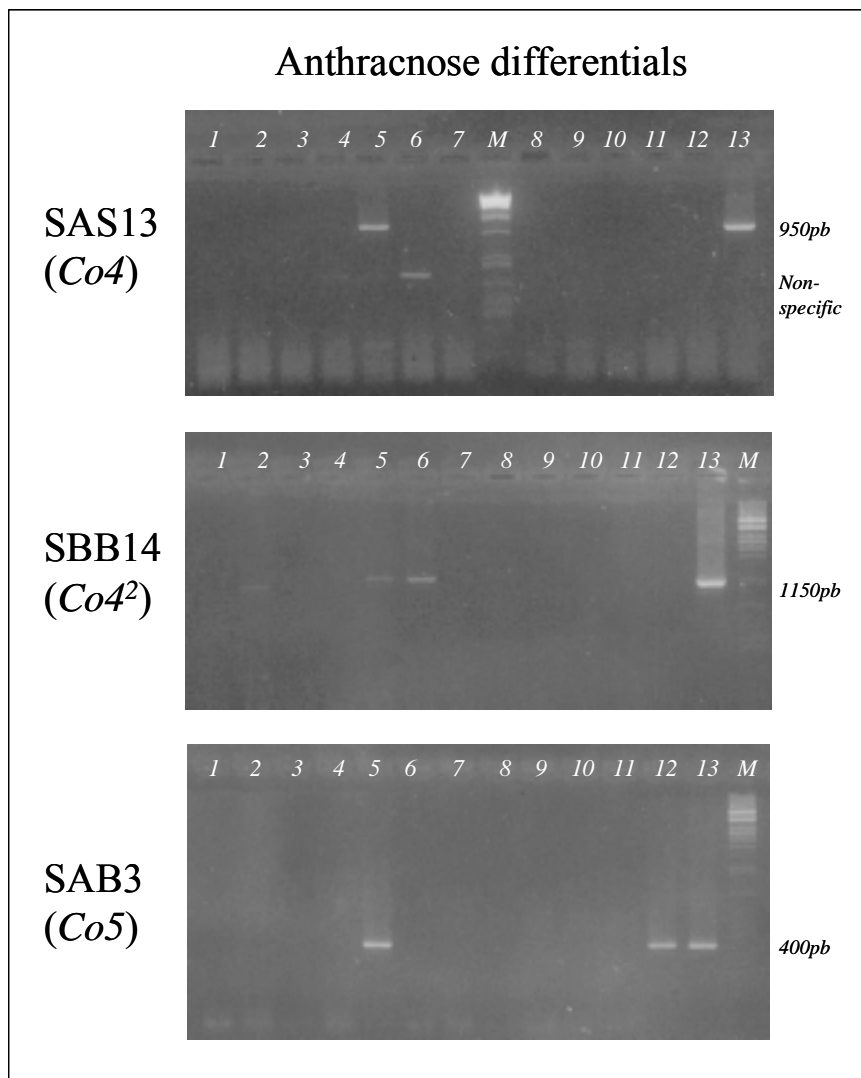


Figure 29. Amplification of anthracnose SCAR markers using alkaline extraction DNA for twelve differentials (lane 1. MDRK, 2. Perry Marrow; 3. Kaboon; 4. Michelite; 5. G-2333; 6. AB136; 7. Cornell 47-292; 8. Mexico 222; 9. PI207262; 10. Widusa; 11. TO; 12. TU) and one control (lane 13. 1:10 dilution of miniprep DNA for the source genotype, G2333).

Marker assisted selection: Of the 574 genotypes extracted a total of 132 had G2333 in their pedigree (the remaining individual DNAs were used for *bc3* marker assisted selection) and these were evaluated for whether they were positive or negative for the SAS13 (*Co-4²*) or SAB3 (*Co-5*) markers (Table 53). Of this total, 41 genotypes were mid-altitude climbing bean selections in Palmira and 93 were mid-altitude/highland selections in Darién. Both groups of selections were made in the 2004A season. The SAB3 marker was run on the full set of genotypes while SAS13 was only run on the 41 genotypes from Palmira. A total of 21 selections were predicted to have the *Co-4²* gene, while 35 were predicted to have the *Co-5* gene. The segregation ration was close to expected for the SAS13 marker (1:1) while the segregation of the SAB3 marker was skewed towards presence in the Palmira selection and towards absence in the Darién selections. This may indicate that SAS13 is in a region of the genome where the allele from G2333 has a neutral phenotypic effect on selection in both environments while SAB3 is in a region of the genome where the allele from G2333 has a positive effect in Palmira but a negative effect in Darién. This would need to be confirmed in larger populations as most of the crosses presented here produced from as little as 2 to at most 25 selections (average of 8.25 selections each). Interestingly mass selection to the F_{5,6} generation was probably as effective as pedigree selection to the F_{5,6} generation for selecting marker positive genotypes. Pedigree selection fixed the genes in an early generation and recombinants were fewer.

Table 53. Climbing bean advanced lines evaluated for the *Co-4²* and *Co-5* SCAR markers in semester 2004A.

Pedigree	SAS13 Co-4 ²		SAB3 Co-5		Total no. of lines
	+	-	+	-	
Palmira					
Pedigree Selection – F _{2,3,5,6}					
G2333 x SEL1447	0	2	0	2	2
G2333 x SEL1448	6	0	6	0	6
Mass Selection – F _{5,6}					
G2333 x BRB29	1	2	2	1	3
G2333 x BRB152	2	4	1	5	6
G2333 x BRB32	4	1	4	1	5
SEL1385 x G2333	1	1	2	0	2
G2333 x SEL1447	0	3	0	3	3
G2333 x BRB197	7	7	10	4	14
Subtotal	21	20	25	16	41
Darién					
BRB183 x (G12572 x G2333)	--	--	2	21	23
BRB183 x (G12621 x G2333)	--	--	1	24	25
(BRB29 x G 2333) x G23614	--	--	1	8	9
G2333 x Q'oscoporoto	--	--	1	5	6
Kori Inti x (Kori Inti x G2333)	--	--	5	10	15
(G12623 x BRB197) x (G12621 x G2333)	--	--	0	3	3
G20393 x G2333	--	--	0	9	9
Kori Inti x G2333	--	--	0	3	3
SubTotal			10	83	93
Total	21	2	35	99	132

The markers evaluated in this study were relatively easy to use since they are dominant and in coupling to the disease resistance gene. The marker was for the most part exclusive to the resistance gene source G2333 so that no false positives are expected. Marker assisted selection was beneficial because it allowed us to select for anthracnose resistance without using pathogen inoculation and in seasons where disease pressure would have been low due to environmental conditions. Marker assisted selection has other advantages over disease inoculation in allowing the harvest of clean seed and the evaluation for other characteristics which are masked by infection.

Future work: We plan to test the fidelity of the SCAR markers tested here by confirming resistance with inoculation of Andean races in Popayán. We also plan to make additional selections in another set of simple and triple cross populations and apply markers to earlier generation selection and/or gamete selection. We will attempt to increase the efficiency of the markers by testing multiplexing strategies both at the PCR and gel loading level. Furthermore, the single-resistance gene and multiple-resistance gene stocks created here will be distributed and used for further crosses.

References:

- Awale, H.E., and J.D. Kelly. 2001. Development of SCAR markers linked to Co-4² gene in common bean. *Ann. Rept. Bean Improv. Coop.* 44:119-120.
- Vallejo, V., and J.D. Kelly. 2001. Development of a SCAR marker linked to Co-5 gene in common bean. *Ann. Rept. Bean Improv. Coop.* 44:121-122.
- Young, R.A., M. Melotto, R.O., Nodari and J.D. Kelly. 1998. Marker assisted dissection of the oligogenic anthracnose resistance in the common bean cultivar G2333. *Theor. Appl. Genet.* 96:87-94

Collaborators: MW Blair, LN Garzón, HF Buendia, (SB-2), R Chirwa (CIAT-Malawi), P. Kimani (CIAT– Kenya), G. Ligareto (Univ. Nacional – Bogota)

Progress towards achieving output milestones:

- Several stable and high yielding lines in various market classes (large red kidney, sugar, red mottled) showed to have multiple resistances to ALS and FLS at Chitedze and Bembeke in Malawi. A few others in large red kidney and sugar market types combined multiple disease resistance with tolerance to low soil fertility.
- Several advanced lines with resistance to 4 bean diseases were identified. These materials constitute an important set for use in breeding programs intended for multiple constraint improvement.
- The development of virus-resistant bean cultivars depends on the identification of sources of resistance. Bean Virology has been identifying suitable parental materials that possess resistance to the different begomoviruses that affect common bean in Latin America and elsewhere.
- Advanced lines and progenies resistant to *Pythium* root rot and others combining resistance to angular leaf spot and *Pythium* root rot were identified. They will be distributed to partners for multi-ecology evaluations and selection.
- High yielding mid-altitude climbers with *bc-3* resistance to BCMNV have been obtained.
- Markers for anthracnose resistance genes that are great utility for improving Andean beans have been adapted for use in MAS.

Activity 2.2 Developing germplasm resistant to insects

Highlights:

- Marker assisted selection of Arcelin-derived bruchid resistance was applied to advanced red mottled breeding lines and showed promise for substituting the serology-based assays presently in use for selection. These lines will be useful for Africa, the Andes and the Caribbean where *Zabrotes* weevils are prevalent in storage and cause severe losses.
- Tolerance to *Empoasca kraemerii* was confirmed in Andean bred lines.

2.2.1 Microsatellite-based marker assisted selection of Arcelin-derived bruchid resistance in Andean genotypes of common bean

Background: The Arcelin resistance gene is the most effective resistance factor for the most common storage pests of common bean, namely the Mexican bean weevil, *Zabrotes subfasciatus* (Boheman). We have tested a series of microsatellite markers that are linked to the Arcelin resistance gene and found two to be very effective at distinguishing resistant (of which there are seven variants) and susceptible alleles. Last year we tested these two markers using both miniprep and alkaline extraction derived DNA and found that miniprep DNA worked best and that Pv-ATCT001 (M68913) was the most closely linked marker. This year we improved the amplification conditions for alkaline extraction derived DNA so as to test for marker assisted selection in the field with a total of 261 genotypes segregating for Arc 1 resistance allele. The long-term objective of this work is to increase the efficiency of breeding for multiple constraint resistance and facilitate the pyramiding of bruchid resistance with other biotic and abiotic stress resistances. The conversion of the protein based selection of arcelin to a usable DNA marker obviates the need for arcelin-specific antibodies and protein electrophoresis and streamlines arcelin selection with the widespread use of other SCAR markers that we have also embarked on in our breeding program. In addition to its compatibility with other types of DNA based markers, the advantages of using the microsatellite over the time-consuming protein based selection was that it was amenable to high-throughput, rapid analysis.

Methodology:

Genetic materials and DNA extraction: A total of 261 advanced lines from two families of red mottled bush beans from the Andean bean breeding program were planted in Darién in the 2004A season. DNA was extracted by alkaline lysis from leaf disks harvested into 96 well plates that were packed on ice and processed at the CIAT marker lab. The alkaline extraction technique is a rapid, high-throughput “microprep” method based on alkaline lysis. The resulting DNA was diluted by 1:10 in sterile water before being used in PCR reactions.

Microsatellite markers: The microsatellite marker Pv-ATCT001 (M68913) was used for the marker assisted selection scheme. Microsatellite amplifications were conducted according to standard PCR protocols. Microsatellite amplifications were run at 1800 volts, 120 Watts and temperature of 45°C for one to two hours on 4% polyacrylamide gels and silver-stained with a re-circulating tank system. Alleles were identified as reported in the 2002 annual report for the parental materials used in multiple crosses to generate the advanced lines tested this year.

Results and Discussion: The microsatellite Pv-ATCT001 (M68913) presented only two alleles in susceptible materials. This was an advantage for multiplexing. In addition, the marker presented a unique allele for the parent that provided Arcelin 1 (RAZ44) so was used as a diagnostic test for this widely used allele of the Arcelin gene. This marker produced single amplification products where the resistant allele of Arcelin 1 was associated with the 190 bp band while all susceptible alleles were associated with the 195 and/or 200 bp bands. The amplification of Pv-ATCT001 with alkaline extracted DNA (Figure 30) was comparable to the previous amplifications with miniprep DNA. As marker assisted screening proceeded, improvements were made in the experimental technique resulting in successful amplification of over 96% of the genotypes using Pv-ATCT001 (only 10 null alleles were registered among the 261 tested genotypes and these were not scored).

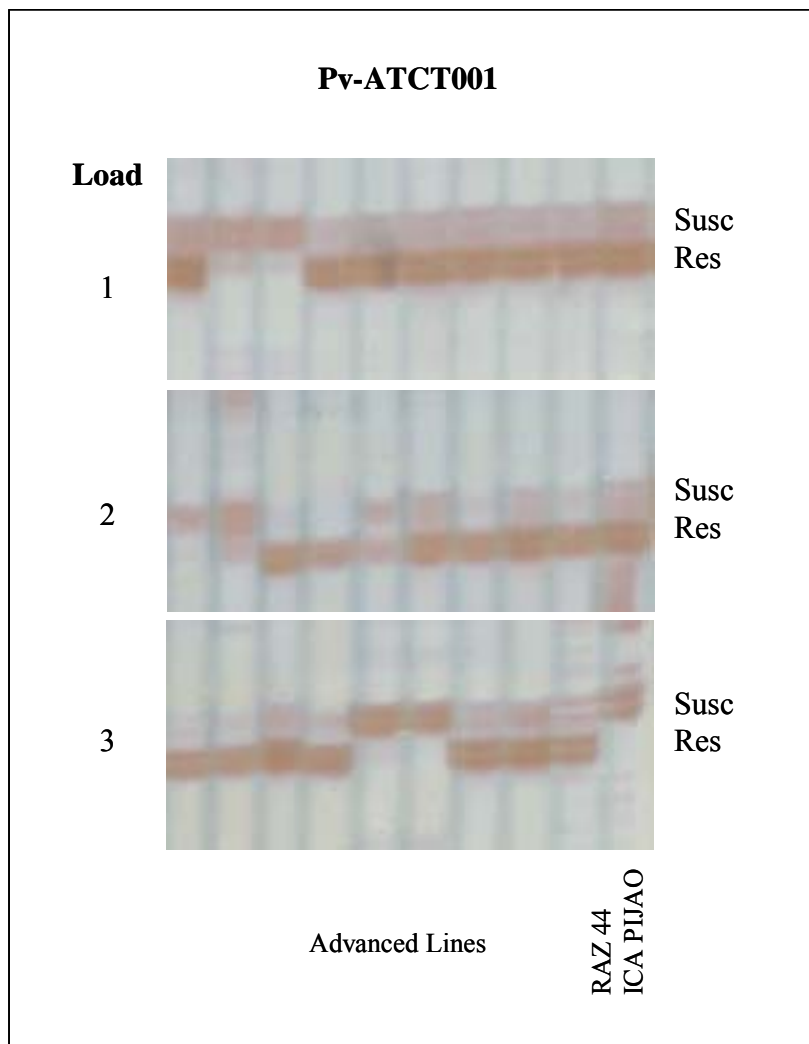


Figure 30. Examples of the marker assisted selection for the Arcelin gene in Andean red mottled bush bean lines. Control genotypes were RAZ44 (Arc1 positive) and ICA Pijao (Arc1 negative).

Marker assisted selection proved useful for screening the advanced lines derived from single plant selection in the F5 generation. Of the overall total of 261 advanced lines screened from the two cross combinations, a total of 58 positives were selected with 161 negatives and 32 heterozygotes (Table 54). In the case of the first cross A36 x (A36 x ((RAZ44 x ROYAL RED) x (CATRACHITA x WILK2))), the segregation ratio fit the expected 3:1 negative:positive ratio for the test crosses between the negative recurrent parent A36 and the positive Arcelin1 containing heterozygotes that had been selected by the Bean Entomology project in the F1 generation using the protein assay. These results show that the two assays can be combined effectively in a breeding program and the strength of the molecular assay in screening a large number of advanced lines.

Table 54. Results of microsatellite screening for the Arcelin resistance gene in two families of Andean red mottled bush bean lines.

Crosses	Positive	Negative	n. a.	Het	Overall
A36 x (A36 x ((RAZ44 x ROYAL RED) x (CATRACHITA x WILK2)))	42	161	10	32	245
A483 x ((MAR1 x RAZ50) x (PVA9576-34-1 x G 17340))	16	0	0	0	16
Grand Total	58	161	10	32	261

While it appeared that all the lines derived from the cross A483 x ((MAR1 x RAZ50) x (PVA9576-34-1 x G 17340)) were fixed, a substantial number of the lines derived from the cross A36 x (A36 x ((RAZ44 x ROYAL RED) x (CATRACHITA x WILK2))) were scored as heterozygous. The larger than expected number of heterozygotes may be a misinterpretation of a faint amplification product for the upper band (Figure 30). We will confirm whether these genotypes continue to segregate or whether the marker assay is sensitive to DNA quality or mixtures.

Future work:

- Improve the efficiency of the screening technique, adapting additional arcelin linked microsatellites to the alkaline extraction technique.
- Determine the level of linkage disequilibrium between the markers and the arcelin locus in breeding populations.
- Use the markers to select for greater recombination around the arcelin locus and break the linkage drag associated with this locus that has a negative affect on plant vigor of arcelin-derived lines.

Collaborators: M.W Blair, H.F. Buendia (SB-2) C. Cardona (IP-1)

2.2.2 Developing Andean lines tolerant to Empoasca

For details of breeding activities, please refer to section 2.2.1. As in 2003, studies were aimed at developing Andean type bean with improved tolerance to the leafhopper, *Empoasca kraemeri*. We will highlight results of the work trying to develop Andean type beans (crosses with PVA 773 and CAL 143) with improved tolerance to the leafhopper, *Empoasca kraemeri*. Lines selected for lower damage scores and higher reproductive adaptation scores in previous years performed relatively well under moderate levels of leafhopper infestation (4.3 nymphs per leaf, seasonal average) (Figure 31). Given that susceptibility to leafhopper is usually very high in large-seeded Andean beans, these results indicate that substantial progress has been made in incorporating resistance to leafhopper in these types of beans. Another set of lines derived from crosses between Saladin and selected EMP lines did not perform so well (Figure 32), possibly due to the inherent susceptibility of Pompadour-type beans. Nevertheless, eight lines that showed moderate tolerance were selected for further testing.

Contributors: J. M. Bueno, C. Cardona, M. Blair.

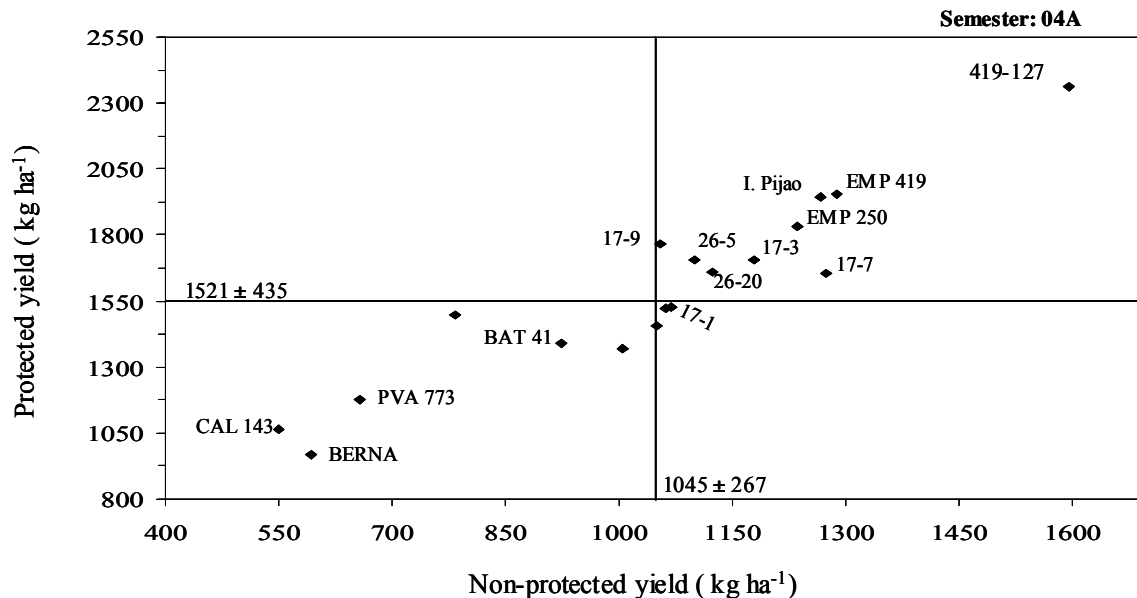


Figure 31. The relationship between protected and non-protected yield in selected Andean bean lines bred for tolerance to *Empoasca kraemeri*. PVA 773 and CAL 143 are susceptible parents. EMP 250 is the tolerant parent. BAT 41 and Pijao are susceptible and tolerant checks, respectively

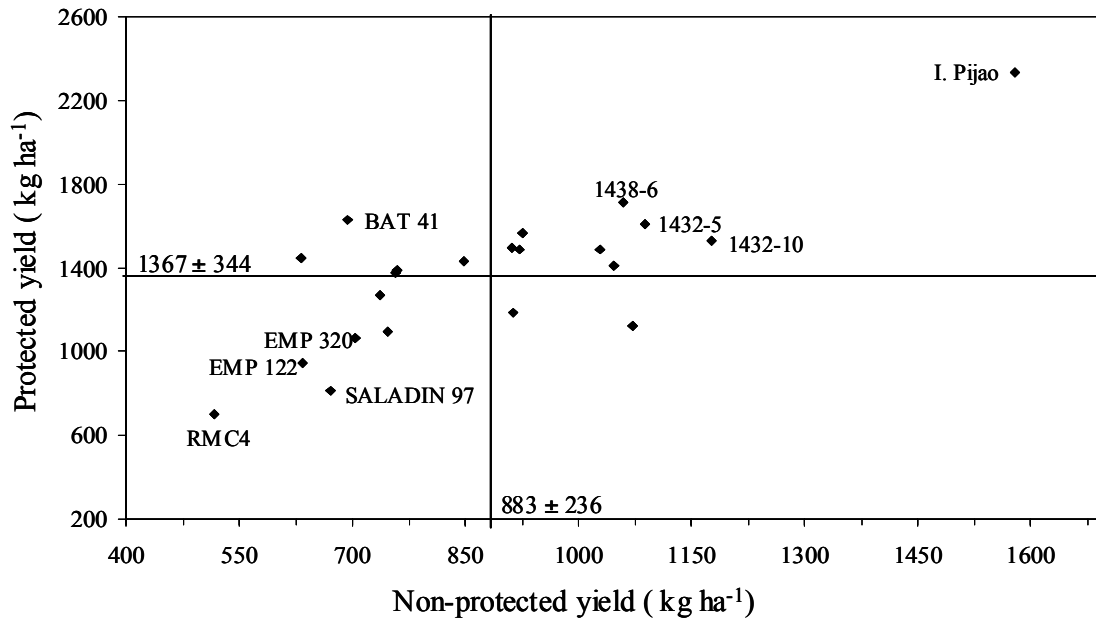


Figure 32. The relationship between protected and non-protected yield in selected Andean bean lines bred for tolerance to *Empoasca kraemeri*. Saladin 97 is a commercial variety in Dominican Republic.

Progress towards achieving output milestones:

- MAS for arcelin will permit integrating selection for bruchid resistance into other selection protocols for disease resistance genes, obviating the need for either antibody-based selection or protein analysis.
- Substantial progress has been made in incorporating resistance to leafhopper in Andean type beans.

Activity 2.3 Incorporating wider genetic diversity into beans

Highlights:

- Selections were made for low phosphorus tolerance in red and cream mottled Andean bush beans. Additionally, Colombian released varieties were compared for low phosphorus tolerance and yield index under low vs. high phosphorus conditions.

2.3.1 Improving Andean beans for tolerance to drought

Rationale: Andean beans are often planted in relatively more favorable environments compared to Mesoamerican beans, but in any case farmers are subject to variability in rainfall. Regions where Andean beans are preferred such as southern Africa are afflicted by frequent droughts. In previous years CIAT executed a project to improve Andean common bean for Iran, and the national program requested crosses for drought tolerance. In this report we present yield data of advanced lines derived from those crosses.

Materials and Methods: A small number of Andean genotypes (ICA Quimbaya, AND 125) had presented a relative degree of drought tolerance in previous years and were chosen as parents. Additionally, Durango type beans of the Mesoamerican gene pool (Pinto Villa, flor de junio Victoria) were identified for crossing. These have medium size seed and a type 3 growth habit that is similar to that used in Iran. These were crossed to Iranian cultivars including Talash, Khomein and CIAT line COS 16 which has *I* gene resistance to BCMV. Double crosses were selected over several years and lines were created from individual plant selections in F₃. Sixteen advanced lines were tested under the same conditions as described for the Mesoamerican germplasm in Output 1, activity 1.1.1.1. Checks in this trial included DOR 390, SEA 5, SEA 15, and ICA Quimbaya which is considered to be the best Andean genotype to date under drought stress in CIAT conditions.

Results and Discussion: The three best lines were all derived from the same cross, (Pinto Villa x Quimbaya) x (Talash x COS 16). Although the best line produced 22% more than Quimbaya, no line outyielded the Andean check Quimbaya by a statistically significant margin (Table 55). However, given the lack of genetic variability in Andean types, these lines should be studied further to determine if indeed they have an advantage. Several are segregating and may have genetic variability within families that can still be exploited.

Conclusion: Efforts to improving drought tolerance in Andean types have been very modest and progress slow. However, the present families may have a narrow advantage over available sources and will be purified for future evaluation.

Table 55. Andean lines with cream striped, cream or pink grain color derived from crosses for tolerance to drought.

Cross / Line	Yield as % checks ¹	Yield check
(Pinto Villa x Quimbaya) x (Talash x COS 16)		
SX 14337-MC-1C-MC	122	1057
SX 14337-MC-19C-MC	121	1057
SX 14337-MC-9C-MC	112	1057
(Flor de junio Victoria x CAL 125) x (Local de Khomein x COS 16)		
SX 14331-MC-20C-MC	111	1057
SX 14331-MC-22C-MC	103	1057
SX 14331-MC-35C-MC	102	1057

¹ Yields of lines were calculated as per cent of the yield of commercial check Quimbaya.

Contributors: S. Beebe, H. Terán, and M.A. Grajales

2.3.2 Inheritance of seed darkening / non-oxidizing seed coat trait in Andean bayo beans

Rationale: Seed coat darkening is thought to be due to oxidation of polyphenolics in the seed coat of common bean and affects consumer preference in common bean varieties especially those with cream-colored backgrounds, including both Mesoamerican types such as Pintos and Cariocas as well as Andean types such as Sugars and Cranberries (Cream Mottled classes). Oxidation is especially important in Bayo beans, found both among the Mesoamerican and Andean gene pools, and produced predominantly in Mexico and Peru. Among other Andeans, yellow beans especially Canarias, seem less affected by the problem, while in red beans darkening is masked by the already intense coloration of the grain. The seed coat of white beans does not generally darken. The objective of this study was to study the inheritance of seed coat darkening in a cross of two Peruvian Bayo varieties that were identified by INIA to differ in their rate of seed coat darkening.

Materials and Methods: The Peruvian cream seeded variety ‘Bayo Mochica’ (BM) with non-oxidizing seed coat character, was crossed with a similar Peruvian genotype, ‘Bayo Florida’ (BF) which does oxidize. Crosses were made in reciprocal directions. F₂ seed was harvested from individual F₁ plants to ensure that the cross was effective. F₂ plants were harvested individually and advanced by single seed descent until the F_{4.5} generation. A total of 116 recombinant inbred lines (RILs) were developed from the BM x BF cross and 128 RILs from the reciprocal cross of BF x BM. Seed Darkening was evaluated by storing the F_{3.4} seed for three months at room temperature and comparing to freshly harvested seed of the F_{4.5} generation. A 1 to 5 color scale was used where 1 = non-oxidized, cream colored seed coat and 5 = very oxidized, brownish seed coat.

Results and Discussion: The inheritance of seed darkening appears to be quantitative as shown by the population distributions for BM x BF and BF x BM (Figure 33). However, the possibility of a major gene influencing the trait is suggested by the more binomial distribution of the BM x BF population. There were few overall differences between the reciprocal populations suggesting that maternal inheritance is not important for this trait.

Conclusions and Future Plans: We plan to use the recombinant inbred lines in QTL analysis of the trait if funding is available. This will also await the results of a parental survey to identify the level of genetic polymorphism between the parents of the cross. Once the inheritance of seed darkening is known in this cross it may be interesting to apply the results to other cream-colored seed classes.

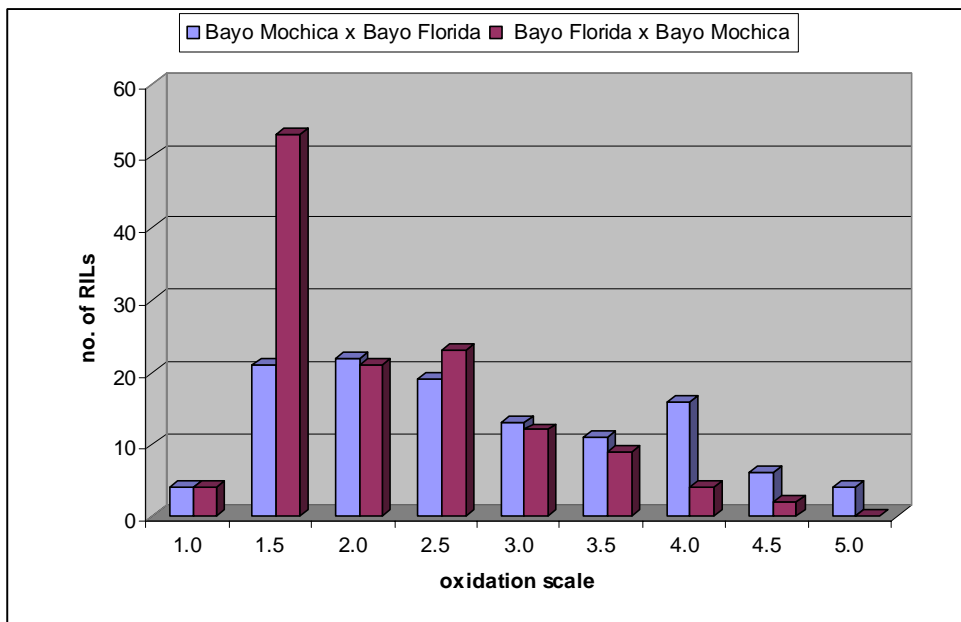


Figure 33. Recombinant inbred line (RIL) population distributions for seed darkening in two crosses of Peruvian Bayo beans.

Collaborators: M.W. Blair, A. Hincapie (IP-1), A. Valladolid (PROMPEX-Promenestras-Peru),

2.3.3 Yield testing of low phosphorus tolerant Andean bush beans

Rationale: Eighty-two percent of the soils in Latin America are deficient in phosphorus. Phosphorus deficiency is widespread in East Africa as well, possibly affecting over 50% of soils there. Studies at CIAT have identified several sources of tolerance to low phosphorus conditions. These genotypes can take up or use phosphorus more efficiently. Good tolerance to P-deficient environments has been observed in a liborino type, yellow-and-red seeded landrace from Peru, G19833, that is a parent of the CIAT mapping population (Blair et al., 2003). The mechanism of phosphorus deficiency tolerance in this genotype is thought to be better phosphorus use efficiency through root hair exudation and other potential mechanisms (Liao et al., 2004). In the breeding programs at CIAT, one of our long-term objectives is to increase the capacity of new breeding lines to grow under low P conditions. In this research we analyzed advanced lines that were selected from crosses between G19833 and BCMV resistance sources from the BRB series.

Materials and Methods: A large number of advanced lines were developed from crosses between G19833 and four BRB lines (BRB156, BRB183, BRB211 and BRB217). Two trials were planted in Darien (Valle) during the rainy season in semester 2003B under low phosphorus (fertilization of 50 kg ha⁻¹ TSP (7.5 kg P₂O₅)) conditions, one for red mottled selection and one for cream mottled selections, with totals of 112 and 93 genotypes, respectively. Each trial consisted in a randomized complete block with three replicates. Double row plots were 3 m long and were separated by a constant susceptible check genotype, DOR390, spaced between every plot. Additional controls within the trials were the breeding line checks BRB156, BRB183, BRB211, BRB217 and CAL149 for the red mottled trial and BRB211, BRB217 and SUG47 for the cream mottled trial. The genotypes, G4017 (low P tolerant Mesoamerican), G14665 (low P tolerant Andean) and G19833 (Parent 1) were also included as checks in each experiment.

Results and Discussion: Table 56 shows the top 20 lines selected for each experiment. The range in production was from 575 kg ha⁻¹ and 645 kg ha⁻¹ to close to 1000 kg ha⁻¹ in the case of both experiments. The highest yielding line was 1036.7 kg ha⁻¹ in the case of the cream mottled lines and 941.7 kg ha⁻¹ in the case of the red mottled lines, significantly outyielding all the Andean checks including the parent G19833 in both experiments. Among the checks, the Mesoamerican genotype, G4017 was the most tolerant to the low P conditions, yielding an average of 1265 kg ha⁻¹ across the two experiments. In the cream mottled lines SUG47 was the second highest yielding check, while CAL149 was the second highest yielding check among the red mottled lines. G19833 was the third highest yielding among the checks in the cream mottled lines but ranked lower among the checks of the red mottled line experiment. The average yield across both experiments for G19833 was 440 kg ha⁻¹.

These results indicate that breeding for low P tolerance in Andean beans is possible. Surprising results can occur with some evidence for transgressive segregation in the breeding process as shown by the higher yield of the progeny compared to the parents under low P conditions.

Table 56. Yield testing of low phosphorus tolerant Andean bush beans in Darién in semester 2003B.

Cream mottled					Red Mottled				
Entry no.	pedigree	DF	g pl ⁻¹	yield	Entry no.	pedigree	DF	g pl ⁻¹	yield
2	G19833 X BRB211	43.5	4.5	1036.7	12	G19833 X BRB211	43.5	5.5	941.7
78	G19833 X BRB156	41.0	4.3	946.3	94	G19833 X BRB156	38.5	4.7	905.0
9	G19833 X BRB211	43.5	5.6	822.7	78	G19833 X BRB183	44.5	4.8	814.0
13	G19833 X BRB211	41.5	4.1	813.7	18	G19833 X BRB211	44.0	3.7	795.0
93	G19833 X BRB183	43.5	4.4	811.3	4	G19833 X BRB211	40.0	3.9	780.3
11	G19833 X BRB211	44.5	5.3	803.7	3	G19833 X BRB211	40.5	3.4	714.0
58	G19833 X BRB217	41.5	3.7	767.0	106	G19833 X BRB156	37.0	4.1	705.0
4	G19833 X BRB211	38.5	3.9	759.7	77	G19833 X BRB183	44.0	4.0	669.7
60	G19833 X BRB217	42.0	4.3	731.0	17	G19833 X BRB211	44.5	4.5	668.0
39	G19833 X BRB217	39.5	3.1	720.3	8	G19833 X BRB211	41.5	5.3	663.3
3	G19833 X BRB211	41.0	3.5	715.0	10	G19833 X BRB211	43.5	3.1	660.3
61	G19833 X BRB217	42.5	3.1	693.3	101	G19833 X BRB156	38.5	3.9	653.0
23	G19833 X BRB211	45.0	3.9	691.3	75	G19833 X BRB183	44.0	3.0	616.0
81	G19833 X BRB156	41.5	3.1	689.0	1	G19833 X BRB211	40.0	3.3	598.3
1	G19833 X BRB211	41.5	3.7	680.0	112	G19833 X BRB156	44.5	2.9	593.0
17	G19833 X BRB211	41.0	3.3	669.7	9	G19833 X BRB211	43.5	3.3	583.7
24	G19833 X BRB211	43.0	2.9	665.0	15	G19833 X BRB211	44.0	2.7	577.7
15	G19833 X BRB211	39.5	3.9	660.7	16	G19833 X BRB211	44.0	2.6	576.3
62	G19833 X BRB183	44.5	4.1	654.7	30	G19833 X BRB217	37.5	2.9	576.3
71	G19833 X BRB183	41.5	3.8	645.0	90	G19833 X BRB156	41.0	2.9	575.0
97	G4017	45.0	8.3	1216.0	120	G4017	44.5	7.4	1314.3
99	SUG47	36.0	3.7	757.0	119	CAL149	44.0	6.0	1058.3
98	G19833	45.5	2.5	466.7	118	G14665	41.5	3.1	582.3
95	BRB211	38.0	2.5	394.7	116	BRB183	44.0	3.2	455.0
96	BRB217	36.0	2.1	351.3	117	G19833	44.5	2.4	412.7
100	G14665	42.0	1.9	339.7	115	BRB217	36.0	1.6	268.7
94	BRB156	34.5	1.4	316.7	114	BRB211	38.0	1.7	233.7
					113	BRB156	37.0	1.0	145.3
	LSD	3.7	3.2	316.9		LSD	2.3	1.8	350.7
	CV	4.5	55.6	32.4		CV	2.9	40.9	44.5

Future Plans: The lines developed in this project will be tested for anthracnose resistance and adaptation under low P soils in Popayán before being prepared for nurseries. The lines would be of interest in Eastern and Southern Africa given the high market value seed types: large red mottleds and sugars.

Collaborators: MW Blair, A. Hoyos

2.3.4 Yield testing of a collection of Colombian varieties under low and high phosphorus treatments

Background: Bean breeding in Colombia has produced a wide range of large-seeded Andean varieties for many different agroecological zones. The country is home to a wide range of traditional farmer varieties and landraces. The objective of this research was to test a representative number of improved and traditional Colombian varieties under low and high phosphorus treatments to get a more precise idea of their range of adaptation. This study was also used as a test case for biomass evaluations by kite aerial photography in collaboration with the Land Use/GIS unit.

Materials and Methods: A total of 40 bush bean genotypes were tested in a replicated yield trial in Darien in semesters 2003B and 2004A under two fertilization treatments: low phosphorus 50 kg ha⁻¹ TSP (10 kg P) and high phosphorus 350 kg ha⁻¹ TSP (70 kg P). Native soil P is 2 to 10 mg kg⁻¹. Experimental design consisted in three replications in randomized complete block with plots separated by DOR390 as check rows. Data is presented only from the 2004A semester trial since the 2003B semester trial was lost due to root rots that are a secondary problem of low phosphorus sites during very wet growing periods. During 2004A, Darién was a favorable site for all the genotypes given its location at 1500 masl and average temperature of 19°C and annual rainfall of 1,200 mm (500 during the cropping season). The genotypes included 22 large-seeded red mottled (Calima) or red (Radical) varieties released by ICA or CORPOICA over the past 30 years (DIACOL and ICA series), 11 landraces from Berruecos, Darién, Sevilla and Tenerife (Valle) as well as Ocaña and Zaragoza (N. Santander) and seven CIAT lines as controls (A36, AFR188, AFR612, AFR619, AFR735, AND279 and CAL96).

Results and Discussion:

The range in yields for the varieties went from a low of 309 kg ha⁻¹ to a high of 1781 kg ha⁻¹ in the low phosphorus treatment and from a low of 580 kg ha⁻¹ to a high of 3164 kg ha⁻¹ in the high phosphorus treatment (Table 57). The same variety was the lowest yielding in these two environments, namely the type I genotype DIACOL Nutibara, a variety poorly adapted given its origin in colder climates. The highest yielding variety in the high phosphorus treatment was the type II breeding line AFR619, while the highest yielding variety in the low phosphorus treatment was the type III landrace Palisero (Berruecos) which was also the second highest yielding in high phosphorus. As a result Palisero had a relatively high lowP/high P yield index (59.9%) which was similar to several of the landrace genotypes, including Blanquillo (73.8%), Morado Moteado (62.1%), Sangretoro (64.3% and 72.0%). The average index for the landraces (55.7%) was higher than for the improved released varieties (50.8%) showing that landraces tend to be better for low fertility conditions and pointing out a deficiency of some of the released varieties, except for ICA Tundama, a cold climate variety with a high yield index (72.0%) and reasonable yields under low P (1032 kg ha⁻¹) and high P (1433 kg ha⁻¹).

Table 57. Yield trial of Colombian released varieties and landraces in Darién, Valle in semester 2004A.

Entry no.	Ident	Low P				High P				LP/HP index
		DF	DM	g.pl	yield	DF	DM	g.pl	yield	
1	ICA Guali	36.0	81.3	3.6	774.8	36.3	79.7	6.1	1377.6	56.24
2	DIACOL Calima	38.3	78.7	2.2	515.9	37.0	81.3	5.2	1204.6	42.83
3	ICA Palmar. INIA 17	42.0	83.7	3.0	666.2	43.3	86.7	7.3	1502.3	44.34
4	DIACOL Nutibara	39.0	75.7	1.4	309.3	39.7	71.7	2.4	580.1	53.32
5	ICA Duva	37.3	84.3	3.5	802.5	37.3	82.0	8.5	1913.3	41.94
6	Sangretoro	42.3	84.7	3.7	885.2	39.7	79.0	6.6	1377.5	64.26
7	DIACOL Nima	41.7	86.7	3.6	759.0	40.3	85.0	8.3	1694.3	44.80
8	ICA Tone	38.3	80.3	2.4	450.0	38.7	77.3	4.4	943.8	47.68
9	ICA Cuna	39.7	82.0	2.4	585.3	38.3	82.3	5.5	1201.3	48.73
10	ICA Tundama	48.0	90.0	5.0	1032.4	48.0	90.0	9.1	1433.2	72.03
11	DIACOL Catio	42.7	85.7	2.6	592.9	40.3	85.3	7.9	1480.4	40.05
12	Frijolica P-1.1	43.0	87.0	3.5	849.0	41.3	79.3	3.9	852.4	99.60
13	AFR 619	45.7	92.3	5.5	1315.1	42.0	85.3	16.0	3164.4	41.56
14	ICA L-59 ARS-59	42.7	87.3	4.5	966.1	40.0	88.7	8.5	1821.5	53.04
15	ICA Bachue	35.7	82.0	3.1	675.4	38.0	80.7	5.6	1220.3	55.35
16	ICA Cerinza	42.7	84.7	2.2	560.6	39.3	78.0	6.2	1244.9	45.03
17	Radical Cerinza	36.7	83.7	3.6	816.2	37.3	84.0	8.2	1805.4	45.21
18	ICA Citara	35.7	79.3	3.3	798.1	36.3	82.7	6.8	1524.8	52.34
19	AND 279	40.3	86.0	5.7	1080.6	39.7	84.0	10.2	1741.9	62.04
20	ICA L-66	37.0	77.3	2.1	421.0	37.0	81.3	6.8	1529.1	27.53
21	ICA Caucaya	44.0	87.3	4.6	988.3	41.3	82.0	8.6	1720.5	57.44
22	ICA Cafetero	41.7	84.0	2.4	525.0	40.3	83.0	6.0	1365.7	38.44
23	ICA Quimbaya	38.0	84.0	2.5	577.7	37.0	83.3	5.9	1395.2	41.40
24	Chocho (Tenerife)	39.7	78.7	2.7	572.1	38.0	74.3	5.4	1211.6	47.22
25	ICA Guanenta	37.3	76.7	3.0	706.6	37.3	80.0	5.7	1280.3	55.19
26	Radical Froylan	39.7	85.0	2.7	633.7	38.5	88.0	8.6	1901.1	33.33
27	Cargabello (Darién)	41.0	80.0	2.7	663.6	40.0	80.7	6.4	1405.1	47.22
28	Rosado Zaragoza	35.7	75.0	2.7	558.5	36.0	74.3	3.9	923.1	60.50
29	Rosado Ocana	35.3	75.0	1.5	370.9	35.3	76.0	3.8	867.3	42.77
30	Radical (Restrepo)	40.3	85.3	5.0	1072.8	39.7	83.7	8.1	1927.0	55.67
31	Morado (Restrepo)	38.3	82.0	4.5	1082.3	37.3	82.3	7.2	1741.8	62.14
32	Sangretoro (Berruecos)	45.7	92.7	7.4	1658.4	43.0	90.3	11.2	2303.1	72.01
33	Palisero (Berruecos)	45.3	93.0	7.7	1781.6	44.7	92.3	13.8	2976.9	59.85
34	Blanquillo (Berruecos)	49.0	90.0	6.0	1466.2	48.3	90.0	10.8	1986.1	73.82
35	Mina (Berruecos)	38.3	83.3	3.4	773.5	37.5	80.0	12.3	2816.6	27.46
36	CAL 96	39.3	80.7	3.2	706.5	37.3	80.7	7.2	1490.1	47.41
37	AFR 188	40.3	91.3	6.1	1422.0	38.3	85.0	7.8	1660.4	85.64
38	AFR 735	37.7	82.7	5.3	1277.8	37.0	86.7	12.6	2302.5	55.50
39	A 36	47.0	95.0	4.1	850.0	46.0	90.0	9.4	2001.1	42.48
40	AFR 612	43.7	89.3	4.7	1147.0	41.3	90.0	13.8	2545.9	45.05
LSD		2.2	2.8	2.0	413.4	2.3	2.1	2.6	546.8	
CV		3.3	2.1	29.1	29.9	3.5	5.6	20.2	20.6	

The more recently-developed breeding lines tended to do better than the released varieties and had an average yield index of 54.2%. Two notable breeding lines in this respect were AFR188 (yield index of 85.6%) and AND279 (62.4%). As mentioned earlier, AFR619 was an interesting genotype due to its high responsiveness to P fertilization in the high P treatment but its yield index was relatively low (41.6%). Overall, the average yield of the breeding lines (2129.5 kg ha⁻¹) exceeded that of the landraces (1776.0 kg ha⁻¹) and the improved varieties (1446.3 kg ha⁻¹) under high P treatment. The same pattern was seen for breeding lines (1114.1 kg ha⁻¹), landraces (989.5 kg ha⁻¹) and released varieties (712.7 kg ha⁻¹) under low P treatment. The differences between groups may be due to the fact that the landraces included long season, small seeded higher yielding indeterminate genotypes while the released varieties included some with more specific agro-ecological adaptation, especially those from colder climates. This was evident when comparing the days to flowering and maturity differences between the two groups (Table 57). Meanwhile the breeding lines included genotypes that were locally selected at the experimental site which might explain their greater adaptation. All together, the results are interesting in pointing out the yield stability of traditional landraces, the site-specificity of some of the released varieties and the improvements made in low P adaptation in breeding lines when compared to released varieties. Darién was a good environment to test the genotypes because most genotypes were well adapted there and the native low P soils were uniform and easy to manage for both the low P and high P treatments. Many of the landraces adapted quite well even though they were from very different environments originally. This might reflect a wider stability of some landraces over some of the improved germplasm. Apart from yield, the effect of low P treatment was notable in delaying flowering and days to maturity by an average of 1.8 and 2.2 days respectively overall and in some cases by as much as 3.7 days for flowering date and 7.7 days for maturity date. Interestingly this occurred most notably in some but not all of the varieties with better performance under low P stress (eg. AFR188, AFR619 and Sangretoro) suggesting that delayed phenology may be a mechanism for low P stress tolerance in Andean beans, although significant correlations were observed between many of the traits.

Conclusions and Future Work: We plan to test the same genotypes in Popayán for adaptation to biotic and abiotic stresses. Collaborators at CORPOICA have planted the same genotype in Rionegro, Antioquia so we will compare data from that location. We have also analyzed the nutritional quality in terms of micronutrients possessed by these varieties when grown in Palmira, Darién, as well as by FIDAR in Nariño as part of our biofortification work. In collaboration with the land use project of CIAT we have used this experiment for low altitude photographic comparisons of biomass accumulation, data for which will analyze in the coming months. In collaboration with CORPOICA, FIDAR and GIS we would like to make a compendium of information about these varieties that could be useful for producers, consumers and plant breeders.

Collaborators: MW Blair, A. Hoyos (IP-1), T. Oberthur, V Gonzales and H.Usma (Land Use Project).

Progress towards achieving output milestones:

- Initial studies on abiotic stress resistance in Andean types suggests that significant genetic variability exists that should be exploited, and that recent bred selections may have a slight advantage over earlier released varieties.

Activity 2.4 Developing more nutritious large seeded bean varieties

Highlights:

- The high iron NUA (Andean nutrition) breeding lines developed last year are being tested in on-farm trials with an NGO in Nariño and Valle departments, Colombia. Mineral analysis has confirmed the high iron status of four sister lines that are all well-adapted red mottled derivatives of CAL96. Low iron sister lines have also been identified and are also well adapted. Notably, one of the high iron sister lines, NUA56, has average iron content of 93 mg kg⁻¹ across three sites and up to 112 mg kg⁻¹ in one site, one of the highest seed iron values found to date. Additional Andean red seeded high iron varieties have been identified. From this analysis we have identified potential genotypes to include in nutrition nurseries and hybridizations.
- At CIAT, we are analyzing genotype x environment interaction in trials with recombinant inbred lines and finding good correlations across sites for iron content.
- Mineral analysis is also being used to identify the highest iron content in Cerinza-derived red and red mottled advanced breeding lines (BIF series) and among all Colombian released varieties.
- A crossing block for nutritional improvement of bush and climbing beans from Africa and Latin America has generated a total of 120 combinations using high iron landraces and the breeding lines being developed above.
- QTL mapping of nutritional traits has become an important way to increase our understanding of how to breed common bean for better mineral content as part of the HarvestPlus Challenge Program. We are using a mix of traditional breeding, biochemistry, genetics and genomics to dissect nutritional quality traits.
- We are also studying the inheritance of soluble and insoluble tannins, which are implicated as anti-nutrients in mineral absorption. We have conducted a QTL analysis of five segregating populations of common bean. We have also analyzed a population for the seed darkening/non-oxidizing seed coat trait.
- Collaboration between CIAT and USDA-Houston is centering on a basic mechanism for mineral uptake in legumes using common bean as a model for the tropical legumes, namely iron reductase. Initial results suggest a relationship between a QTL for seed iron and one for iron reductase.

2.4.1 Multi-location testing of high iron NUA (Andean-nutrition) lines in Nariño

Introduction: Iron deficiency anemia and other micronutrient deficiencies affect large number of people worldwide and in Colombia. Legumes are a good source of iron and other essential micronutrients that are found only in low amounts in the cereals or root crops. Unlike many cereals that are polished before eating, resulting in significant loss of nutrients, beans and other grain legumes are usually consumed whole, thus conserving their nutritional content. An ongoing project, has shown that bean seeds are variable in the amount of minerals (iron, zinc and other elements), vitamins and sulfur amino acids that they contain and that these traits are likely

to be inherited quantitatively. We have started a breeding program to introgress the high iron trait into new red mottled breeding lines using the high iron climbing bean genotype G14519. A single backcross to the recurrent parents CAL 96 and CAL 143 was used to develop BC₁F₁ families that were selected amongst and within to develop BC₁F₃ and BC₁F₄ derived breeding lines that were high in seed iron accumulation. In this study we tested the best of these new NUA (Andean nutrition) lines in three locations in southern Colombia in on farm trials in collaboration with farmers and a local non-governmental organization.

Materials and Methods: A total of seven advanced NUA breeding lines selected for high and low iron content were tested at three sites in the Department of Nariño during the 2003B season. The high iron selections were NUA 30, NUA 35, NUA 45 and NUA 56, while the low iron selections were NUA 4, NUA 43 and NUA 50. The check varieties included four large, red mottled genotypes: AFR612, CAL96, CAL143 and Diacol Calima; and four large, red-seeded genotypes: Chocho, Quimbaya, Sangretoro and Radical Cerinza. The total number of genotypes in the experiment was 15. Three replicated trials were conducted in the municipalities of Consacá, Sandoná and Yacuanquer all at elevations between 1500 and 2000 masl, where the genotypes were evaluated for growth habit, resistance to diseases (anthracnose, ascochyta, web blight, rust and powdery mildew were prevalent) and consumer acceptability during the 2003B season. All experiments consisted in randomized complete block designs with three replicates each. Seed mineral content was evaluated at CIAT by grinding 4 g of grain from each separately harvested replicate plot into a fine powder using a modified Retsch mill with aluminum chambers and grinding balls and analyzing the resulting powder with a wet digestion method and atomic absorption spectrophotometry in the Analytical Services Laboratory of CIAT for both iron and zinc concentration measured in mg kg⁻¹.

Results and Discussion: In the analysis of variance, significant differences were observed between locations and varieties for iron, however for zinc content variety effects were significant but location effects were not (Table 58). In addition, variety x location effects were less significant for iron (P<0.05) than for zinc (P<0.0001). This may have to do with soil status for zinc as reflected in Table 59 for Consacá which were lower than those for Yacuanquer and Sandoná (data not shown). Replication x Location effects were not significant for iron but were significant for zinc, therefore field replication was still useful especially for the more variable factor, zinc. Coefficients of variation were low for the complete experiment (5.6% for iron and 4.5% for zinc).

Table 58. Analysis of variance for iron and zinc concentration in 15 varieties tested over three locations (Consacá, Sandoná and Yacuanquer) in the department of Nariño, Colombia in 2003B.

Source	DF	SS	MS	F	P
Iron Analysis					
LOC	2	4663.5	2331.77	132.04	0.0000
TRAT	14	9035.6	645.40	36.55	0.0000
LOC*REP	3	19.3	6.45	0.36	0.7786
LOC*TRAT	28	1060.1	37.86	2.14	0.0123
Error	42	741.7	17.66		
Total	89	15520.3			
Zinc Analysis					
LOC	2	1.89	0.9467	0.46	0.6327
TRAT	14	1354.65	96.7604	47.30	0.0000
LOC*REP	3	31.67	10.5576	5.16	0.0040
LOC*TRAT	28	340.39	12.1569	5.94	0.0000
Error	42	85.92	2.0458		
Total	89	1814.53			

Table 59. Analysis of soils from Consacá in the department of Nariño, Colombia in 2003B.

Sample No.	Site	N-Total (mg/kg)	P-BrayII (mg/kg)	K (cmol/kg)	B (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	pH (Un)
S-151-1	Consacá	4614.76	8.77	1.15	0.96	6.12	2.17	5.26
2		3003.72	4.13	0.53	0.82	7.01	1.95	5.49
3		2731.86	2.48	0.28	0.41	12.17	1.51	5.38
4		2779.25	4.93	1.08	0.79	11.65	1.86	5.51

For the variety contrasts, the highest iron lines were the advanced breeding lines from CIAT in all three environments and on average (Table 60). NUA 56, NUA 45 and NUA 35 were notable in having average iron contents close to 90 mg kg⁻¹ and one location, Yacuanquer presented iron contents above 100 mg kg⁻¹. These values surpassed those of all of the agronomic check varieties including Quimbaya and Chocho, two red seeded genotypes that were relatively high in iron in the previous experiment (Section I). Zinc concentrations were correlated with iron concentration. Notably, Quimbaya was at the higher end of the range of zinc content. Among the three locations, average iron content was higher in Yacuanquer (85 mg kg⁻¹) than Sandona (71 mg kg⁻¹) or Consaca (69 mg kg⁻¹). In contrast average zinc content was similar in all three environments (average 32 mg kg⁻¹).

Table 60. Mean seed iron and zinc concentration in mg kg⁻¹ of 15 bean varieties among and within three locations in Nariño (Consaca, Sandoná and Yacuanquer) in 2003B.

YACUANQUER				SANDONA			
	Iron		Zinc		Iron		Zinc
NUA 56	112	NUA 56	43	NUA 35	83	NUA 56	36
NUA 45	102	AFR 612	41	NUA 56	82	Radical Cerinza	36
NUA 35	102	Quimbaya	38	NUA 45	79	Quimbaya	35
Chocho	91	Chocho	36	NUA 30	77	NUA 45	35
Quimbaya	90	NUA 45	35	Chocho	74	Chocho	35
Radical Cerinza	90	Radical Cerinza	34	Quimbaya	74	NUA 35	33
AFR 612	86	NUA 35	33	Radical Cerinza	74	NUA 30	33
NUA 50	85	NUA 30	32	CAL 143	73	AFR 612	32
NUA 4	80	NUA 50	27	AFR 612	70	Diacol Calima	32
NUA 30	79	CAL 143	27	NUA 50	69	Sangretoro	29
CAL 143	77	Diacol Calima	27	NUA 4	69	CAL 143	29
CAL 96	75	Sangretoro	27	CAL 96	65	NUA 4	29
Diacol Calima	75	NUA 43	26	Diacol Calima	65	NUA 43	28
Sangretoro	67	CAL 96	24	NUA 43	53	NUA 50	28
NUA 43	65	NUA 4	23	Sangretoro	52	CAL 96	27
CONSACA				MEAN			
	Iron		Zinc		Iron		Zinc
NUA 56	86	Quimbaya	38	NUA 56	93	NUA 56	38
NUA 45	84	Radical Cerinza	36	NUA 35	89	Quimbaya	37
NUA 35	81	NUA 45	36	NUA 45	88	NUA 45	36
Quimbaya	79	NUA 56	35	Quimbaya	81	Radical Cerinza	35
NUA 4	73	Chocho	33	Radical Cerinza	77	AFR 612	35
Radical Cerinza	70	NUA 35	32	Chocho	76	Chocho	34
NUA 30	68	AFR 612	32	Sangretoro	75	NUA 35	33
AFR 612	67	Diacol Calima	32	NUA 30	75	NUA 30	32
Diacol Calima	66	NUA 30	32	AFR 612	75	Diacol Calima	30
CAL 143	66	NUA 4	31	NUA 4	74	Sangretoro	28
NUA 50	66	NUA 50	29	NUA 50	73	NUA 50	28
CAL 96	65	Sangretoro	29	CAL 143	72	NUA 4	28
Chocho	64	CAL 96	28	Diacol Calima	69	NUA 43	27
NUA 43	53	CAL 143	27	CAL 96	69	CAL 143	27
Sangretoro	51	NUA 43	9	NUA 43	57	CAL 96	27

Future Plans and Conclusions: The genotypes described here will be analyzed for mineral content by ICP (Inductive coupling plasma) analysis to validate the results obtained with the wet digestion method. We will be comparing these genotypes to other advanced lines from the Andean breeding as they are produced and have introduced them as parents into crosses with other Andean genotypes with favorable agronomic characteristics.

Collaborators: M.W. Blair, C. Astudillo, S. Beebe (IP1 Project, CIAT), J. Restrepo, P. Ojeda, LC Bravo (FIDAR), O. Mosquera (CIAT – Analytical Services)

2.4.2 Genotype x Environment studies of mineral accumulation in advanced lines and released varieties from Colombia

Introduction: We are continuing to evaluate advanced lines and released varieties for their mineral content. One group of genotypes derived from Cerinza are of special interest given that this Colombian variety has favorable commercial characteristics and average iron content between 75 and 80 mg kg⁻¹. Given variability between sites detected in previous studies we are replicating these trials at two to three locations each. To date a total of two trials were prepared:

- 1) A total of 64 advanced lines (from the BIF series) were selected from an advanced backcross CAL 96 x (RAD-CERINZA x (G 24390 x RAD-CERINZA)) breeding population with a high iron parent (Radical Cerinza) in the hope of obtaining a higher iron segregant with red or red mottled seed type derived from the Andean ALS-resistant line CAL96. Of these 26 were large-seeded red lines and 37 were large seeded red mottled lines. The full set of genotypes was tested for agronomic adaptation in Nariño during the 2004A growing season. The trial was prepared for two locations as a randomized complete block design with 3 repetitions each and 4 row plots.
- 2) A total of 39 Colombian varieties were prepared as a nursery for one site in Nariño (Consacá) and for one site in Valle (Darién). The experiments were designed as randomized complete block design with three replicates of four-row plots for each genotype. These genotypes represent all the bush bean varieties released by ICA and CORPOICA over the past thirty years along with standard check varieties and a few standard landraces. The majority of the varieties are red mottled 'Calima' or 'Nima' classes followed by large reds 'Radicales' or 'Duva' types.

Methodology: Atomic absorption mass spectrophotometry was practiced to obtain information on mineral content. The lines from trial I had average amounts of iron and zinc (Figure 34) except for two lines which surpassed 70 mg kg⁻¹ (no. 8, a red seeded line and no. 61, a red mottled line). The iron and zinc content of the trial II genotypes is being evaluated.

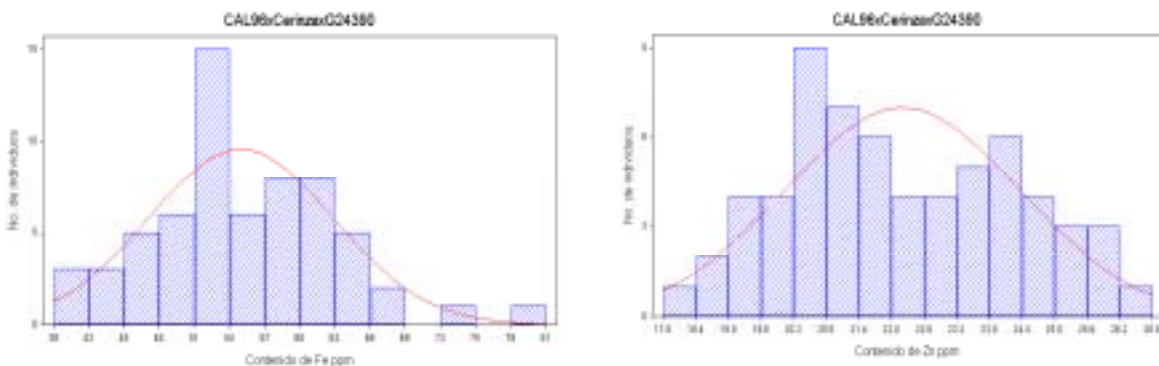


Figure 34. Distribution of iron and zinc content in advanced BIF lines derived from advanced backcross breeding with the moderate iron parent, Radical Cerinza.

Collaborators: M.W. Blair, A. Hoyos, C. Astudillo (IP-1), O. Mosquera (Analytical Services), J. Restrepo, D. Villada, P. Ojeda, LC Bravo (FIDAR).

2.4.3 Hybridizations of Andean genotypes for high micronutrient content

Introduction: As part of the HarvestPlus Challenge program we are developing new populations of Andean bush and climbing beans using three proven sources of high iron and high zinc genes: G14159 (Mesoamerican genotype from the USA with brown-colored high protein seed and average iron content of over 80 mg kg⁻¹); G21242 (Andean genotype from Colombia with cream mottled seed and average iron content close to 90 mg kg⁻¹); G23824E (Andean genotype from Peru with average iron content of 100 mg kg⁻¹).

Methodology: A total of 84 and 36 simple crosses were made for bush and climbing beans, respectively, using the 3 high iron landraces (G14519, G21242 and G23823E), 2 high iron backcross inbred lines (BID29 and BID115) as well as 13 selections from large-red high iron populations (SEL1457 to 1469) that were crossed to 12 Andean bush bean (AFR298, AFR612, CAL143, CAL144, CAL96, Canadian Wonder, Dore Kirundo, Kablanketi, PVA773, Radical Cerinza, Radical San Gil and SUG131) and 6 Andean climbing bean (AND497, Bolivar, CAB19, Caballero, Cargamanto and ICA Viboral) varieties from Africa and Latin America as recurrent parents (Table 61).

Table 61. Simple crosses made in the 2004A season for nutritional quality in Andean beans.

1) Bush beans		
AFR298 x G23823E	Dore Kirundo x G23823E	BID 29 x CAL144
AFR298 x BID 29	G23823E x Kablanketi	BID 29 x G23823E
AFR298 x BID115	Kablanketi x G23823E	BID 29 x Kablanketi
AFR612 x G23823E	PVA773 x BID 29	BID 29 x PVA773
AFR612 x BID 29	PVA773 x G23823E	BID 29 x SUG131
AFR612 x BID115	Radical Cerinza x G23823E	BID115 x AFR298
CAL143 x G23823E	Radical Cerinza x BID115	BID115 x Canadian Wonder
CAL144 x G23823E	Radical San Gil x G23823E	BID115 x G23823E
CAL144 x BID 29	Radical San Gil x BID115	BID115 x Kablanketi
CAL96 x G23823E	SUG131 x G23823E	BID115 x PVA773
Canadian Wonder x G23823E	SUG131 x BID115	BID115 x Radical San Gil
Canadian Wonder x BID115	BID 29 x AFR298	BID115 x SUG131
2) Climbing beans		
AFR298 x G14519	G14519 x SEL1461	G23823E x G14519
AFR298 x G21242	G14519 x SEL1462	G23823E x ICA Viboral
AFR612 x G14519	G14519 x SEL1463	G23823E x SEL1457
AFR612 x G21242	G14519 x SEL1464	G23823E x SEL1458
AND497 x G14519	G14519 x SEL1469	G23823E x SEL1460
AND497 x G23823E	G14519 x SEL1467	G23823E x surco 6517
Bolivar x G14519	G14519 x SEL1468	G23823E x SEL1462
CAB19 x G23823E	G21078 x G23823E	G23823E x SEL1464
CAL144 x G14519	G2124 x SEL1463	G23823E x SEL1469
CAL144 x G21242	G21242 x AND497	G23823E x SEL1465
Canadian Wonder x G14519	G21242 x Bolivar	G23823E x SEL1466
Dore Kirundo x G21242	G21242 x CAB19	G23823E x SEL1467
G12242 x SEL1458	G21242 x Caballero	G23823E x SEL1468

Table 61. cont'd

G14519 x AND497	G21242 x G23823E	G23823E x SEL1461
G14519 x CAB19	G21242 x SEL1457	G4825 x G23823E
G14519 x Caballero	G21242 x SEL1458	ICA Viboral x G21242
G14519 x Canadian Wonder	G21242 x SEL1460	Kablanketi x G14519
G14519 x Cargamanto	G21242 x SEL1461	Kablanketi x G21242
G14519 x Dore Kirundo	G21242 x SEL1462	PVA773 x G14519
G14519 x ICA Viboral	G21242 x SEL1464	PVA773 x G21242
G14519 x Kablanketi	G21242 x SEL1465	Radical Cerinza x G14519
G14519 x SUG131	G21242 x SEL1466	Radical Cerinza x G21242
G14519 x SUG31	G21242 x SEL1466	Radical San Gil x G14519
G14519 x BID 29	G21242 x SEL1467	Radical San Gil x G21242
G14519 x BID115	G21242 x SEL1468	SUG131 x G14519
G14519 x SEL1457	G23823E x Bolivar	SUG131 x G21242
G14519 x SEL1458	G23823E x Caballero	BID 29 x G2124
G14519 x SEL1460	G23823E x Cargamanto	SEL1463 x G23823E

Of these, several are released varieties in their respective countries: CAL144 in Bolivia; AFR298 (ICA Quimbaya), AFR612 (unofficial release – widely adopted), Cargamanto, ICA Viboral, Radical Cerinza and Radical San Gil in Colombia; Dore Kirundo in Congo; SUG131 and CAL143 in Malawi; Caballero in Peru; AND497 and CAB19 in Rwanda; Canadian Wonder and Kablanketi in Tanzania; and CAL96 in Uganda (K132). Three standard types for improvement among the red mottled bush bean are CAL96, CAL143 and PVA773 which has been released in Bolivia (Rojo Oriental), Colombia (as ICA Caucaya), Ecuador (INIAP Yunguilla) and Mozambique.

Results and Discussion: F₁ seed has been obtained and selection of populations is pending.

Future Work:

All three high iron genotypes are indeterminate climbing or semi-climbing beans therefore for those crosses with bush bean parents we are planning to backcross the F₁ plants so as to be assured of good bush bean architecture in the segregants. For the climbing bean crosses we plan to make selections within simple crosses and backcrosses. We will also plan to make a range of double and triple cross populations for the climbing beans. For bush beans, we plan to involve a larger number of Andean genotypes from Eastern and Southern Africa as well as from Latin America.

Collaborators: MW Blair, A. Hincapie (SB-2), P. Kimani, R. Chirwa, S. Beebe (IP-1)

2.4.4 Analysis of iron reductase as a mechanism for enhanced iron uptake and mineral seed content in common beans: QTL analysis and candidate gene cloning

Background: Nutritional genomics is being used as part of the HarvestPlus Challenge Program to discover the basic mechanisms for mineral uptake and accumulation. As part of this program CIAT is collaborating with the Grusak lab at the USDA-Baylor College of Medicine to determine the genes in common beans that determine iron uptake and utilization. As part of the overall genomics approach, information from other well studied species such *Medicago truncatula*, peas and soybeans, as well as other model species such as *Arabidopsis thaliana* that have extensive genetic and molecular resources are being used for gene discovery and functional analysis. The underlying concepts of this work are to take advantage of metabolic unity among plants to characterize gene function and to apply bioinformatics and molecular cloning approaches to identify potential orthologous genes. As a first example of this approach the Grusak lab is trying to dissect the importance of iron reductase in the accumulation of iron in beans by assaying iron reductase activity in roots and by cloning an ortholog of the gene from common bean based on similarity to the same gene already isolated from *Medicago truncatula* and from *Pisum sativum*. Iron reductase is a member of the protein superfamily of flavocytochromes and functions to convert iron from an unavailable form (ferric, Fe^{3+}) to an available form (ferrous, Fe^{2+}) that can be readily absorbed by plants. The iron reductase protein (FRO) is located in roots and straddles the root cell membrane where it is active for iron reduction. The gene for iron reductase was first isolated from *Arabidopsis* and *Pisum* (Pea). Both species are fairly efficient at extracting iron from the soil and serve as models for enzyme activity. Other candidate genes include a family of zinc transporters.

Methodology:

Plant Material: The experiments have been carried out on two populations of recombinant inbred lines that are being used to genetically map seed micronutrient content QTL: DOR364 x G19833 and G21242 x G21078. The first population is from an Andean x Mesoamerican inter-gene pool cross and the second is from an Andean x Andean intra-gene pool cross.

Mineral Analysis: Seed mineral accumulation data has been obtained for both populations using atomic absorption (AA) spectrophotometry at CIAT and/or inductive coupling plasma (ICP) analysis at the University of Adelaide in Australia. Samples consisted in ground whole bean seeds that were processed in a Retsch Mill in the case of the AA samples and in a coffee grinder in the case of the ICP samples.

Library screening: the Grusak lab selected conserved primers for RT-PCR based on the *Pisum* iron reductase gene (PsFRO1) and used them to amplify common bean reductase candidates which were then used to screen filters from a leaf cDNA library made in the CUGI-CIAT collaboration.

Reductase Assay: In the Grusak lab, seeds are germinated for 3-4 days then planted in a hydroponic system for 12 days of growth in various levels of iron concentration (eg. 2, 5, 10 and 20 μM Fe). Iron reductase assay is conducted at the end of this period by removing the entire root systems of four plants and staining for reduced iron measured as $\mu\text{mol Fe reduced g FW}^{-1} \text{ hr}^{-1}$.

Results and Discussion:

Phenotyping: The distribution of iron content in seeds of the DOR364 x G19833 population RILs is shown in Figure 35. Iron content ranged from 39 to 84 mg kg⁻¹ and zinc content ranged from 17 to 37 mg kg⁻¹. Correlations between iron and zinc were significant ($r=0.612$). Results of the G21242 x G21078 screening are described separately in this annual report.

Library Screening: The Grusak lab has been screening a common bean leaf cDNA library which we made at CIAT and has found partial sequences with homology to iron reductase using the Medicago reductase clone and sequences with similarity to Aquaporins using the Zinc transporter family. They will begin next year to screen a set of two leaf cDNA libraries, where the mRNAs for iron reductase and zinc transporters are more likely to be expressed.

Reductase assays: The iron reductase assay is producing interesting differences between the parents of both mapping populations for their ability to reduce iron at two different iron regimes. These differences are evident more at low Fe concentration than at high iron concentration and seem to be somewhat correlated with the seed iron status of the parents.

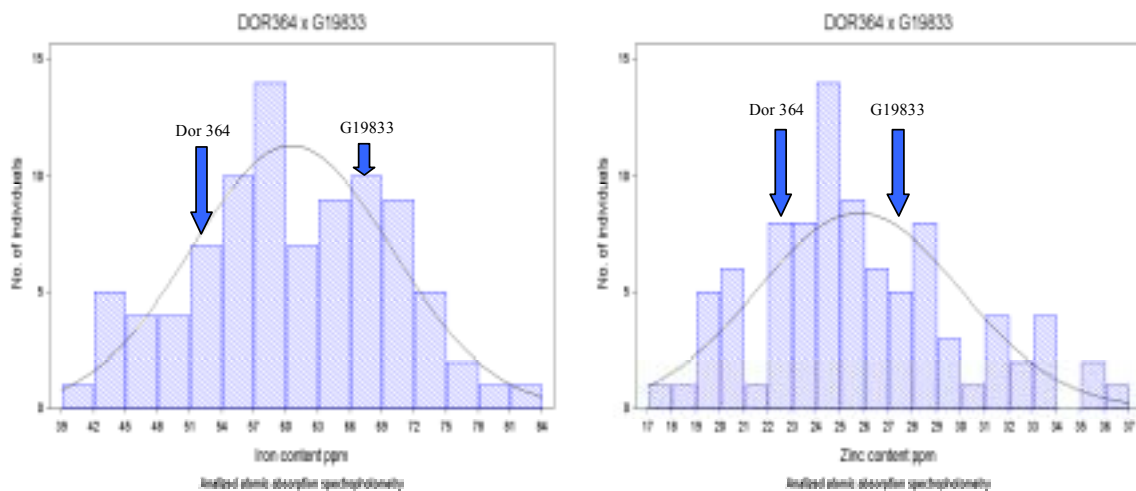


Figure 35. Distribution of seed iron and zinc content among RILs of the DOR364 x G19833 population as determined by atomic absorption spectrophotometry.

The bimodal nature of the population distribution for DOR364 x G19833 recombinant inbred lines (Figure 36) suggests that inheritance of iron reductase activity may be due to one or a few genes. QTL analysis confirms that there is one major QTL under iron sufficiency and this QTL is different from the one under iron deficiency. Therefore it can be postulated that iron reductase is represented by several differentially expressed genes, whereby: one iron reductase gene is expressed in iron deficiency (1 μM) and is found on Chromosome b02; another iron reductase gene is expressed in iron sufficiency (15 μM) and is found on Chromosome b11.

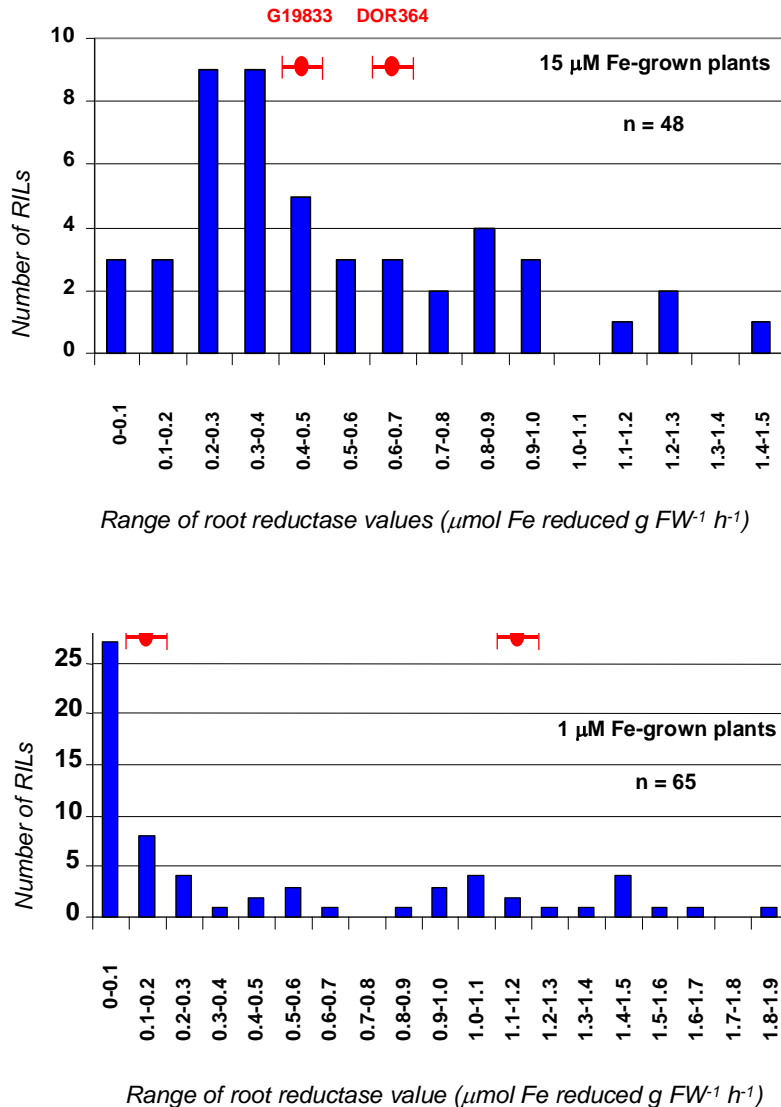


Figure 36. Distribution of iron reductase values among RILs of the DOR364 x G19833 population.

To understand the relationship of iron reductase to seed iron accumulation we analyzed the ICP results that we had obtained on seed of the recombinant inbred lines in a preliminary QTL analysis and identified two QTLs controlling seed iron accumulation in this population – one very important QTL on Chromosome b11 and another important QTL on Chromosome b08.

Although the correlation of iron reductase activity with seed iron accumulation was not significant in this populations at either 1 uM ($r=0.044$) or at 15 uM (-0.163), it was interesting to see that the iron reductase activity QTL on chromosome 11 was located in the same place as the seed iron content QTL. This did not hold true for the other seed iron QTL on chromosome 8.

Future Steps:

- Evaluate Fe reductase activity in a greater number of parents of other populations and a range of Fe concentrations for each parent.
- Perform QTL analysis with the G21242 x G21078 population and an improved genetic map that we have constructed.
- Identify any other potential QTL for iron accumulation and for Fe reductase activity at other genomic locations based on other populations.
- Develop a DNA marker for Fe reductase activity either based on QTL mapping or cloning and mapping of orthologs of the Fe reductase gene.

Collaborators: M.W. Blair, C. Astudillo (SB-2), M Grusak, CM Li, SJB Knewton (USDA-Baylor College of Medicine), T. Fowles, R Graham (Univ. Adelaide), S. Beebe (IP-1), J. Tohme (Harvest Plus CP).

2.4.5 Field evaluation of an Andean population developed to study seed mineral accumulation

Rationale: Legumes provide essential micronutrients that are found only in low amounts in the cereals or root crops. An ongoing project has shown that bean seeds are variable in the amount of minerals (iron, zinc and other elements), vitamins and sulfur amino acids that they contain and that these traits are likely to be inherited quantitatively. The objective of our most recent studies has been to tag some of the quantitative trait loci (QTLs) controlling seed mineral content in several recombinant inbred line (RIL) populations of common bean. In this study we analyzed the results of a single RIL population derived from an Andean x Andean cross between G21242, a Colombian cream mottled climbing bean with ‘C’ Phaseolin and G21078, an Argentinean cream seeded climbing bean with ‘T’ Phaseolin, that was grown in multiple locations and in a replicated trial.

Methodology:

Plant materials: The population was analyzed over two seasons, Popayán 1998B and Darién 2003A with a total of 100 RILs planted in Popayán and a subset of 83 of the same RILs planted in Darién. A lattice design was used for the first trial (with 3 repetitions) and a randomized complete block design was used for the second trial (with 2 repetitions). Both experiments were planted with trellis supports since the population is predominantly made up of climbing bean genotypes and agronomic management consisted in recommended practices. In both seasons, plots were bulk harvested and grain was combined across repetitions before sub-sampling for mineral analysis.

Mineral Analysis: Two methods of mineral analysis were implemented. The harvest from Popayán was analyzed first with Inductive Coupling Plasma (ICP) analysis at the University of Adelaide and second with Atomic Absorption (AA) Spectrophotometry at the CIAT analytical services lab. The harvest from Darién was only analyzed with the second technique. Sample preparation for the ICP technique involved grinding 10 g of seed in a coffee mill, while for the AA technique 5 g of seed was ground in aluminum chambers using a Retsch mill and aluminum grinding balls. Replicate sampling with two repetitions each was done for the AA mineral analysis but not for the ICP analysis due to cost considerations. As the ICP analysis was presented in the 2002 Annual report, here we concentrate on the results of the AA analysis.

Results and Discussion: Iron and zinc content in the RILs presented a continuous distribution, suggesting that mineral content behaved as a quantitative trait (Figure 37). Iron content ranged from 27.3 to 96.2 mg kg⁻¹ (average 55.3 mg kg⁻¹) in Darién, and from 22.5 to 91.3 mg kg⁻¹ (average 49.2 mg kg⁻¹) in Popayán. Zinc content ranged from 14.5 to 37.7 mg kg⁻¹ (average 26.5 mg kg⁻¹) in Darién and from 21.0 to 59.6 mg kg⁻¹ (average 31.4 mg kg⁻¹) in Popayán.

The parents of the population were significantly different and tended to be on the edges of the population distribution (Figure 37). G21242, the high mineral parent, was always higher in mineral content than G21078, the low mineral parent. In the case of iron concentration, G21078 tended to have values similar to the means of the population while G21242 was closer to the upper extreme of the population distribution, while in the case of zinc concentration the parents were more intermediate but still contrasting. Given this, transgressive segregation for low iron and for both high and low zinc was evident in the population.

Previous results with ICP analysis showed a similar trend for the population distribution as with AA spectrophotometry. However G21078 had been lower in iron concentration in the ICP analysis (36.6 mg kg⁻¹) than in the AA analysis, even though G21242 had been similar (89.3 mg kg⁻¹). For zinc, ICP values were higher than those found with AA (49 mg kg⁻¹ for G21242 and 28.5 mg kg⁻¹ for G21078) but the population distribution was similar. AA spectro-photometry provided a savings in reagent costs and required smaller amounts of ground samples so was the preferred method. Reliability of the AA spectrophotometric method was high with coefficients of variation averaging 6.8% for iron and 5.6% for zinc in the analysis of variance conducted for each location.

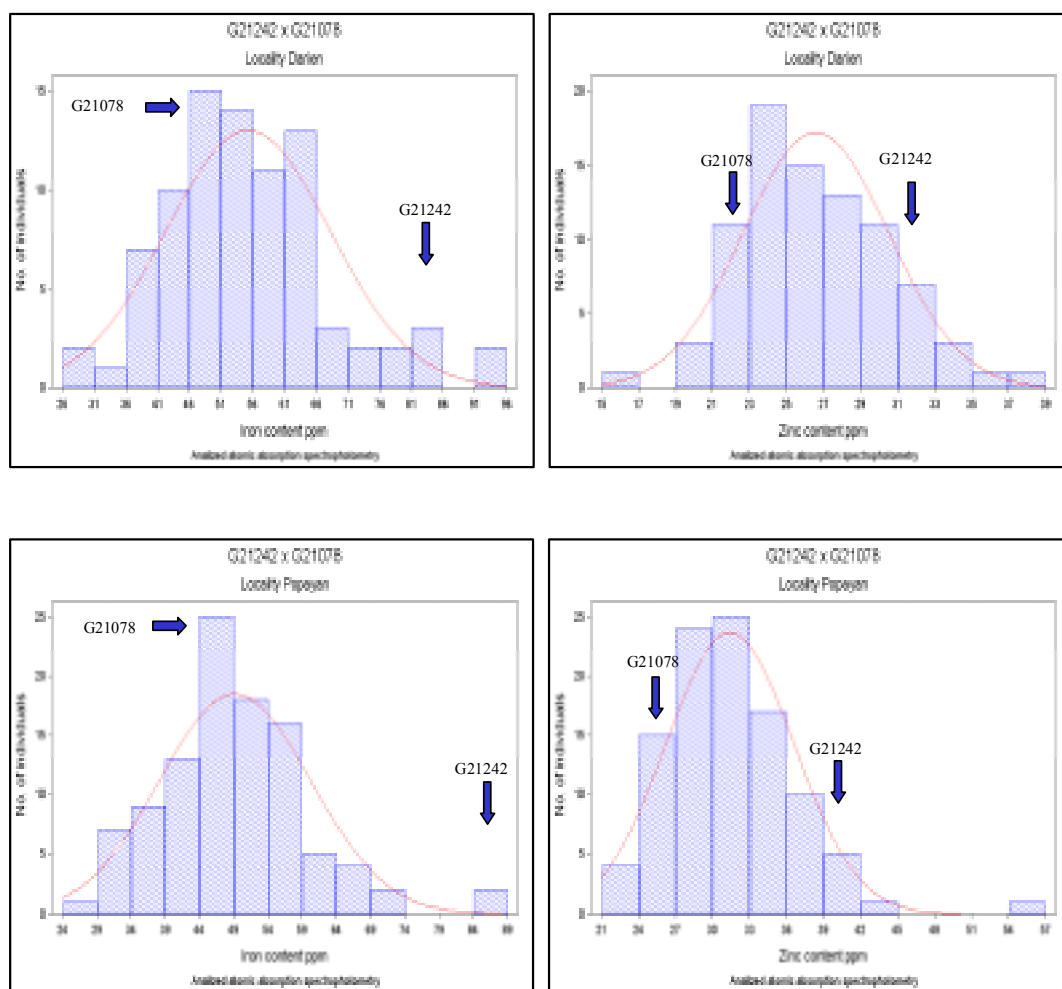


Figure 37. Population distribution for seed iron and zinc content in Andean recombinant inbred lines from the cross of G21242 x G21078 tested over two locations in Darién and Popayán, Colombia.

Genotype x environment interaction was measured for the AA results for seed iron and zinc content in a combined analysis over the two locations, Darién and Popayán (Table 62). Location, treatment and location x treatment effects were all significant at $P=0.0000$ level, showing that $G \times E$ was important for both minerals, confirming the difference in the distribution and parent means seen in the histograms. It was notable that location effects were stronger for zinc than for iron however location x treatment effects were similar for the two minerals. Despite the significant $G \times E$ effects, highly significant correlations were also observed between locations for both iron ($r=0.665$ and $r=0.715$) and for zinc content ($r=0.439$ and $r=0.450$) irregardless of the mineral detection method. Indeed, correlations were even higher between the AA and ICP results for both iron ($r=0.849$) and zinc ($r=0.860$) for the harvest from Popayán

(Table 63). Correlations were also high between iron and zinc concentration in both Darién ($r=0.301$) and Popayán ($r=0.653$ for AA and $r=0.651$ for ICP).

Table 62. Analysis of variance for seed iron and zinc content in the G21242 x G21078 population tested over two locations (Popayán 1998b and Darien 2003a).

Source	DF	SS	MS	F	P
Iron Analysis					
LOC	1	2213.7	2213.66	202.45	0.0000
TRT	77	39118.1	508.03	46.46	0.0000
LOC*TRT	77	7621	98	9.05	0.0000
Error	154	1683.9	10.93		
Total	311	51091			
Zinc Analysis					
LOC	1	2128.61	2128.61	798.32	0.0000
TRT	77	4637.78	60.23	22.59	0.0000
LOC*TRT	77	1757.97	22.83	8.56	0.0000
Error	154	410.62	2.67		
Total	311	8935.09			

Table 63. Correlations between locations and mineral detection methods for seed iron and seed zinc content and between minerals within each location and method in an Andean recombinant inbred line population grown in Darién and Popayán and analyzed with Inductive coupling plasma (ICP) and atomic absorption spectrophotometry (AA).

Location	Mineral detection method	Iron vs. Iron			Zinc vs. Zinc			Iron vs. zinc
		1	2	3	1	2	3	
1. DARIEN	AA	1.0			1.0			0.301
2. POPAYAN	AA	0.665	1.0		0.439	1.0		0.653
3. POPAYAN	ICP	0.715	0.849	1.0	0.450	0.860	1.0	0.651

Future Plans:

- Complete the QTL analysis with this population and a more complete genetic map for the G21242 x G21078 RILs.
- Determine correlations with other minerals analyzed in the ICP study, which include Mn, Ca, Mg, K, P and S, and with iron reductase activity.
- Compare agronomic response, heritability and QTLs across populations.
- Characterize the population for other nutrition related traits including, tannin content and sulfur containing amino acids (SAA).

Collaborators: M.W. Blair, C. Astudillo (SB-2), S. Beebe (IP-1)

2.4.6 Evaluation of five common bean mapping populations for tannin content

Rationale: Part of the effort to increase the nutritional quality of common bean has concentrated on increasing iron bioavailability, where bioavailability is the proportion of the consumed nutrient that is digested, absorbed and utilized by human beings. Bioavailability is determined by both food composition and the nutrient status of the consumer as well as a mix of promoters (such as sulfur amino acids: methionine and cysteine, vitamin A or C) and anti-nutritional factors (including fiber, lectins, phytates, polyphenolics and tannins, as well as Calcium and Manganese). Among the anti-nutrients, tannins are important because of their ability to interact with proteins and to chelate minerals which results in reductions in protein digestibility and mineral bioavailability. Tannins are derived from phenolic compounds and contribute to the coloring found in the seed coats of common beans (*P. vulgaris*) and their relatives. They can be divided into hydrolyzable / soluble tannins (derived from Gallic acid) and condensed tannins / proanthocyanidins (derived from polymerized flavonoids), which are measurable by different techniques. Some of the tannin fractions and flavonoid precursors have been suggested to have a positive effect on health through anti-oxidant activity. Therefore it is important to have a greater understanding about the inheritance of total tannin content and its component fractions. Given this we began a program to identify genetic variability for condensed tannins in seed coats of common bean mapping populations. In the previous year we reported the results of this analysis in the DOR364 x G19833 population and in this study we applied the extraction techniques developed over the last two years to the analysis of four additional populations of recombinant inbred lines. Our ultimate objective is to identify the QTLs associated with tannin accumulation in common bean.

Materials and Methods:

Plant Material: A total of 500 lines from five populations (averaging 100 RILs each) were analyzed in this study. The populations represented both inter-gene pool crosses (DOR364 x G19833, G19839 x G2333, BAT93 x JALOEPP558) and intra-gene pool crosses (Andean G21242 x G21078 and Mesoamerican G14519 x G4825). Each population was grown at a single location and seed was freshly harvested for analysis.

Seed Coat preparation: Seed coats were peeled from common bean seed and ground into a fine powder to use in the analysis. An n-heptane treatment was used facilitate seed peeling which consisted in 12 hours immersion in n-heptane after which the seed was dried and peeled by hand. Different amounts of ground seed coat were used for the parents (15 g) than for the individual recombinant inbred lines (10 mg). This was done to obtain enough purified tannin from the parents to construct the concentration calibration curves used in the analysis of the progeny. Three replicates were used per seed coat sample for the analysis.

Tannin Extraction: Total condensed tannin extraction and analysis of soluble and insoluble condensed tannins were as reported last year. Colorimetric tannin analysis was realized with a Butanol-HCl method which allows total condensed tannins to be measured. A butanol-water (5%) mix was used as a blank.

Tannin Purification and Establishment of the Calibration Curve: Seed coat of the parents of each population was extracted for tannins and purified with Sephadex LH-20. A dilution series of different tannin concentrations was evaluated in the colorimetric assay described above. The calibration curve was then established by plotting average absorbance against tannin concentration for the two parents of each population.

Results and Discussion: Condensed tannins were successfully purified from the parents of each population to use for the determination of the calibration curves for absorbance vs. concentration and to use in estimating the amount of tannins in the progeny. When the progeny and parents were evaluated, a range of seed coat tannin concentrations (expressed in percent) were observed for the four populations (Figure 38). Tannin measurements were consistent between repetitions showing that the Butanol-HCl method used for analysis is technically sound.

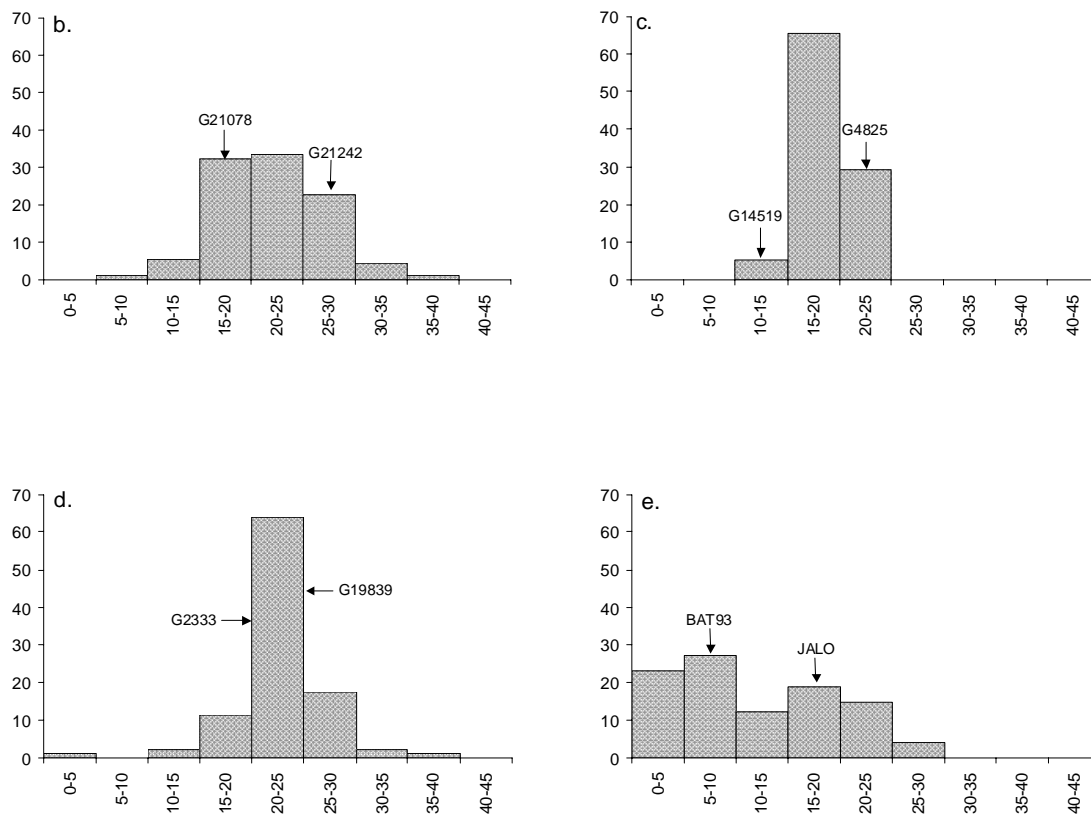


Figure 38. Population distribution for total condensed tannins (as percentage of total tannins) in four populations of common bean: a. G21242 x G21078, b. G14519 x G4825, c. G2333 x G19839, d. BAT93 x JALO EEP558. The Y-axis is the per cent of individuals in each phenotypic class.

Average soluble, insoluble and total condensed tannins were found to vary significantly between populations (Table 64). The DOR364 x G19833 population had the highest soluble condensed tannins and since soluble condensed tannins make up the bulk of total condensed tannins this population was also highest in this category. G2333 x G19839 and G21242 x G21078 has lower amongst of soluble tannin but had the highest amounts of insoluble tannins. The other two populations, especially BAT93 x Jalo EEP558 were low in both soluble and insoluble condensed tannins. The normal distribution found in total condensed tannin concentration, and both soluble and insoluble condensed tannins, in most of the populations suggests that the traits are inherited quantitatively (Figure 38). However given that the BAT93 x Jalo population was distributed binomially, there is the possibility that inheritance of tannin content is more qualitative. Correlations between the amount of soluble and insoluble tannins (Table 65) was low in the intra-gene pool populations but was significant for the inter-gene pool populations (ranging from $r=0.20$ to $r=0.55$). This may indicate that the inheritance of soluble and insoluble tannin content is independent in the first set of populations but linked in the other populations.

Table 64. Average condensed tannin content in five populations of common bean recombinant inbred lines.

Population ¹	Soluble	Insoluble	Total
DOR364 x G19833	26.45 A ⁽²⁾	2.88 B	29.38 A
G2333 x G19839	19.31 B	3.41 A	22.74 B
G21242 x G21078	18.34 B	3.52 A	21.88 B
G14519 x G4825	15.88 C	2.98 B	18.88 C
BAT93 x JALO	9.49 D	2.36 C	11.87 D

¹ Population differences significant at $P<1\%$; ² Means separation by Ryan Einot Gabriel Welch test

Table 65. Correlation between soluble and insoluble condensed tannin content and total tannin content for each of five recombinant inbred line populations.

Population	Correlation		
	Ins vs. Sol	Ins. vs Tot	Sol vs. Tot
DOR364 x G19833	0.20	0.39	0.98
G21242 x G21078	0.05	0.21	0.99
G14519 x G4825	-0.04	0.18	0.97
G2333 x G19839	0.44	0.58	0.99
BAT93 x JALO	0.55	0.69	0.99

The search for QTLs in the DOR364 x G19833 population identified two QTLs for total tannin content on linkage groups b03 and b10 (Figure 39). The QTL on linkage group b10 was also associated with QTLs for both traits independently while the QTL on linkage group b03 was only significant for total tannin content. These QTLs map to the same locations as the seed coat color genes “Z” (b03) and “J” (b10) on the classical genetic map of common beans showing an association between seed color and tannin content which will be investigated further.

Conclusions and future plans: We plan to complete the QTL analysis with the additional populations to determine the genes involved in tannin content in common bean seed coats and use this information to devise a strategy for reducing specific fractions of tannins with the hope of increasing bioavailability of iron in beans. We also plan to evaluate the flavonoid components of the tannin fraction using HPLC analysis and determine if there are correlations between tannin content and iron/zinc accumulation in the seed.

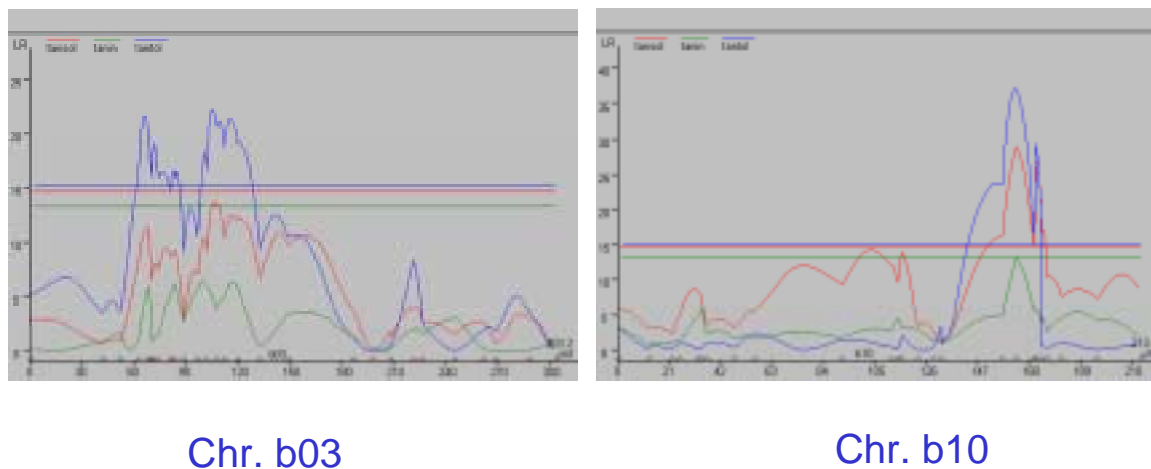


Figure 39. Quantitative trait loci (QTLs) for condensed tannin content detected with composite interval mapping analysis in the DOR364 x G19833 mapping population of common bean.

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Collaborators: P. Avila, C. Lazcano (IP-3), S. Beebe (IP-1), P. Gepts (UC-Davis).

Progress towards achieving output milestones:

- One high iron sister line, NUA56, has average iron content of 93 mg kg⁻¹ across three sites. Additional Andean red seeded high iron varieties have been identified.
- Good correlations across sites for iron content confirm the potential of identifying a stable genetic component of improved iron content of beans.
- A total of 120 combinations of high iron landraces and breeding lines crossed to elite breeding lines with commercial grain and agronomic characters have been developed.
- QTL mapping of nutritional traits has revealed QTL for iron concentration, tannin concentration, and iron reductase.

Output 3: Strategies developed for managing diseases and pests in bean-based cropping systems

Activity 3.1 Characterizing and monitoring pathogen and insect diversity

Highlights:

- The causal agents of three new diseases of common bean that have recently emerged in Colombia have been identified.
- We showed a lack of host differential interaction in the common bacterial blight/common bean pathosystem, and that the CBB pathogens might not have co-evolved with common bean gene pools.
- A molecular assay for specific detection and differentiation of CBB pathogens in bean seed, and the protocol for its application were developed.
- It was shown that the population structure of *C. lindemuthianum* is changing, as evidenced by the resistance of previously susceptible varieties.
- It was demonstrated that the varieties Widusa, Kaboon (Andean) and G 2333 (Mesoamerican) can be used to effectively manage all anthracnose races found in Colombia.
- The infection process of the angular leaf spot pathogen, *P. griseola*, was elucidated.
- The immune response of G 10474 to several pathotypes of *P. griseola* might be mediated through production of an antifungal compound.
- A protocol was developed for routine transformation of *P.griseola* and the fungus was transformed to express the GFP protein. Some transformants have lost their ability to infect bean (insertional mutagenesis).
- One hundred and thirty-four *Pythium* isolates from areas affected by bean root rots in Kenya and Rwanda were characterized by sequencing the ITS-1 region of ribosomal DNA and grouped into 22 species of which nine are new additions. Distribution maps for *Pythium* species were developed.
- Important changes in whitefly species composition in the target area were detected. Varying levels of resistance or susceptibility to some of the insecticides commonly used for whitefly control were observed.

3.1.1 Characterization of bean leaf crumple virus, a new whitefly-borne virus affecting common bean in Colombia

In 2003 Bean Virology described the emergence of a new viral disease of snap bean in the Cauca Valley of Colombia. The new virus severely affects the only snap bean cultivar ('Blue Lake') grown in this region, to the extent that snap bean production has been practically abandoned. In preliminary molecular characterization studies, we had reported an 85% homology between the new virus and *Bean golden yellow mosaic virus* (BGYMV) at the capsid protein level located in component DNA-A. The characterization of this virus was continued in 2004 in order to obtain partial sequence of DNA-B, the viral component that determines the pathogenicity of the virus to a large extent. This study showed that the B ss-DNA component of the snap bean begomovirus is most closely related to a group of begomoviruses present in the Americas, namely: *Cabbage leaf curl virus* (CaLcuV), *Squash leaf curl virus* (SLCV), and *Tomato yellow mosaic virus* (ToYMV).

Of these viruses, Bean Virology has detected begomoviruses in the Cauca Valley, closely related to CaLcuV (in soybean) and ToYMV (in tomato). It is thus apparent that this is a recombinant virus (Figures 40 A and B) capable of infecting common bean.

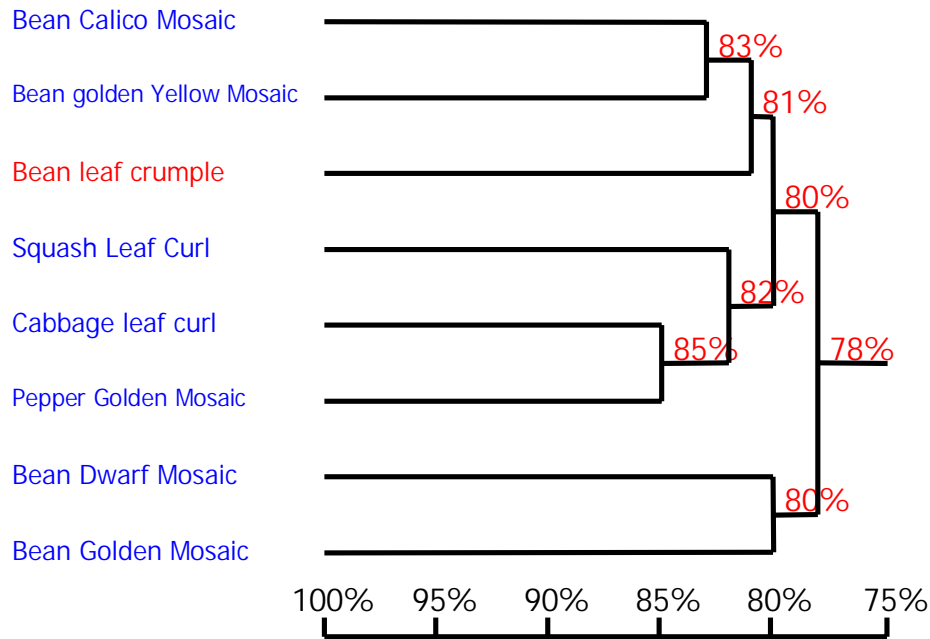


Figure 40 A. Phylogeny of Bean leaf crumple virus (DNA-A/capsid protein)

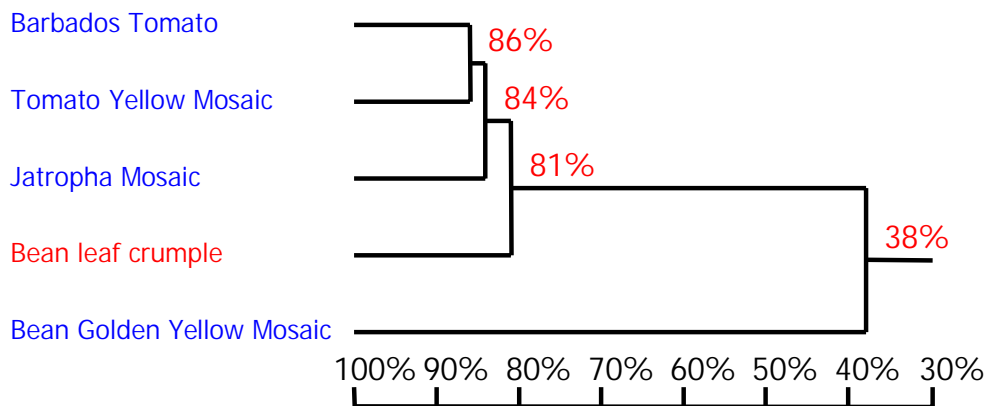


Figure 40 B. Phylogeny of Bean leaf crumple (DNA-B/Movement protein)

3.1.2 Characterization of a virus inducing systemic necrosis in common bean genotypes planted in the experiment station of Santander de Quilichao, Cauca, Colombia

Samples taken from common bean plants showing partial systemic necrosis under field conditions, were brought to CIAT for electron microscopy, partial molecular characterization by PCR, and pathogenicity tests for strain identification. The electron microscopy examination revealed the presence of flexuous filamentous virus-like particles approximately 750 nm in length and 15 nm in diameter. The PCR test was performed using primers specifically designed for potyviruses. A band of the expected molecular size was amplified, cloned and sequenced at CIAT. The comparison of the sequence obtained with that of other plant viruses filed in the GeneBank, indicated that the potyvirus was an isolate of the necrosis-inducing strain of *Bean common mosaic necrosis virus* (BCMNV). Whereas this strain is ubiquitous in temperate regions of South America and in Eastern Africa, it had not caused any problems in this part of the world in the past. However, the pathogenicity tests carried out at CIAT, using the differential common bean genotypes used for BCMV and BCMNV strain characterization, showed that the new virus does not behave exactly as the BCMNV-NL3 strain in these genotypes (Table 66).

Table 66. Reaction of the differential common bean genotypes used for BCMV/BCMNV strain characterization to a new necrosis-inducing potyvirus.

Genotype	SQ Virus*	BCMNV-NL3
Genotypes possessing recessive (I^+ I^+) resistance		
Dubbele Witte	+	+
Stringless Green Refugee	-	+
Redlands Greenleaf C	-	+v
Puregold Wax	-	+v
Imuna	-	+v
Redlands Greenleaf B	-	+
Great Northern 123	-	+
Sanilac	+	+
Michelite 62	+	+
Red Mexican 34	+	+
Pinto 114	-	+
Monroe	-	
Great Northern 31	-	
Red Mexican 35	-	
Genotypes possessing dominant (II) resistance		
Widusa	+	+
Black Turtle Soup	+	+
Jubila	-	+
Topcrop	-	+
Improved Tendergreen	-	+
Amanda		

* Virus from Santander de Quilichao, Cauca, Colombia; BCMNV=*Bean common mosaic necrosis virus*.

In fact, the pathogenicity of the potyvirus isolated in Santander de Quilichao, is quite different from the one expected for BCMNV-NL3, and it is practically identical (with the exception of the negative reaction of Stringless Green Refugee) to the spectrum of pathogenicity described for BCMNV-NL8, a different strain of the same species. The results obtained for the PCR test and partial molecular characterization of the SQ virus as BCMNV-NL3, are probably related to the close molecular organization of the NL3 and NL 8 strains of BCMNV.

3.1.3 Monitoring of Peanut stripe virus at CIAT-Headquarters

In 2002, Bean Virology reported on the detection of Peanut stripe virus affecting plots of the common bean cultivar ‘Quimbaya’ at CIAT Headquarters, Palmira, Colombia. This virus had been previously detected at CIAT infecting the forage legume species, *Arachis pintoii*. This forage species has also been utilized at CIAT as a cover crop in fruit orchards, which has been acting as a permanent virus reservoir for migrant aphids that acquire the virus from *A. pintoii* and transmit it to susceptible common bean genotypes on campus. Besides ICA-Quimbaya, commercial plots of cultivars ICA-Cafetero and Diacol-Calima have been affected by this virus at CIAT. Peanut stripe virus is currently considered as a strain of *Bean common mosaic virus*, but its biological behavior is different from that of most BCMV strains, being able to infect four of the six groups of bean genotypes possessing recessive resistance to BCMV. Peanut stripe virus does not induce systemic necrosis in common bean genotypes possessing the dominant *II* gene. The fact is that Peanut stripe virus has become an endemic pathogen of common bean in CIAT-HQ fields, but only in those old genotypes that do not have resistance to BCMV. This virus should not pose a problem for any of the advanced breeding lines developed by CIAT with resistance to BCMV.

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3.1.4 Determination of pathogenic variation within the common bacterial blight pathogens (*Xanthomonas campestris* pv *phaseoli* (Xcp) and *Xanthomonas campestris* pv *phaseoli* var *fuscans* (Xcpf))

Rationale: The question of physiological races within common bacterial blight has been the subject of much discussion. Some studies have reported the presence of physiological races in the CBB pathogens while others have found the contrary. The presence of physiological races would suggest a gene for gene interaction, which would have profound influence as to how breeding for CBB resistance is undertaken. To date, all information shows that CBB resistance in *Phaseolus vulgaris* is quantitative in nature. To test the hypothesis of the presence of physiological races in the CBB pathogen, we collected all bean genotypes that have been reported in the past to show differential response when challenged with the CBB pathogen, and inoculated these under greenhouse conditions, using isolates of a diverse origin. The objective was to provide insights into the co-evolution of Xcp and Xcpf with Andean and Mesoamerican gene pools, and corroborate the results of Gilbertson et al. (2004). In addition, this would lead to the formulation of a differential series, that can be used to rapidly characterize the CBB pathogen, identify the most effective resistance genes to use in breeding programs, as well as formulate ways to effectively deploy CBB management strategies.

Materials and Methods: Bacterial isolates: Bacterial isolates were selected to represent different geographical areas where bean is grown, and for which we had isolates in stock. A total of 29 isolates were selected, 15 Xcp and 14 Xcpf.

Bean germplasm: Fifty bean genotypes were used in this study, 26 belonging to the Andean gene pool and 24 to the Mesoamerican gene pool (Table 67). The majority of these genotypes have previously been reported to show a differential reaction to the CBB pathogen and as having the capability to distinguish between isolates. In addition, six lines specifically developed for resistance to the CBB pathogen (VAX 1 to VAX 6) through interspecific hybridization of *P. vulgaris* and *P. acutifolius* and embryo rescue techniques were included.

Table 67. Reaction of *Phaseolus* genotypes to inoculation with 14 isolates of *Xanthomonas campestris* pv. *phaseoli* var *fuscans* (Xcpf) and 15 isolates of *Xanthomonas campestris* pv. *phaseoli* (Xcp).

Genotype	Gene Pool ^a	Xcp		Xcpf	
		Incompatible ^b	Compatible ^c	Incompatible	Compatible
Nuña maní Roja	A	2	13	7	7
A 196	A	1	14	3	11
Bola 60 días	A	1	14	1	13
Burros Argentinos	A	1	14	1	13
G 76	A	0	15	0	14
Taylor	A	0	15	0	14
ICA CERINZA	A	0	15	0	14
A 475	A	0	15	0	14
A 36	A	0	15	0	14
G 5686	A	0	15	0	14
Jatu Rong	A	0	15	0	14
Ecuador 1056	A	0	15	0	14
Jalo EEP 558	A	0	15	0	14
Alubia Cerrillos	A	0	15	0	14
Mortiño	A	0	15	0	14
Bolón Bayo	A	0	15	0	14
Ecuador 299	A	0	15	0	14
G 11867	A	0	15	0	14
MCD 4011	A	0	15	0	14
MCD 4012	A	0	15	0	14
Radical San Gil	A	0	15	0	14
Frutilla Corriente	A	0	15	0	14
Coscorrón Corriente	A	0	15	0	14
Tórtolas Corriente	A	0	15	0	14
Caballero	A	0	15	0	14
Bolón Rojo	A	0	15	0	14
VAX 3	M	15	0	14	0
VAX 4	M	15	0	14	0
VAX 6	M	15	0	14	0
VAX 5	M	14	1	14	0
VAX 1	M	12	3	13	1
VAX 2	M	12	3	11	3
XAN 266	M	7	8	8	6
Guanajuato 31	M	3	12	5	9
SEA 14	M	1	14	3	11
SEA 13	M	1	14	2	12

Table 67. cont'd

Genotype	Gene Pool ^a	Xcp		Xcpf	
		Incompatible ^b	Compatible ^c	Incompatible	Compatible
Durango 222	M	1	14	2	12
Cejita	M	1	14	2	12
San Cristóbal	M	0	15	1	13
APN 114	M	0	15	1	13
MAM 28	M	0	15	1	13
DICTA 17	M	0	15	1	13
Flor de Mayo Bajío	M	0	15	1	13
Carioca	M	0	15	1	13
Porrillo Sintético	M	0	15	0	14
Orguloso	M	0	15	0	14
Riό Tibagi	M	0	15	0	14
Zacatecano	M	0	15	0	14
Ojo de Cabra	M	0	15	0	14
Frijola	M	0	15	0	14
Garbancillo Zarco	M	0	15	0	14
Flor de mayo IV	M	0	15	0	14
Amarillo 154	M	0	15	0	14
México 235	M	0	15	0	14
México 309	M	0	15	0	14
BAT 41	M	0	15	0	14

^a *Phaseolus* gene pool; A = Andean; M = Mesoamerican.

^b Number of isolates that had a resistant response.

^c Number of isolates that had a susceptible response.

Plant inoculation: Each bacterial isolate was inoculated onto the first trifoliate leaf of six plants for each genotype using the multiple needle method (CIAT, 2003), at a concentration of 5×10^7 CFU. Disease severity and progression was recorded starting 10, 13 and 17 days after inoculation using the CIAT 1-9 scale.

Results and Discussion: Considering the Andean genotypes only, 98.7% had a susceptible response to inoculation with Xcp isolates and 96.7% were susceptible when inoculated with Xcpf isolates, revealing that Andean genotypes were equally susceptible to both Xcp and Xcpf isolates of CBB (Table 67). A similar result was evident for Mesoamerican genotypes when inoculated with Xcp (96.1% susceptible) and Xcpf (91.6% susceptible). These results show no significant differences in the reaction of Andean and Mesoamerican gene pools to Xcp and Xcpf isolates, revealing a lack of co-evolution of Xcp or Xcpf with bean gene pools as has been reported (Mkandawire et al., 2004). Principal component analysis showed no differences in the reaction of Andean and Mesoamerican genotypes to Xcp and Xcpf. (data not shown). Contrary to reports of differential interaction between bean and CBB isolates, no such interaction was apparent in this study (Table 67). The VAX lines showed high levels of resistance to all isolates, in particular VAX 3, VAX 4, and VAX 6.

Conclusion: The results obtained in this study do not permit us to establish host differential varieties for the CBB pathogen, as no differential interaction was observed in the interaction of bean and the CBB pathogens from different geographical areas. In addition, these results reveal a lack of co-evolution between Xcp or Xcpf with gene pools established for the common bean host. However, such a conclusion can only be made following evaluation of wild beans with the same spectrum of CBB isolates, as the genotypes that have been used in this study are improved, therefore the original host diversity might have been lost during bean improvement. We are in the process of evaluating Andean and Mesoamerican wild bean accessions.

References:

CIAT 2003. Annual Report, Bean Program 2003. CIAT, Cali, Colombia annual.

Mkandawire, A.B.C., Mabagala, R.B., Guzmán, P., Gepts, P., and Gilbertson, R.L. 2004. Genetic diversity and pathogenic variation of common blight bacteria (*Xanthomonas campestris* pv. *phaseoli* and *X. campestris* pv. *phaseoli* var. *fuscans*) suggests pathogen coevolution with the common bean. *Phytopathology* 94: 593-603.

Contributors: C. Jara, G. J. Fory, G. Castellanos, G. Mahuku

3.1.5 A specific molecular assay for detecting and differentiating *Xanthomonas campestris* pv. *phaseoli* and *Xanthomonas campestris* pv. *phaseoli* var. *fuscans*

Rationale: Common bacterial blight and fuscous blight, caused by *Xanthomonas campestris* pv. *phaseoli* (xcp) and *Xanthomonas campestris* pv. *phaseoli* var. *fuscans* (xcpf) respectively, are major diseases of common bean world wide. Yield losses range from 0 to 40% on susceptible cultivars. The two pathogens are seed borne, this being the principal source of inoculum and means of dissemination to new areas. One way to minimize the impact of the CBB pathogens is to ensure the distribution of disease-free seed. Current assays to identify and quantity *X. c. phaseoli* in bean tissues include plating on selective media, phage typing, immunoassay, and host inoculation. Although valuable, they are labor intensive and not sufficiently precise for routine use. We describe the development of a rapid, sensitive and specific assay for detecting the CBB pathogens in seed, and for differentiating between the two causal agents of the disease.

Material and Methods: Previous studies reported the presence of an Xcpf diagnostic 820 bp fragment following amplification with the RAPD primer OPG11 (Birtch et al., 1997). Amplification of representative Xcp and Xcpf isolates using this primer resulted in two fragments, a 900 bp fragment that was present in all Xcp isolates and an 820 pb present in all Xcpf isolates (Figure 41). The fragments were excised from gels, cloned, DIG labeled and used as probes in Southern hybridization analysis of total genomic DNA either digested with EcoRI or not digested and PCR amplified products, to confirm specificity of these fragments to the two bacteria. Once confirmed, the fragments were sequenced and specific primers designed. The specificity of these primers for Xcp or Xcpf was tested using DNA from different bacteria

(*Xanthomonas campestris* pv. *phaseoli*, *Xanthomonas campestris* pv. *phaseoli* var. *fuscans*, *Xanthomonas campestris* pv. *manihotis*, *Xanthomonas campestris* 36062 and *Xanthomonas campestris* 1622/16 isolated from *Bracharia*, *Xanthomonas campestris* pv. *oryzae*, *Agrobacterium tumefaciens*, *Pseudomonas fuscovaginae*), *Phaseolus vulgaris*, and from several fungi that infect beans (*Pythium ultimum*, *Colletotrichum lindemuthianum*, *Phaeoisariopsis griseola* and *Macrophomina phaseolina*). DNA amplification was performed in an MJ Research Thermal Cycler with one cycle at 94°C for 5 min, 65°C for 40 s and 72°C for 2 min, followed by 35 cycles at 94 °C for 1 min, 65°C for 40 s and 72°C for 2 min and a final cycle at 72°C for 10 min. Reactions were carried out in 12.5 µl reaction volumes containing 5ng of genomic DNA, 0.5 unit Taq polymerase (Promega), 0.16 µM of each primer, 200 µM of each dNTP, 1x PCR reaction buffer, and 1.5 mM MgCl₂.

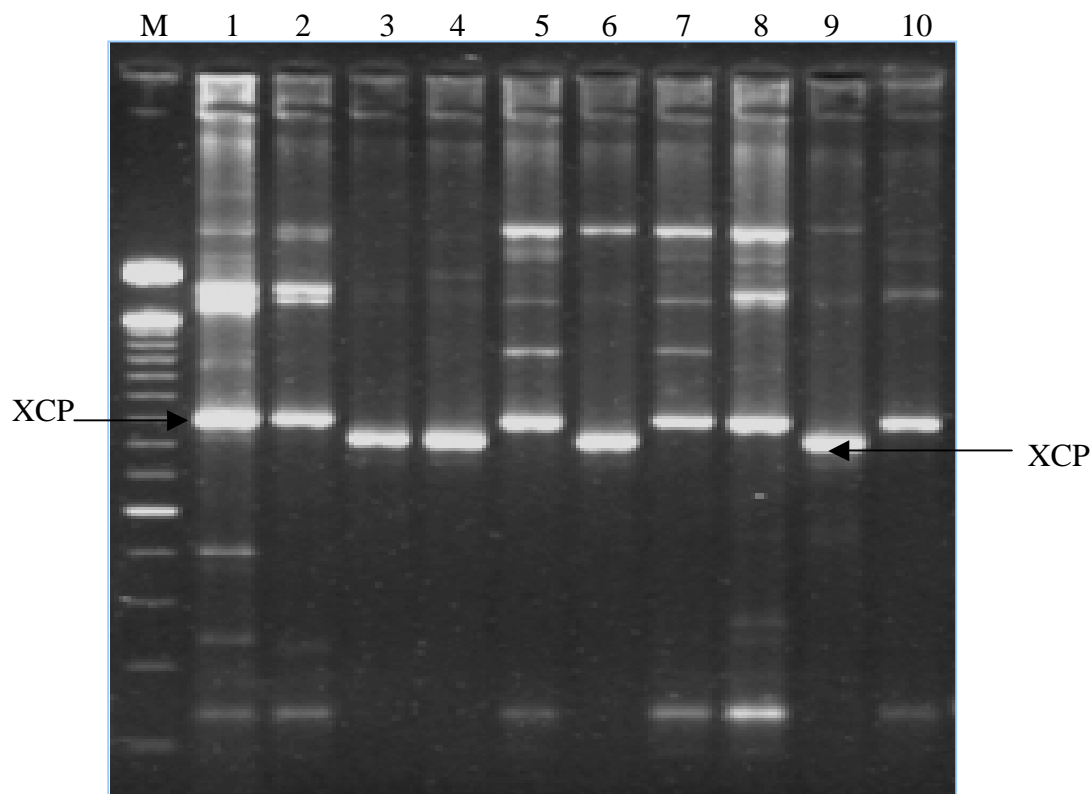


Figure 41. Amplification of *Xanthomonas campestris* pv. *phaseoli* (Xcp), *Xanthomonas campestris* pv. *phaseoli* var. *fuscans* (Xcpf) using RAPD primer OPG11. Lanes 1, 2, 5, 7, 8, and 10 are Xcp isolates; lanes 3, 4, 6, and 9 are Xcpf isolates. Lane M is the 100 bp molecular size marker.

Utility of developed probes

The utility of the designed probes for detecting the CBB pathogens was validated by amplification of DNA from seeds collected from known infected pods and leaf tissues. In addition, bacterial DNA extracted using different methods (Mahuku, 2004) were used to test the sensitivity of this method to impurities in the PCR assay.

DNA extraction from seed

Ten seeds were washed with sterile distilled water, placed in a plastic bag and 4 ml of a salt solution (8.5 g NaCl in 1 liter of sterile distilled water) added. Alternatively, ten seeds in a plastic bag were macerated in NaCl solution. The bags were put on a shaker (~100 rpm) at room temperature for ~18 hrs, the contents transferred to a 15 ml falcon tube, centrifuged (4000 rpm) for 1 hr at 4°C. The pellet was resuspended in 100 µl of sterile double-distilled water and a serial dilution of up to 1:500 done. One µl from each dilution was used in a 12.5 µl PCR reaction volume.

Extraction of bacterial DNA from single seeds

A single bean seed from infected pods was thoroughly washed with sterile distilled water, macerated in a plastic bag and the contents washed into a 2 ml eppendorf tube using 100 µl of NaCl solution. A plastic pestle that tightly fits the eppendorf tube was used to further macerate and homogenize the solution, the mixture was left standing for ten minutes at room temperature. The supernatant was transferred to a new tube, and centrifuged at 800 rpm for 5 minutes at 4°C. The supernatant was removed, the pellet resuspended in 100 µl of sterile distilled water and a 1 µl of a 1:100 dilution used in a 12.5 µl PCR reaction volume.

Detection level (specificity)

To determine the detection level, 1 µl of the pellet was added to 100 µl of sterile distilled water and plated on YCGA medium and incubated at 28 °C. After 18-24 hrs, the number of CFUs was counted, incubated for 48 hrs, to distinguish between Xcpf and Xcp.

Results and Discussion:

Amplification with OPG11 resulted in two diagnostic fragments, a 900 bp for Xcp and an 820 bp fragment for Xcpf (Figure 41). Southern blot analysis revealed that these fragments were unique to Xcp and Xcpf respectively (Figures 42A and 42B). A set of three primer combinations was developed; one set (xcpG11-L1/xcpG11-R1) was specific to the CBB pathogens (Xcp and Xcpf), amplifying an 800 bp (Figure 43A). This primer pair did not amplify DNA from other pathogens or bean DNA (Figure 43). The primer pair xcpfG11-L1/xcpfG11-R1 was specific for Xcpf (Figure 43B), while the primer pair xcpG11-L2/xcpG11-R1 was specific to Xcp (Figure 43C). When tested on seed from infected pods of plants that had been inoculated with Xcpf under field conditions, only Xcpf was detected (Figure 44C). Amplification with the CBB general primers (Figure 44A) revealed the presence of the bacteria, while amplification with Xcp specific primers revealed the absence of Xcp in seed (Figure 44B). Cultures of the same seeds after seed

washings revealed that they were infected with Xcpf, and all seeds that were negative in the PCR assay were also negative using the culturing method, showing that this assay can potentially be used as a faster method of detecting the CBB pathogens in seed. This PCR assay could detect a minimum of 5 CFU of the bacterium.

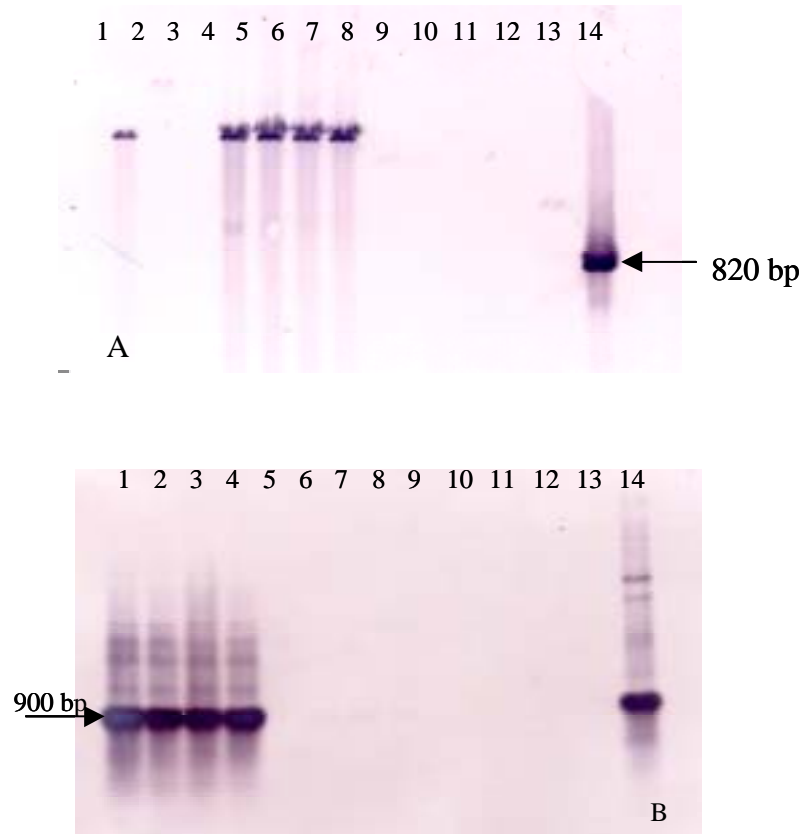


Figure 42. Specificity of the CBB probes for *Xanthomonas campestris* pv. *phaseoli* (Xcp) and *X. campestris* pv. *phaseoli* var *fuscans* (Xcpf). (A): Genomic DNA was digested with EcoRI and hybridized using the DIG-labeled Xcpf specific fragment; Lane 1, 3 4 correspond to Xcp, lanes 2, 5, 6, 7, 8 are Xcpf isolates; Lane 9 is *X. campestris* pv. *manihotis*; lane 10 is *X. campestris* pv. *oryzae*; lane 11 is *Phaeoisariopsis griseola*, Lane 12 is *Colletotrichum lindemuthianum*; lane 13 is bean and lane 14 is the plasmid containing the 820 bp fragment specific to Xcpf. (B) PCR amplified DNA using RAPD primer OPG11 and hybridized using the DIG-labeled Xcp specific fragment. of Xcp, Xcpf. Lanes 1-4 is Xcp isolates, lanes 5-8 is Xcpf; Lane 9 is *X. campestris* pv. *manihotis*; lane 10 is *X. campestris* pv. *oryzae*; lane 11 is *Phaeoisariopsis griseola*, Lane 12 is *Colletotrichum lindemuthianum*; lane 13 is bean and lane 14 is the plasmid containing the 820 bp fragment specific to Xcp

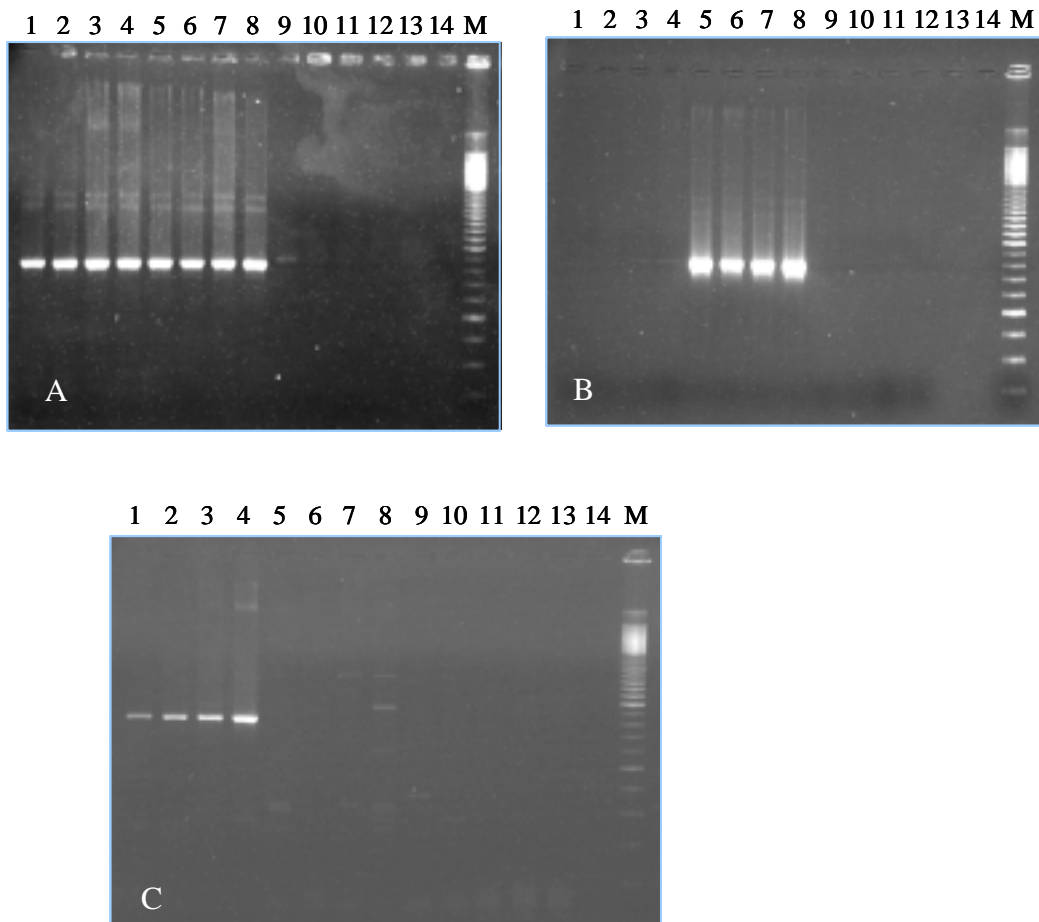


Figure 43. Specific detection of the common bacterial blight pathogens. Lane 1-4; *Xanthomonas campestris* pv. *phaseoli* , lane 5-8 *Xanthomonas campestris* pv. *phaseoli* var, *fuscans*; lane 9; *Xanthomonas campestris* pv. *manihotis*, lane 10; *Xanthomonas campestris* pv. *oryzae*, lane 11; *Phaeoisariopsis griseola*, lane 12; *Colletotrichum lindemuthianum*, lane 13; *Phaseolus vulgaris*, lane 14; negative control, lane 15; 100 pb molecular ladder. (A) Specific detection of the CBB pathogens (Xcp and Xcpf); (B) specific detection of Xcpf; and (C) specific detection of Xcp.

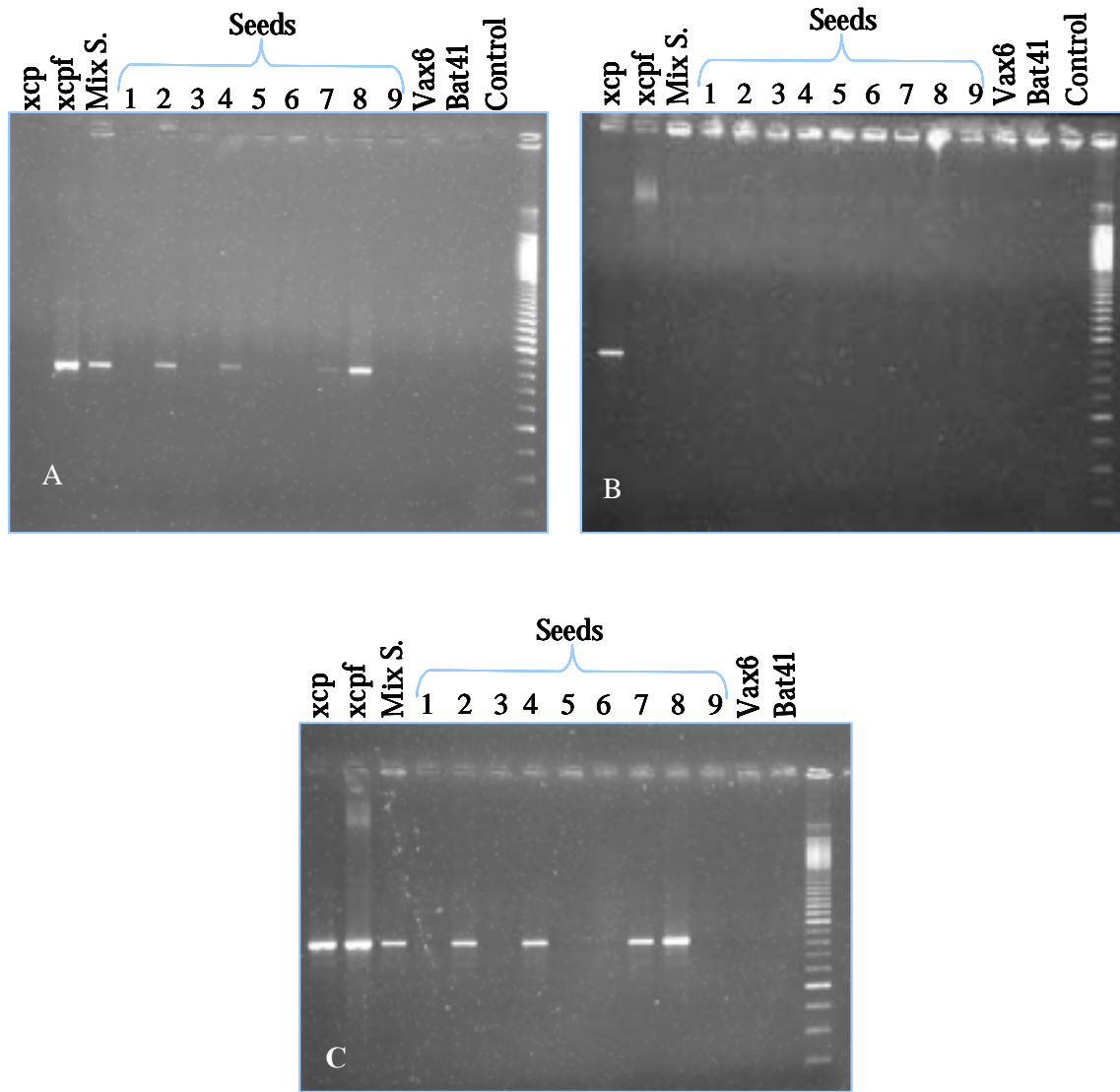


Figure 44. Detection of CBB pathogens in common bean seed, collected from infected pods of BAT 41 inoculated with *Xanthomonas campestris* pv. *phaseoli* var. *fuscans* (Xcpf). Lane 1 is Xcp, lane 2 Xcpf, lane 3 is DNA extracted from mixed seeds; lanes 4 individual seeds, lane 12 is bacteria free seed from VAX 6, lane 13, bacteria free seed from BAT 41. (A) the CBB pathogen specific primers were used for PCR amplification in A; while (B) Xcp specific primers were used, and in (c), Xcpf specific primers were used.

Conclusions: A fast and accurate method for detecting the CBB pathogens in seed was developed. This method should significantly improve the accuracy and efficiency of diagnostic of bean common blight and can be easily implemented to certify seed lots.

References:

- Birch, P.R.J., Hyman, L.J., Taylor, R., Opio, A.F., Bragard, C., Toth, I.K. 1997. Rapid PCR-based differentiation of *Xanthomonas campestris* pv. *phaseoli* and *Xanthomonas campestris* pv. *phaseoli* var. *fuscans*. Eur. J. Plant. Pathol. 103: 809-814.
- Mahuku, G. 2004. A simple extraction method suitable for PCR-Based analysis of plant, fungal and bacterial DNA. Plant Molecular Biology Reporter 22: 71-81.

Contributors: M.A. Henríquez, M. Navia, G. Mahuku

3.1.6 Pathogenic characterization of *Colletotrichum lindemuthianum* isolates from different regions of Colombia

Rationale: Anthracnose of common bean, caused by *Colletotrichum lindemuthianum* continues to be one of the most important diseases of common bean in Colombia, especially in high areas with cool temperatures, high rainfall and relative humidity. Farmers in these areas produce climbing beans, mainly Cargamantos, Bola roja, Radicales, Mortiño. These varieties fetch high prices in the market. Since 2002, we have been monitoring the population structure so as to determine the most prevalent races and compare this with information collected in the eighties, in the hopes of determining whether there has a shift in the pathogen population structure, introduction of new pathogen races or both.

Materials and Methods: Forty-three samples were received from different departments of Colombia where anthracnose of common bean is a serious problem. A total of 43 single spore isolates were made, 16 from Antioquia, 21 from Cundinamarca, 4 from Santander and 2 from Darién in the Cauca valley (Table 68). Fungal characterization on a set of 12 differential varieties (Table 69) established for *C. lindemuthianum* was done in the greenhouse as described previously (Mahuku et al., 2003).

Results and Discussion: Sixteen pathotypes were identified among the 43 isolates and the most frequently characterized pathotype was 3 (Table 68). This pathotype (with 17 isolates) was present in all the departments from where samples were received. All pathotypes have been described before in Colombia. The most susceptible varieties were Michelite (infected by 93% of the isolates), MDRK (58.1%), PI 207262 (46.51%), Perry Marrow (32.6%), Cornell 49242 (25.2%), and TU (4.6%) (Figure 45). None of the isolates infected Widusa, Mexico 222, Kaboon, and G 2333, and these can potentially serve as source of anthracnose resistance. In addition, the resistance genes in Widusa and Kaboon have been well characterized and tagged, making the use of molecular markers in MAS in breeding programs involving these genotypes possible.

Table 68. Frequency distribution of *Colletotrichum lindemuthianum* races characterized from different departments of Colombia

Pathotype	Locality				
	Altiplano Norte	Oriente Antioqueño	Santander	Cundinamarca	Valle
1		1			
3		4	4	8	1
5	2				
7				1	
11				1	
129		1			
131				1	
132		1		2	
133		1		2	
135	1				
137		1		4	
139	1			1	
141	1	1			
143					1
515		1			
641				1	
Total isolates	5	11	4	21	2

Table 69. Common bean Anthracnose differential varieties and their respective identified resistance genes.

Code	Differential Variety	Gene Pool ^a	Resistance(s) gene ^b	Binary Value ^c
A	Michelite	M	?	1
B	MDRK	A	Co-1	2
C	Perry Marrow	A	Co-1 ³	4
D	Cornell 49242	M	Co-2	8
E	Widusa	M	Co-1 ⁵	16
F	Kaboon ^d	A	Co-1 ²	32
G	Mexico 222	M	Co-3	64
H	PI 207262	M	Co-4 ³ , Co-9	128
I	TO	M	Co-4	256
J	TU	M	Co-5	512
K	AB 136	M	Co-6, Co-8	1024
L	G 2333 ^d	M	Co-4 ² , Co-5, Co-7	2048

a= *Phaseolus* gene pool; A = Andean; M = Mesoamerican.

b = identified resistance genes.

c=Binary value assigned for each differential variety and used for race designation.

d= differential varieties that are resistant to all isolates that have been characterized from Antioquia and Santander.

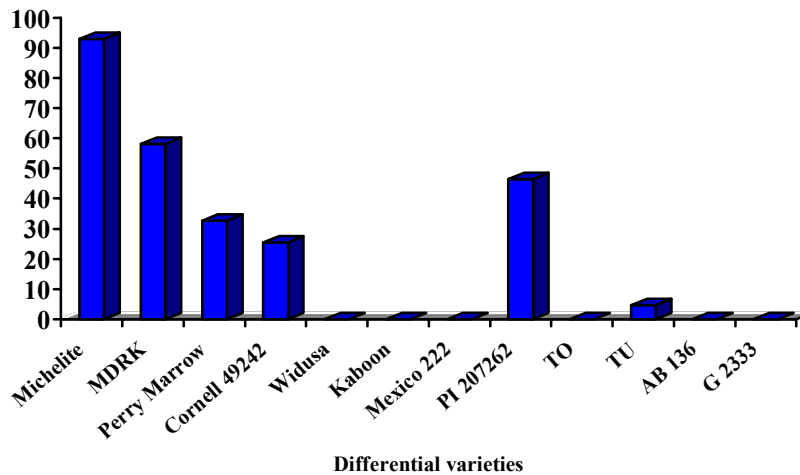


Figure 45. Percent susceptibility of anthracnose differential varieties inoculated with 43 isolates of *Colletotrichum lindemuthianum* from different zones in Colombia

Conclusion: Kaboon and G2333 continue to be immune to isolates from Colombia. The use of the resistance genes from these genotypes in bean improvement for anthracnose resistance in the different zones of Colombia should provide complete anthracnose resistance. Kaboon carries the Co-1² allele while G 2333 has three resistance genes (Co-4², Co-5, Co-7). Molecular markers linked to these resistance genes are available, making MAS possible in crosses involving these varieties.

References:

Mahuku, G., Jara, C., Cajiao, C., and Beebe, S. 2003. Sources of angular leaf spot (*Phaeoisariosis griseola*) in common bean core collection, wild *Phaseolus vulgaris* and secondary gene pool. *Euphytica* 130: 303-313

Contributors: C. Jara, J. Fory, G. Castellanos, J.B. Cuasquer, G. Mahuku.

3.1.7 Elucidating the infection process of resistant and susceptible bean genotypes by *Phaeoisariopsis griseola*

Rationale: Active resistance of plants to pathogens depends on recognition of the pathogens and initiation of defense mechanisms. Invasion by the pathogen triggers recognition and response in the plant leading to signaling cascades and the up- or down-regulation of numerous genes involved in the interaction that in turn may lead to adaptation or evasion by the pathogen. As host resistance is the best strategy to manage the angular leaf spot pathogen, several sources of resistance have been identified that can potentially be used in bean improvement for resistance to the angular leaf spot disease. These potential sources of resistance exhibit different types of resistance mechanisms that include (i) immunity – no symptom expression, (ii) hypersensitive (*HR*) response, and (iii) reduced or slow disease development and progression. The different types of resistance mechanisms can potentially be exploited in developing varieties that resist the angular leaf spot pathogen. To better understand the basis of immunity and *HR* response, we used light and electron microscopy to study the infection process in three genotypes differing in their response to infection by *P. griseola*, (G 10474 -immunity), G 19833 - *HR* response and PAN 72 susceptible). G 10474 has been found to have an immune response to over 99% of *P. griseola* races that we have tested, making the resistance gene(s) in this genotype a good candidate for managing bean angular leaf spot disease.

Material and Methods:

Fungal and Plant material: *P. griseola* pathotype 63-63, which overcomes the resistance in all angular leaf spot differential genotypes was inoculated onto three bean genotypes, G 10474 and PAN 72 (Mesoamerican), and G 19833 (Andean). G 10474 has an immune response when challenged with pathotype 63-63, G 19833 a hypersensitive response (*HR*) and PAN 72 a susceptible response. Inoculum production, inoculation, plant handling and disease evaluations were done in the greenhouse and as described previously (Mahuku et al., 2003).

Light microscopy: Samples of each genotype were collected 0, 4, 8, 12, 16, 20, 24, 28, 32, and 36 hours after inoculation (hai), and thereafter, daily until 14 days after inoculation (dai). For each sample, 10 leaf discs (1.5 cm in diameter) were cut using a cork borer, cleared and stained following the method described by Chongo et al. (2002), with the following modification: leaf discs were cleared by incubation in acetic acid:ethanol (1:2) for 24 hrs. The solution was changed, and the discs incubated for another 24 hrs. Leaf discs were stained using a lactophenol –Trypan blue (25% w/v phenol crystals, 50% lactic acid, 2.5 mg ml⁻¹ trypan blue) for 4 minutes, mounted and fixed in a drop of 80% glycerol. The discs were viewed under light microscope Laborlux D (Leitz Wetzlar, Germany). To evaluate the infection process in each variety, data were collected for number of germinated conidia, size of conidia and length of the germ tube for the first 24 hours. Leaves collected 14 dai were put in humid chambers to induce pathogen sporulation, and evaluated 3 days later for the presence of fungal fruiting structures under a stereomicroscope.

Electron microscopy: Samples for scanning and transmission electron microscopy were collected 2, 3 and 7 dai. Samples were processed as described by Hsieh et al.(2001).

Results and Discussion:

Infection process: *P. griseola* spores started germinating 4 hours after inoculation (Figure 46A-C). Conidia germination occurred either on one side (unipolar) or both sides (bipolar) and occasionally, laterally. In some cases, the infection hyphae formed structures similar to aspersoria, and this was observed principally in the susceptible genotype, PAN 72 (Figure 46D; Figure 47A). The majority of the conidia germinated within the first 24 hrs after inoculation (Table 70). By 24 hours after inoculation, an average of 97% of the spores had germinated (Table 70). Germ tube length 24 hai was significantly short in G 19833 (69 μm) compared to the Mesoamerican genotypes, PAN 72 and G 10474 (88 and 89 μm , respectively) (Table 71). Duncan's multiple range test revealed significant differences in germ tube development for the three genotypes, with a coefficient of variation of 59.26.

Penetration: Infection started earlier in the Mesoamerican genotypes, G 10474 and PAN 72 (8 hours after inoculation) and was observed much later in G 19833 (12 hrs), probably signifying differences in leaf morphology of the two bean gene pools (Figure 46B and 46E). Infection was principally through stomata (Figure 46B and 46C; Figure 47B), and occasionally directly (Figure 47C). Only 1.8% of the spores had penetrated leaf tissue by 24 hai, and numerous events of penetration were observed much later, up to 3 days after inoculation.

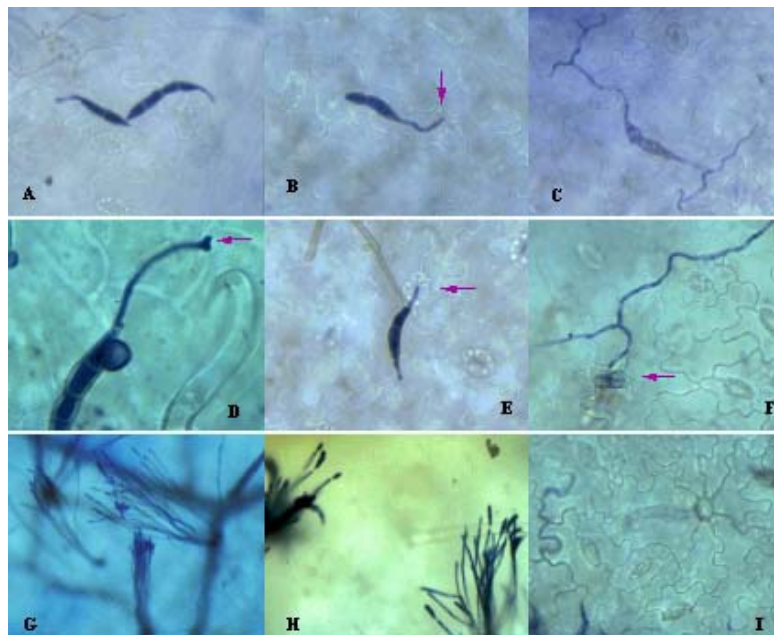


Figure 46. Light microscopy studies of the infection process of *Phaeoisariopsis griseola* (Pg) pathotype 63-63 on susceptible and resistant bean genotypes. (A) Pg conidia germinating on G 10474 at 4 hai; (B) Pg penetration through stomata of G 10474 at 8 hai (C); development of infection hyphae on leaf surface of G 10474 at 24 hai; (D) Pg infection hyphae showing aspersorium formation on PAN 72; (E) Pg penetration through stomata of G 19833 at 12 hai; (F) Necrosis of infected cells of G 19833 (HR response) 7 dai; (G) Pg fruiting structures (synema) on leaves of the susceptible genotype, PAN 72 following 3 day incubation of leaves collected 14 dai; (H) fruiting structures and sporulation on G 19833; (I) no fruiting structures or sporulation on leaves of G 10474 following incubation for 3 days.

Figure 47. Electron microscopy pictures of the infection process of *P. griseola*. (A) Presence of an aspersorium-like structure in the germ tube of *P. griseola* isolate on PAN 72; (B) Penetration through stomata of the resistant genotype G 10474; (C) Direct penetration by *P. griseola* on G10474; (D) normal development of a compatible race of *P. griseola* on G 10474; (E) transverse section of compatible interaction of G 10474 with a compatible *P. griseola* race (7-55) showing normal mycelium development 7 dai; (F) and an incompatible interaction involving G 10474 at 7 dai with race 63-63.

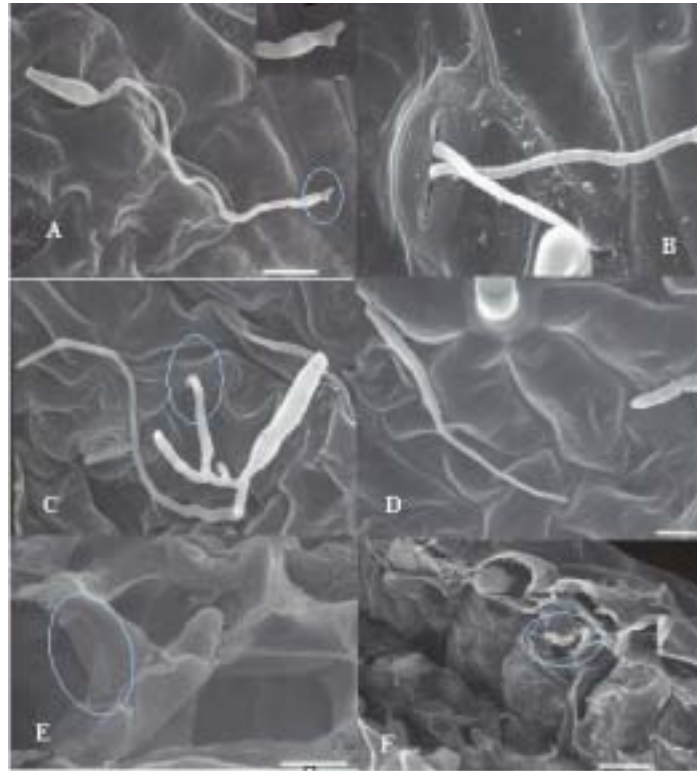


Table 70. Percent germinated spores in three bean genotypes with different levels of resistance to *Phaeoisariopsis griseola* pathotype 63-63.

Genotype	% germinated conidia					
	4 hai	8 hai	12 hai	16 hai	20 hai	24 hai
G 10474	67.8	86.35	92.86	93.69	93.45	95.14
G 19833	72.8	61.65	82.02	92.39	82.76	97.67
PAN 72	69.04	79.66	89.76	92.52	97.75	98.15

Table 71. Mean germ tube length of conidia three bean genotypes with different levels of resistance to *Phaeoisariopsis griseola* pathotype 63-63.

Genotype	Mean germ tube length					
	4 hai	8 hai	12 hai	16 hai	20 hai	24 hai
G 10474	17.62	36.06	51.00	70.26	69.93	89.41
G 19833	8.17	8.88	45.23	51.19	53.00	68.82
PAN 72	11.44	19.40	52.06	56.83	60.24	88.36

The mean is based on 25 germ tubes of unipolar and 25 bipolar germinated conidias.

Disease progression: Disease development varied with the genotype under investigation. In G 19833, small infection points were noticed 4-6 days after inoculation, as chlorotic points that later turned brown and necrotic (Figure 46F), a typical *HR* response. When inoculated leaves were placed under conditions that favor sporulation, the fungus formed synemmas, and had typical fruiting structures (Figure 46G), showing that resistance to pathotype 63-63 in G 19833 is mediated through cell wall fortification, that confines the fungus to infected cells and limits its fungus. However, the fungus was still alive, as exemplified by sporulations from infected cells, when the fungus was put under conditions that favor sporulation. Although this type of response limits the spread of the fungus and restricts colonization of new tissue, the fungus remains alive and under favorable conditions, has the capacity to sporulate and could potentially serve as a source of inoculum.

In G 10474, although *P. griseola* successfully penetrated this genotype (Figure 46B), no symptoms were observed, showing lack of colonization. When inoculated leaves were put under conditions that favor sporulation, no synemmas were observed and there was no sporulation (Figure 46I), revealing the absence of the fungus in plant tissues. Transverse electron microscopy studies of this incompatible interaction showed absence of colonization (Figure 47F). In a compatible interaction involving G 10474 with Pg pathotype 7-55, fungal colonization (Figure 47D, 47E) and sporulation were observed. These results point to the possibility that resistance in G 10474 is mediated through the production and involvement of an antifungal compound that leads to impaired fungal growth.

Normal disease progression and symptom development were observed in the susceptible genotype PAN 72, and profuse sporulation was observed when infected leaves were put under conditions that favored sporulation (Figure 46G).

Conclusion:

The mechanisms of resistance against *P. griseola* are diverse. Resistance in G 19833 is mediated through cell wall fortification that limits the spread of the fungus to infected cells. This could result from lignification and deposition of polyphenolic compounds that restricts the fungus to infected cells. Although the resistance in G 19833 is useful in limiting the colonization of leaf tissues, it might not be ideal, as this genotype could potentially be a source of inoculum, if planted in close proximity with susceptible genotypes, or in mixtures as often happens in Africa. Meanwhile, the immunity observed in G 10474 seems to result from the production of an antifungal compound that either impairs normal fungal growth or interferes with one of the biosynthetic pathways needed for successful fungal development. To further confirm the presence of an antifungal compound mediating resistance in G 10474, we have transformed pathotype 63-63 to express the GFP protein. This system will be used to closely follow and monitor infection events involving compatible and incompatible interactions with G 10474.

References:

- Chongo, G., Gossen, B.D., and Bernier, C.C. 2002. Infection by *Colletotrichum truncatum* in resistant and susceptible lentil genotypes. *Canadian Journal of Plant Pathology* 24: 81-85.
- Hsieh, T.F., Huang, J.W. and Hsiang, T. 2001. Light and scanning electron microscopy studies on the infection of oriental lily leaves by *Botrytis elliptica*. *European Journal of Plant Pathology* 107: 571:581
- Mahuku, G., Jara, C., Cajiao, C., and Beebe, S. 2003. Sources of angular leaf spot (*Phaeoisariopsis griseola*) in common bean core collection, wild *Phaseolus vulgaris* and secondary gene pool. *Euphytica* 130: 303-313

Contributors: M. Navia, G. Mahuku (IP-1), J.A. Arroyabe (Virology Unit)

3.1.8 *Agrobacterium*-mediated transformation of *Phaeoisariopsis griseola*: a tool for host/pathogen interaction studies

Rationale: The ability to transform an organism is a critical experimental tool. It can be used to test the function of cloned genes and, in systems in which the transforming DNA integrates into the target genome, it is a valuable way to create mutants in uncharacterized genes (Covert et al., 2001). The green fluorescent protein (GFP), isolated from the jellyfish *Aequorea victoria*, has been used as a reporter molecule in many eukaryotes and prokaryotes. This protein is especially important for direct evaluation of events directly in living tissues, because only UV or blue light and oxygen is required for visualization. The transformation of *P. griseola* to express the GFP protein offers a tool that can be used to study the interaction of this pathogen with common bean, and facilitate studies to elucidate genes and associated pathways responsible for *P. griseola* pathogenicity. A visual marker of gene expression would be useful in detecting gene activity early in the infection process. In addition, the GFP system can be used to create mutants and further our understanding of the molecular basis of pathogenicity and host specificity in *P. griseola* by facilitating the isolation of novel virulence and avirulence genes. The objective of this study was to develop a method that can be used for routine transformation of *P. griseola* and to have a system for elucidating the mechanism of resistance and nature of the interaction of *P. griseola* with its common bean host.

Materials and Methods:

Fungal isolates and binary vectors: The highly virulent *P. griseola* pathotype 63-63 was used in this study. Fungal growth and handling was as described previously (Mahuku et al., 2003). The *A. tumefaciens* AGL-1 strain was transformed using two binary vectors pPSK1019, (kindly provided by Dr. S. Kang) and pPK2 (kindly provided by Dr. Martin Rep). The GFP gene in the pPSK1019 vector is under the control of *gpd* from *Cochliobolus heterostrophus*, and the construction of the plasmid has been described before (Mullins et al., 2001). The pPK2-HPHGFP is derived from pPK2 (Covert et al. 2001) and the GFP gene is under the control of the *gpd* promoter from *Aspergillus nidulans*.

Transformation of *P. griseola*: The transformation procedure applied is based on the protocol described by Covert et al. (2001) with the following modifications: *A. tumefaciens* strain AGL 1

carrying either the pPK2-HPHGFP or pPSK1019 plasmid was grown overnight at 28°C in LB medium with appropriate antibiotics added to ensure maintenance of the plasmid. The following day, the cells were diluted in Induction Media (10 mM K₂HPO₄, 10 mM KH₂PO₄, 2.5 mM NaCl, 2 mM MgSO₄·7H₂O, 0.7 mM CaCl₂·2H₂O, 9 µM FeSO₄·7H₂O, 4mM (NH₄)₂SO₄, 10 mM Glucosa, 0.5% Glycerol, 40 mM MES) plus 200 µM acetosyringone (AS) to an OD₆₆₀ equal to 0.30. The final volume was adjusted to 20 ml, incubated at 28°C with shaking (150 rpm) for approximately 6 hrs, until reaching the OD₆₆₀ of 0.8. Conidia of *P. griseola* from a 12 day old culture on V8 juice medium (200 ml l⁻¹ juice V8 Campbell, 3 g l⁻¹ CaCO₃, 15 g l⁻¹ agar) were collected by adding sterile water to the plates and rubbing the surface of the V8 juice medium with the end of a sterile micropipette tip. Conidial suspension was filtered through Miracloth to remove large fragments, and washed three times with sterile distilled water and the concentration adjusted to 10⁶ conidia ml⁻¹. The conidia suspension was mixed with an equal volume of *A. tumefaciens* cells. This mix (200 µl per plate) was plated on a 0.45 µm pore, 45-mm diameter polycarbonate filter and placed on co-cultivation medium (same as IM except that it contains 5 mM glucose and 1.5% agar) with 200 µM AS. The plates were incubated for 1, 2 or 3 days at 25°C in the dark, after which the filter was transferred to plates with M-100 medium (Stevens 1974) containing hygromycin B (100 µg/ml) and cefotaxime (400 µg/ml) to kill the *A. tumefaciens* cells. The plates were incubated at 25°C and individual transformants were transferred to M-100 medium with hygromycin B (100 µg/ml) and appropriate antibiotics until conidiogenesis. Conidia of individual transformants were suspended in sterile water and plated on V8 juice medium supplemented with hygromycin B. To create monocultures, one germinated conidium from each transformant was picked and transferred to V8 juice medium with hygromycin B in small petri plate (60 x 15 mm). Spores from these monoconidial cultures were lyophilized for long-term storage or put on filter papers for short-medium term storage.

DNA extraction: Putative transformants were grown in V8 juice liquid medium (20% Jugo V8 Campbell) containing 400 µg/ml cefotaxime and hygromycin B (75 µg ml⁻¹) for 10 days at 25°C with shaking. Mycelium was collected by vacuum-filtration on sterile Whatman paper, washed several times with sterile water before drying between paper towels. The mycelium was lyophilized and macerated to a fine powder in liquid nitrogen and DNA was extracted as previously described (Mahuku, 2004).

Confirmation of transformation by PCR: To verify the integration of the T-DNA into fungal genomes, DNA extracted from putative transformants was amplified using primers targeting the hygromycine gene using the primers Hyg 1 (5'-GCGTGGATATGTCCTGCGGG-3') and Hyg 2 (5'-CCA TAC AAG CCA ACC ACG G-3') as described by Amey et al. (2002).

Confirmation of transformation by Southern hybridization: To determine the presence of the GFP protein, as well as determine the copy number of T-DNA, extracted DNA was digested with HindIII and KpnI and the products separated by electrophoresis on 0.7% gel, blotted onto Hybond-N+ membrane (Amersham Pharmacia Biotech) and fixed by UV cross-linking. Probes were labeled using the PCR DIG probe synthesis kit (Roche Diagnostics, Mannheim, Germany). Southern blot analysis was carried out as described by Sambrook et al. (1989) with 5 – 10µg of DNA in each sample. Prehybridization, hybridization, and high stringency washes of the membrane were completed at 65°C as described by the manufacturer.

Mitotic stability: To determine the stability of transformants, selected transformants were cultured on V8 juice medium without hygromycin B, and the culture repeatedly transferred (five times) to fresh V8 juice medium, after which they were grown on medium containing hygromycin B (75 µg/ml).

Virulence test of co-transformants: Two bean genotypes; G 10474 (resistant) and Sprite (susceptible) were established in the greenhouse. There were three plants of each genotype for each transformant. The wild-type *P. griseola* pathotype 63-63 was included as a control. Inoculum production, inoculation procedure and plant handling were done as described previously (CIAT, 2003). Disease progression and symptom development were monitored up to 14 days after inoculation. The development of the fungus within leaf tissue was monitored microscopically.

Expression of GFP: Putative GFP-expressing colonies were identified using an Eclipse E400 fluorescence microscope (Nikon). The microscope has a mercury lamp with an excitation filter of 450 – 490 nm.

Results:

Analysis of ATMT-mediated transformants: A total of 202 colonies resistant to hygromycin were obtained, 86 using the pPSK-1019 vector and 116 using the pPK2-HPHGFP (Table 72). The wild type pathotype 63-63 did not grow on medium with hygromycin B (100 µg ml⁻¹). Some of the transformants had color changes (lighter) when grown on V8 juice medium without hygromycin B, but the majority of the isolates were not affected, and did not show any notable differences when compared to the wild type (Figure 48).

Table 72. Number of hygromycin B – resistant (Hyg-R) fungal clones after *Agrobacterium tumefaciens*-mediated transformation for two binary vectors and three different days of co-cultivation.

Plasmid	Days of co-cultivation	Hyg-R / plate*
PPSK1019	1	20
	2	10
	3	13
pPK2-HPHGFP	1	7.5
	2	29
	3	22.5

* Values are mean of two replicates.

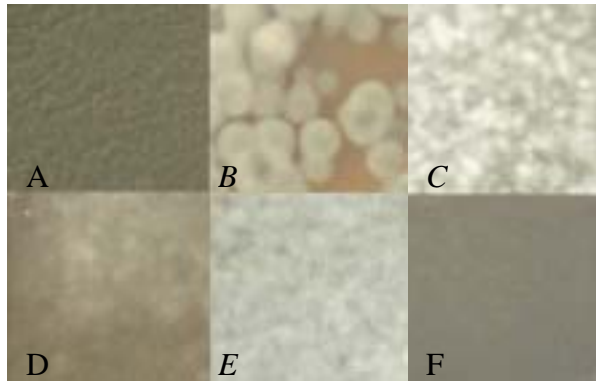


Figure 48. Morphology of hygromycin B –resistant *P. griseola* transformants compared to the wild-type isolate Pg 63-63. (A) Wild-type isolate, (B), (C), (D) and (F) are hygromycin B-resistant transformants. Some transformants are morphologically different from the wild type, while others are similar.

After initial PCR analysis to check for the presence of transforming DNA (Figure 49), Southern hybridization showed that the probe for the hygromycin B resistance gene did not hybridize to digested wild-type genomic DNA. The probe hybridized to all *Agrobacterium*-mediated transformations, indicating integration of the plasmid into genomes of the Pg pathotype 63-63 (Figure 50). The Hind III and Kpn I digest indicates both single and multiple integration events at random loci. The majority of the transformants had single integration. The differences in the sizes of the fragments upon hybridization indicate that the integration events were random. This was confirmed following hybridization with the GFP probe. None of the probes hybridized with the wild-type Pg pathotype 63-63. Hybridization with undigested genomic DNA (data not shown) showed that the signal was associated with DNA of high molecular weight, confirming that the T-DNA was integrated within chromosomal DNA.

GFP expression: Fluorescence microscopy revealed that the majority of transformants expressed GFP. Of the 202 transformants, 80% strongly expressed GFP, 7 did not fluoresce and the rest (20%) had weak fluorescence. Fluorescence was not linked to the number of GFP insertions, and some of the weakly fluorescing transformants had double insertions (Figure 51). As GFP was localized in the cytoplasm, it was possible to observe GFP expression in conidia (Figure 51 A, C, D); mycelium (Figure 51 F, I) and synemas (Figure 51G). The vacuoles did not fluoresce and these are seen as black areas of different sizes within the cytoplasm (Figure 51A, C). The wild-type *P. griseola* isolate did not fluoresce under UV light.

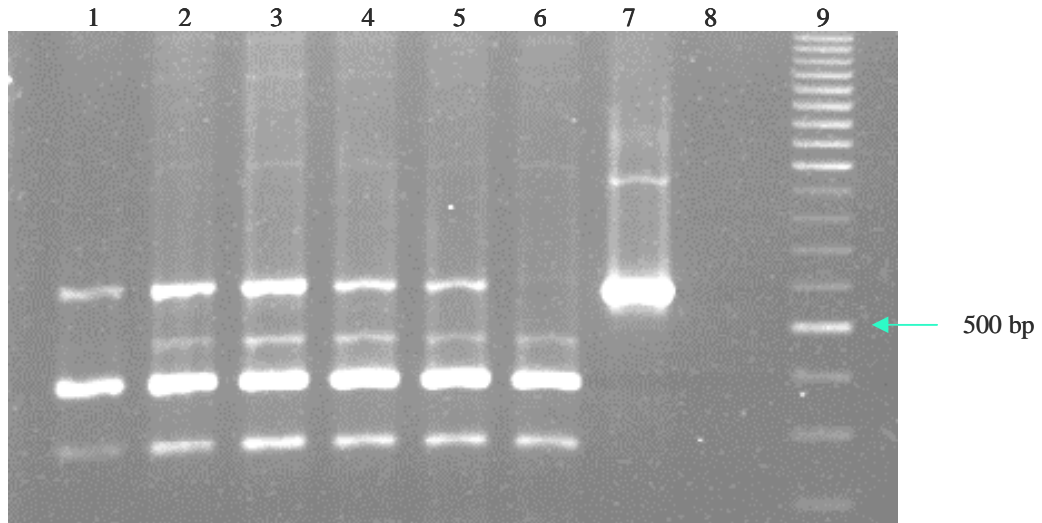


Figure 49. Polymerase chain reaction detection of the *hph* gene of randomly chosen HygB-resistant transformants, using the primers Hyg1 and Hyg2 primers (Amey et al., 2002) for amplification. Lanes 1-3 are transformants using the plasmid pPK2-HPHGFP; lanes 4 and 5 correspond to transformants using the plasmid pPKS-1019; lane 6 is the wild type *P. griseola* pathotype 63-63; lane 7 is positive control (plasmid pPKS-1019); lane 8 is negative control and lane 9 is 100 bp ladder.

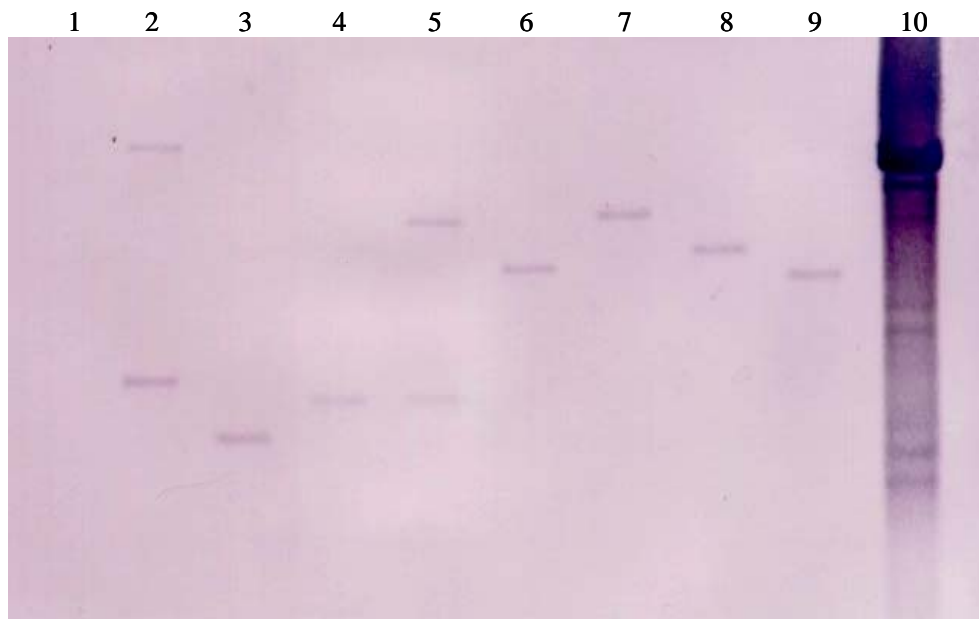


Figure 50. Transforming DNA integrating randomly and in single or double copy number into the target DNA. PCR amplified *hph* gene was used to probe the *Agrobacterium*-mediated transformants. All DNA was digested with Hind III. Lane 1 is wild-type DNA, lanes 2-9 are transformants generated with the pPSK-1019; lane 10 is digested pPSK-1019 plasmid

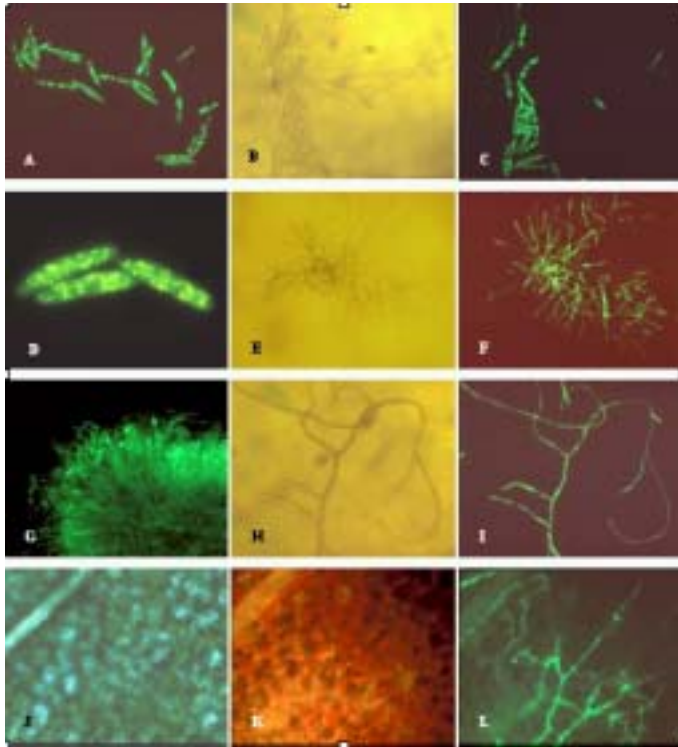
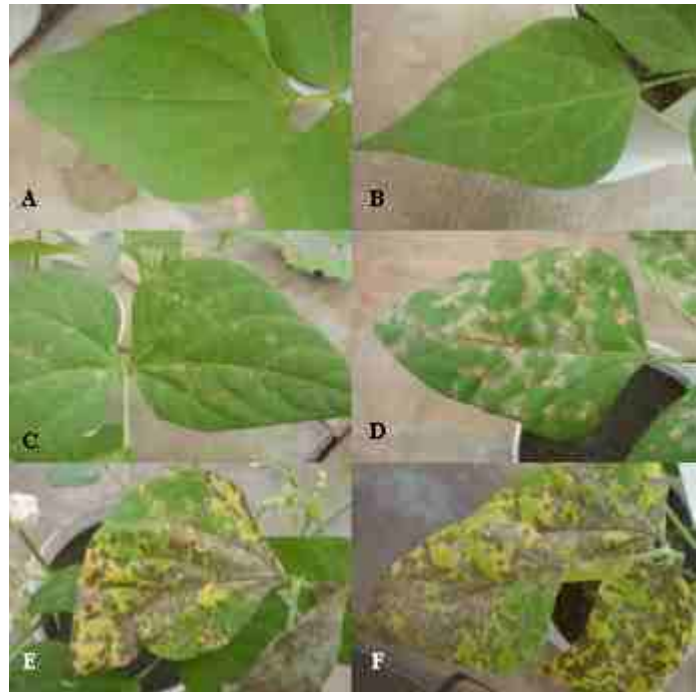


Figure 51. Fluorescence and light micrographs of GFP transformant and control strains. (A) conidia of a transformant carrying the pPK2-HPHGFP plasmid under fluorescent light; (B) conidia of a *P. griseola* transformant under white light; (C) conidia of *P. griseola* seen in (B) but under fluorescent light; (D) conidia of a transformant carrying the pPSK-1019 plasmid; (E) mycelium from transformation with plasmid pPSK-1019 under white light and (F) under fluorescent light; (G) mycelia from fungi transformed with pPK2-HPHGFP and grown on media on a slide; (H) white and (I) fluorescent light images of mycelium; (J) light micrograph of transformant growing inside plant tissue; (K) same leaf tissue under one filter and (L) under a different filter showing the transformant growing inside bean leaf tissue.

Assessment of virulence: It is important to know whether the constitutive promoters place an undesirable metabolic burden on the transformants, and to determine whether the transformants have been altered in their ability to cause disease in the bean host as a result of integration of transforming DNA within the genome. Apart from a difference in mycelium color observed within a few transformants, initial comparisons showed similarity to the wild-type. The rate of infection and symptom development on susceptible bean cultivar were the same as the wild-type Pg 63-63 pathotype for the majority of the transformants (Figure 52). Only three transformants had lost their ability to infect the susceptible bean genotype, Sprite, while another four developed very slowly compared to the wild type. These results are very interesting, as they seem to signify the presence of mutants with the pathogenicity gene disrupted through insertional mutagenesis.

Figure 52. Angular leaf spot symptoms recorded 15 days after inoculating the universally susceptible genotype Sprite with transformed and wild type isolates of *Phaeoisariopsis griseola* pathotype 63-63. (A) control - inoculated with water, B to E represent bean leaves inoculated with transformants expressing the GFP protein, and F is wild type isolate. Some of the isolates have lost their ability to infect this variety, while in others, symptom development was delayed.



Conclusion: *Phaeoisariopsis griseola* was successfully transformed to express the GFP gene using the ATMT system. To the best of our knowledge, this is the first report of the transformation of this fungus. The two promoters driving GFP were expressed in *P. griseola*, but it appears that transformation with pPK2-HPHGFP was more efficient, giving the highest number of transformants. Southern hybridization showed that most of the transformants were a result of single integration events, and that the integration occurred in nuclear DNA. This is particularly important for insertional mutagenesis and subsequent isolation of pathogenicity / virulence genes. The different levels of expression observed could reflect differences in the areas of integration in the genome. GFP expression was conserved following multiple transfer of isolates, revealing mitotic stability of GFP integration. In addition, the GFP protein was expressed in bean tissues, revealing that this system can be used to monitor infection events. A protocol for the transformation of *P. griseola* has been developed, including the subsequent analysis of the protein in fungal and plant material. This will be an important tool in providing information on the interaction of *P. griseola* with its common bean host.

References:

- Amey, R.C., Athey-Pollard, A., Burns, C., Mills, P.R., Bailey, A., and Foster, G.D. 2002. PEG-mediated and Agrobacterium-mediated transformation in the mycopathogen *verticillium fungicola*. *Mycological research* 106: 4-11.
- CIAT 2003. Annual Report, Bean Program 2003. CIAT, Cali, Colombia
- Covert, S., Kapoor, P., Lee, M., Briley, A. and Nairn, J. 2001. *Agrobacterium tumefaciens*-mediated transformation of *Fusarium circinatum*. *Mycological Research* 105(3): 259-264.
- Mahuku, G., Jara, C., Cajiao, C., and Beebe, S. 2003. Sources of angular leaf spot (*Phaeoisariosis griseola*) in common bean core collection, wild *Phaseolus vulgaris* and secondary gene pool. *Euphytica* 130: 303-313
- Mahuku, G. 2004. A simple extraction method suitable for PCR-Based analysis of plant, fungal and bacterial DNA. *Plant Molecular Biology Reporter* 22: 71-81.
- Sambrook, J., Fritsch, E.F., and Maniatis, T. 1989. *Molecular cloning. A laboratory manual*. 2a ed. Nueva York, Cold Spring Harbor Laboratory Press. (Volumen 1 y 2)
- Stevens, R. 1974. *Mycology Guidebook*. University of Washington Press, Seattle.

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3.1.9 Characterization and distribution of *Pythium* spp associated with bean root rot in East Africa

Rationale: There are approximately 100 known species of the genus *Pythium* include pathogenic, saprophytic and biological control groups. Our recent studies in Uganda have shown that over seven *Pythium* spp cause root rots on common beans, but their distribution and relative importance in other countries in East Africa are unknown. Characterization of *Pythium* species and their distribution is therefore considered a necessary pre-requisite in order to develop effective management strategies. However, identification of *Pythium* species using morphological or pathogenic characteristics is difficult given the large species numbers and their mixed occurrence in the soil. We have therefore continued with the characterization of *Pythium* spp., using molecular methods as a basis for developing simpler, accurate and rapid but reliable detection and characterization techniques. We therefore continued to characterize *Pythium* spp. prevalent in Kenya and Rwanda.

Methods: One hundred and thirty-four *Pythium* isolates obtained from root rot affected areas in Kenya and Rwanda were characterized by sequencing using the protocol of Levesque *et al*(1998). The DNA of isolates was amplified with universal eukaryotic primers targeting the internal transcribed spacer (ITS) regions and the 5.8S gene of nuclear ribosomal DNA. Purified template DNA was sequenced using an ABI prism automated sequencer. Sequences obtained were edited and compared to data of *Pythium* spp. managed by Dr. A. Levesque of the Agri-Food and Food and Agriculture Canada.

Results and Discussion: Out of 134 isolates characterized, 22 species were identified (Table 73). Thirteen of these have been reported in our previous pathogen characterization studies in Uganda and Kenya but nine were new additions. All except three (*P. macrosporum*, *P. zingiberis*, *P. graminicola*) were recovered from Rwanda with *P. ultimum* being the most frequent, followed by *P. torulosum* and *P. spinosum*. The three are pathogenic to beans. Fifteen of the 22 species were recovered from Kenya with *P. vexans* being the more frequent species, followed by *P. torulosum*, *P. irregular* and *P. ultimum*. Species distribution maps for Kenya and Rwanda are shown in Figures 53 and 54 respectively. These results are consistent with past observations that overall *P. ultimum* is the most frequent species in the region. Pathogenicity of some of the new species is being determined to establish their role in the bean root rot problem in the region.

Table 73. Identification by sequencing of *Pythium* isolates obtained from bean growing areas associated with bean root rots in Kenya and Rwanda.

Species	<i>Pythium</i> Isolates		Total
	Kenya	Rwanda	
<i>P. acanthicum</i>	2	1	3
<i>P. chamaehyphon</i>	1	2	3
<i>P. folliculosum</i>	3	2	5
<i>P. indigoferae</i>	2	2	4
<i>P. irregulare</i>	9	1	10
<i>P. lutarium</i>	1	3	4
<i>P. macrosporum</i>	1	0	1
<i>P. myriotylum</i>	1	1	2
<i>P. paroecandrum</i>	3	3	6
<i>P. torulosum</i>	9	10	19
<i>P. vexans</i>	10	4	14
<i>P. zingiberis</i>	5	0	5
<i>P. graminicola</i>	4	0	4
<i>P. spinosum</i>	1	7	8
<i>P. ultimum</i>	5	23	28
<i>P. arrhenomane</i>	0	2	2
<i>P. catenulatum</i>	0	1	1
<i>P. deliense</i>	0	1	1
<i>P. diclinum</i>	0	2	2
<i>P. dissotocum</i>	0	3	3
<i>P. rostratum</i>	0	5	5
<i>P. salpingophorum</i>	0	4	4
Total	57	77	134

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Collaborators: R. Otsyula (KARI), L. Butare (ISAR).

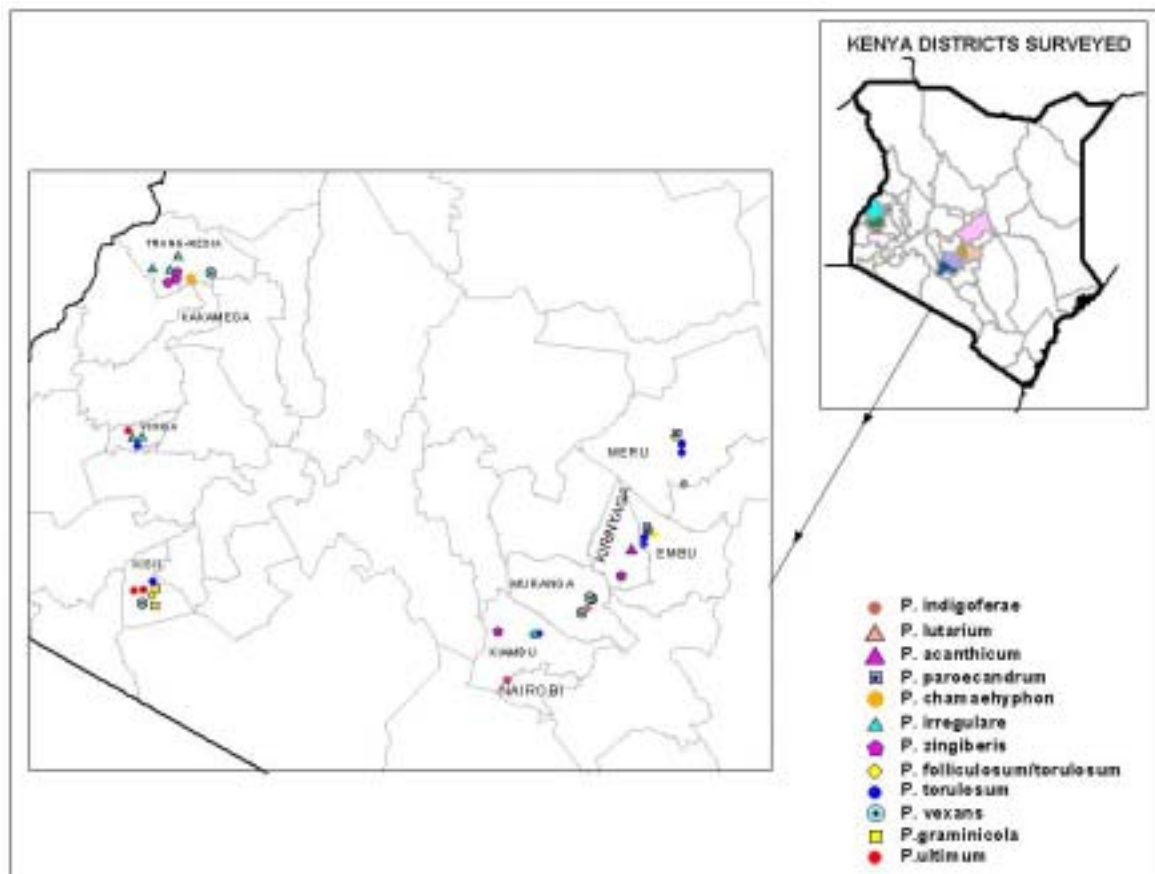


Figure 53. Distribution of *Pythium* species in some districts of Kenya where bean root rots are prevalent. Characterization was based on sequencing of *Pythium* isolates.

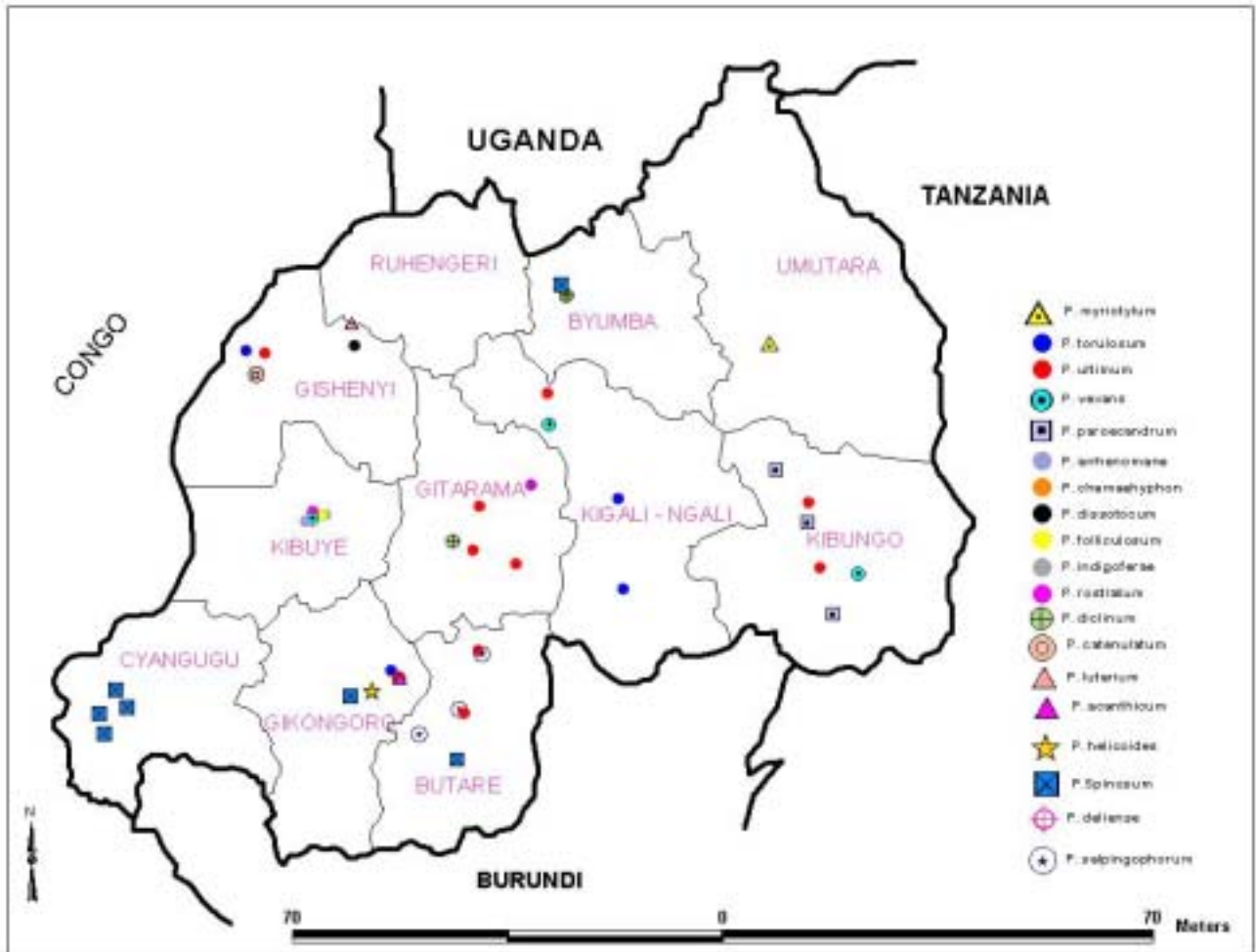


Figure 54. Distribution of *Pythium* species in Rwanda where bean root rots are prevalent. Characterization was based on sequencing of *Pythium* isolates.

3.1.10 Monitoring of the changing situation with whitefly populations in the Andean zone

Rationale: Continuous monitoring of changes in whitefly populations and species composition in target areas is one of the most important objectives of the DFID-funded project on Sustainable Management of Whiteflies. This is needed to develop appropriate management systems and, if necessary, to modify existing systems so as to be able to cope with new situations.

Materials and Methods: In 2004 we processed a total of 105 whitefly samples (adults and pupae) collected in the Cauca Valley and northern coast regions of Colombia. Samples were taken from beans, snap beans, cucurbits, tomatoes and several other annual crops. We used RAPD techniques (primer OPA-04) to identify pupae and adults. Identification was based on morphological characteristics of pupae and comparison between RAPD patterns in samples brought from the field with those of existing mass rearings of different whiteflies maintained at CIAT (Figure 55).

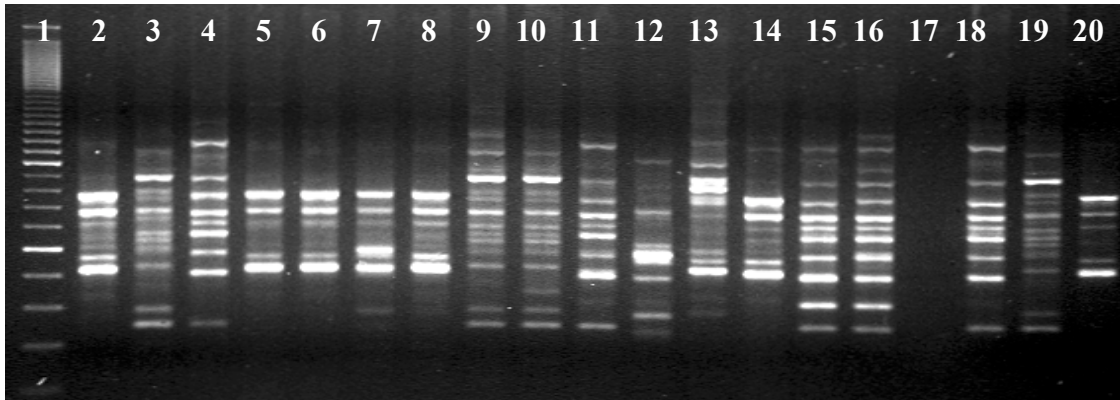


Figure 55. RAPD's for whitefly adults and pupae collected in the Cauca Valley. Amplifications using the OPA-04 primer; 1, DNA molecular marker (100 pb); 2, *T. vaporariorum* from reference rearing maintained at CIAT; 3, *B. tabaci* biotype A from reference rearing; 4, *B. tabaci* biotype B from reference rearing; 5-8 adults (5-6) and pupae (7-8) of *T. vaporariorum* collected in Darien on beans; 9-10, *B. tabaci* A adults collected on soybeans in Jamundi; 11, *B. tabaci* biotype B collected on soybeans in Jamundi; 12, parasitized pupa of *B. tabaci* collected on soybeans in Jamundi; 13-14, *T. vaporariorum* adults on beans in Jamundi; 15-16, *B. tabaci* biotype B pupae on beans in Jamundi; 17, free; 18 *B. tabaci* biotype B from reference rearing; 19, *B. tabaci* biotype A from reference rearing; 20 *T. vaporariorum* from reference rearing.

Results and Discussion: Analysis of 105 samples taken in 24 locations in the Cauca Valley (Colombia) showed that 42% of the whiteflies collected belonged to the B biotype of *Bemisia tabaci*, the most aggressive form of whitefly known to date. This biotype was found affecting snap beans, tomatoes, cucumber, melon, soybeans, pepper, tobacco, and grapes. As in 2003, we found that the B biotype is now occupying niches previously reserved to the A biotype or to *T. vaporariorum*. As shown in Figure 56, species composition in the Cauca Valley has changed drastically in the past seven years. In 1997, *T. vaporariorum* was by far the most important species, representing 73% of the samples taken while the A biotype represented 15% of samples analyzed. At present, the A biotype is difficult to find (1.6% of samples), *T. vaporariorum* represents 11% of the samples and the B biotype is the predominant species with 42% of the samples. Up to 39% of crop samples examined were affected by a combination of *T. vaporariorum* and the B biotype of *B. tabaci*.

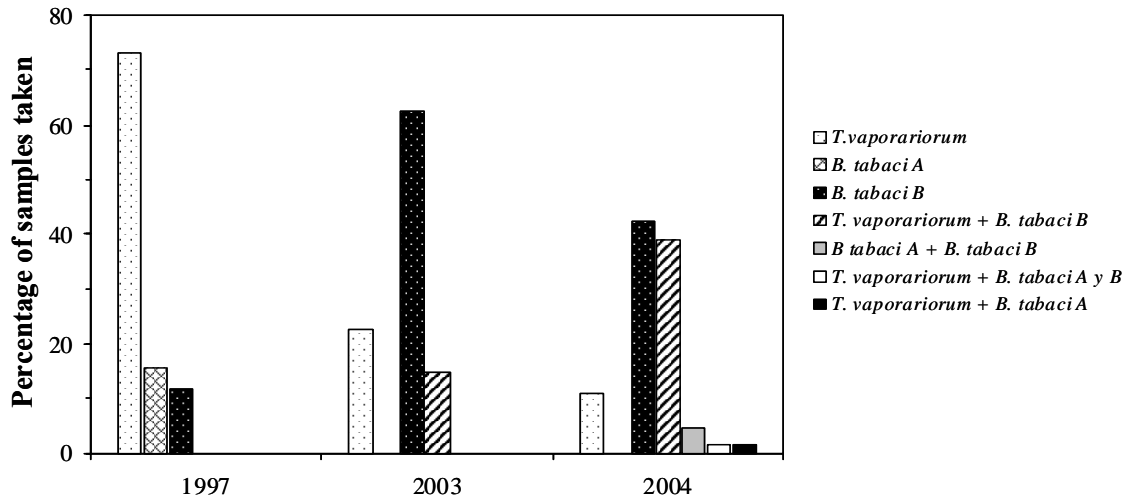


Figure 56. Changes in whitefly species composition in the Cauca Valley of Colombia (1997-2004)

Detailed monitoring of species composition on snap beans in the Pradera reference site revealed that at higher altitudes (1270-1840 masl) *T. vaporariorum* is still the dominant species (Figure 57). At altitudes ranging from 975 to 1120 masl, most individuals collected in the Pradera region belong to the B biotype of *B. tabaci* attacking different crops either alone (33.3% of samples taken) or in combination with *T. vaporariorum* (53.4% of samples). The B biotype is an aggressive form of whitefly that is causing all the serious problems described in our 2003 Report. In snap bean growing areas, it has become the causal agent of a physiological disorder known as pod chlorosis, which renders the produce useless. Most serious, it has become a very effective vector of a geminivirus that is devastating snap beans in the region.

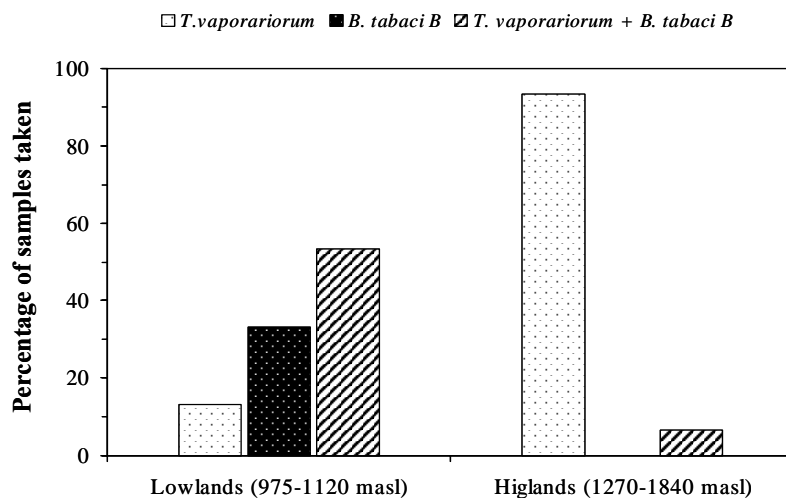


Figure 57. Whitefly species composition in the Pradera (Cauca Valley) reference site; 2004 survey. (masl = meters above sea level).

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3.1.11 Monitoring of insecticide resistance in whitefly populations

Rationale: Monitoring of insecticide resistance is another major objective of the DFID-funded project on Management of Whiteflies in the Tropics. Both major whitefly species and their biotypes in the Andean zone are the targets of excessive use of insecticides. This is reflected in ever increasing levels of resistance to insecticides and difficulties in control. The main purpose of a continuous monitoring of insecticide resistance is to develop alternative management strategies that will help to overcome resistance or delay the onset of this phenomenon.

Materials and Methods: In 2004 we established base-line data for five insecticides commonly used to control adults of the B biotype of *B. tabaci*: monocrotophos, carbofuran, carbosulfan, bifenthrin, and imidacloprid. These data will serve as the basis to establish diagnostic dosages for the species. These in turn will be used for periodic monitoring of resistance levels.

Using previously established diagnostic dosages for nymphs, we tested populations of whiteflies in the Cauca Valley in Colombia. Adult resistance levels were monitored under field conditions by means of the insecticide-coated glass vial technique. Resistance of first instar nymphs was measured using the foliage dipping technique. Systemic novel insecticides (mostly neonicotinoids) were tested using the petri dish technique (see 2003 Annual Report).

Results and Discussion: In general, it can be said that nymphal populations of both *T. vaporariorum* and *B. tabaci* biotype B are still susceptible to the insect growth regulators buprofezin and diafenthiuron and to imidacloprid, a novel neonicotinoid (Table 74). However, reduced responses to buprofezin in the Pradera site deserve further monitoring.

Future work on integrated pest management of whiteflies as pests of beans and snap beans in the Andean zone should include studies on the relative efficiency of the two most important parasitoids affecting whitefly populations in the region: *Encarsia nigricephala* and *Amitus fuscipennis*. Given the excessive use of insecticides, it is important to know what is the present response of these natural enemies to some of the most commonly used insecticides. The base-line data in Table 75 should in the future serve as the basis for possible development of insecticide tolerance in populations of these natural enemies, an optional strategy for management of the whitefly problem.

Comparison of toxicological responses of the whitefly and their parasitoids indicate that all of the insecticides tested are much more toxic to the parasitoids than to the whitefly (Table 76) with up to 100-fold higher tolerance in the herbivore. Nevertheless, the data show that both natural enemies studied do possess innate mechanisms of defense against toxic substances, which may be exploited by continuous mass rearing and selection for higher levels of tolerance followed by mass releases in the field. As such, resistant strains of one or both parasitoids would become management components in an integrated pest management system. .

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Table 74. Response (percentage corrected mortality) of nymphs of *Trialeurodes vaporariorum* and *Bemisia tabaci* biotype B to three insecticides in three consecutive growing seasons. Cauca Valley (Colombia). Diagnostic dosages in ppm

Race	Percentage corrected mortality ^a		
	2001 B	2002 B	2003 B
<i>Trialeurodes vaporariorum</i>			
		buprofezin (16 ppm)	
‘CIAT’ ^b	98.4 a A ^b	100.0 a A	97.6 a. A
La Cumbre	100.0 a A	100.0 a A	100.0 a A
Pradera	87.0 b A	77.4 a A	81.4 b A
		diafenthiuron (300 ppm)	
‘CIAT’	98.2 a A	100.0 a A	96.2 b A
La Cumbre	92.6 a B	97.8 a A	100.0 a A
Pradera	88.6 a A	93.9 a A	90.5 c A
		imidacloprid (300 ppm)	
‘CIAT’	100.0 a A	98.3 a A	93.7 a A
La Cumbre	92.8 b A	93.2 a A	99.0 a A
Pradera	84.9 b A	92.6 a A	93.2 a A
<i>Bemisia tabaci</i> biotype B			
		buprofezin (16 ppm)	
‘CIAT’ ^c	---	98.4 a A	96.9 a A
Rozo	---	80.6 b A	87.8 b A
La Unión	---	100.0 a A	87.7 b B
Santa Helena	---	100.0 a A	92.2 b B
		diafenthiuron (300 ppm)	
‘CIAT’	---	100.0 a A	91.7 a B
Rozo	---	100.0 a A	91.5 a B
La Unión	---	98.2 a A	91.7 a B
Santa Helena	---	100.0 a A	95.1 a B
		imidacloprid (300 ppm)	
‘CIAT’	---	91.1 b A	98.3 a A
Rozo	---	89.3 b A	90.1 b A
La Unión	---	100.0 a A	89.1 b B
Santa Helena	---	100.0 a A	98.6 a A

^a For each species and product, means within a column followed by the same lowercase letter and means within a row followed by the same uppercase letter are not significantly different at the 5% level by LSD. Each species and product were analyzed separately

^b A susceptible strain of *T. vaporariorum* maintained at CIAT

^c A susceptible strain of *B. tabaci* biotype B maintained at CIAT. .

Table 75. Response^a of adults of *Encarsia nigricephala* and *Amitus fuscipennis* to different insecticides

Insecticide	No. of individuals tested	CL ₅₀ (CL 95%) ^b	CL ₉₀ (CL 95%)	χ^2	b ± EEM	P > χ^2
<i>E. nigricephala</i>						
methamidophos	400	0.67 (0.440 – 0.900)	4.04 (2.910-6.800)	1.72	1.64 ± 0.24	0.19 ns ^c
Methomyl	400	0.00915 (0.004 – 0.015)	0.062 (0.044 – 0.110)	0.56	1.54 ± 0.30	0.45 ns
carbosulfan	400	0.09 (0.060 – 0.120)	0.38 (0.280 – 0.670)	0.22	2.04 ± 0.38	0.64 ns
cypermethrin	400	0.65 (0.040 – 1.880)	11.09 (5.680 – 21.65)	0.57	1.04 ± 0.26	0.45 ns
<i>A. fuscipennis</i>						
Bifenthrin	400	0.023 (0.005 – 0.427)	0.171 (0.118 – 0.276)	1.00	1.47 ± 0.33	0.31 ns
Carbofuran	400	0.074 (0.050 – 0.097)	0.380 (0.286 – 0.576)	0.70	1.80 ± 0.24	0.40 ns

^a Values of CL₅₀ y CL₉₀ in µg of active ingredient/ vial

^b Confidence limits at 95%

^c ns, not significant at the 5% level.

Table 76. Comparative responses of the whitefly *Trialeurodes vaporariorum* and its parasitoids *Encarsia nigricephala* and *Amitus fuscipennis* to different insecticides

Insecticide	CL ₅₀ <i>T. vaporariorum</i>	CL ₅₀ parasitoid	Response ratio
<i>E. nigricephala</i>			
methamidophos	5.30 ^a	0.670	7.91
methomyl	0.25 ^a	0.009	27.77
carbosulfan	1.80 ^b	0.090	20.00
cypermethrin	37.0 ^a	0.650	56.92
<i>A. fuscipennis</i>			
bifenthrin	2.40 ^b	0.023	104.35
carbofuran	1.97 ^a	0.074	26.62

^a As determined by Cardona et al. (2001)

^b As determined by Rodríguez et al. (2003).

Progress towards achieving output milestones:

Characterizing and monitoring pathogen diversity / stable strategies for managing pathogens developed.

- The varieties Widusa, Kaboon and G 2333 continue to be effective against all characterized races of *C. lindemuthianum* in Colombia.
- A transformation system for *P. griseola* was developed. This is an important tool in the elucidation of host-pathogen interaction and in pathogenicity gene isolation.
- The nature of immunity of G 10474 was elucidated. This information can be used to devise new ALS management strategies.
- *Pythium* isolates (134) from root rot affected areas in Kenya and Rwanda were characterized by sequencing of ITS-1 region. *P. ultimum* was the most frequent occurring species followed by *P. torulosum*.
- *Pythium* distribution maps showing relative importance of characterized species in Kenya and Rwanda were developed.
- White fly monitoring in the Cauca valley of Colombia demonstrates that *Bemisia tabaci* biotype B has displaced biotype A in most areas in a lapse of seven years.
- Natural enemies of *Bemisia* tend to be much more susceptible than *Bemisia* to common insecticides, although a directed effort to select resistant natural enemies might improve their ability to survive.

Activity 3.2 Characterizing disease and insect resistance genes

Highlights:

- At least two resistance genes condition resistance of G 9833 to four races of *C. lindemuthianum*. The resistance genes in G 9833 are distinct from those in the Andean genotypes Michigan dark red kidney, Kaboon and Perry Marrow, and might be a new Andean resistance locus.
- Two AFLP markers linked to angular leaf spot resistance in Mexico 54 and G 10474 were successfully converted to STS markers and protocols for their use in MAS were developed. Similarly, the RAPD marker OPE4₇₀₉ linked to ALS resistance gene in Mexico 54 was converted to a SCAR marker and a protocol was developed.
- Two AFLP-derived SCAR markers (PF9 and PF11) were developed for G 10474 and Mexico 54.
- The allelic relationship of ALS resistance genes in Mexico 54 with G 10474, G 10909, G 10613, and Cornell 49242 were elucidated.
- Inheritance of resistance to *Pythium* root rot in five resistant genotypes was shown to be conditioned by single dominant genes. Allelism test using the diallel mating scheme revealed that the resistance is conditioned by the same resistance locus.
- Further progress was made on developing a SCAR marker for resistance to *Apion godmani*. A total of seven RAPD bands were cloned and five single copy markers developed which mapped to the same locations as the original RAPDs. In addition a peroxidase fragment was cloned from one of the chromosomal regions with the most consistent *Apion* resistance gene. These markers provide potential assays for use in marker assisted selection.
- Microsatellite and SCAR markers were evaluated for their utility in populations segregating for geminivirus resistance in a collaborative project with the University of Puerto Rico.

3.2.1 Nature and inheritance of angular leaf spot resistance in G 9836 and G 10613

Rationale: Elucidating the nature and inheritance of resistance to angular leaf spot of common bean is one of the activities that has gained precedence in the bean program, because angular leaf spot has become one of the most important diseases in all bean-producing countries in the tropics. To effectively exploit the diversity in bean genes to combine and pyramid useful genes, sufficient characterization of the genetics of resistance is necessary. This is also a prerequisite to tagging these genes and developing an efficient marker assisted selection program. The ultimate objective of this study is to identify diverse sources of ALS resistance and to develop molecular markers that can be used to aid the transfer of ALS resistance to well-adapted market class type bean.

Materials and Methods: This year, we studied the nature of ALS inheritance in two genotypes, G 9836 and G 10613. These genotypes are currently being used in our breeding program. Populations (F₁, F₂, and F₁ backcrosses to resistant and susceptible parents) were made using the variety Sprite as the susceptible parents. Populations were developed as reported previously (CIAT 2003). Greenhouse disease evaluations, and data analysis were done as described

previously (CIAT 2003). Evaluations for disease severity were assessed using a CIAT 1 – 9 scale, where 1 represents no visible symptoms and 9 = severe symptoms and disease expression. Ratings of 1 to 3 were considered resistant and ratings > 4 as susceptible. Area under disease progress curves was calculated to assign genotypes to resistance and susceptibility classes. Several different genetic hypotheses were tested for each population using a Chi-squared test in the SAS program.

Results and Discussions:

G 9836: The observed segregation ratios from F₁, F₂, and back cross to resistant (BC1-R) and susceptible (BC1-S) parents revealed a tendency towards recessive expression of the genes conditioning resistance to *P. griseola* in G 9836 (Table 77). The majority of the F₁ plants and almost all backcross plants to the susceptible parent were infected, revealing that resistance is recessive. It is possible that resistance of G 9836 to race 63-63 is conditioned by a single recessive.

G 10613: All F₁ plants were resistant to pathotype 63-63, revealing a tendency towards a dominant gene conditioning resistance of G 10613 to Pg pathotype 63-63. A 3:1 segregation ratio in the F₂ population revealed that a single dominant gene conditioned ALS resistance of G 10613 to pathotype 63-63 (Table 77).

Table 77: Nature and inheritance of angular leaf spot resistance in some differential varieties and selected resistant sources.

Source	Generation	Observed (R:S)	Expected	X ²	P
G 9836 x Sprite	F ₂	44: 110	1: 3	1.04	0.31
G 9836 x Sprite	F ₁	14:26			
G 9836 x Sprite	BCS	1:39	0:1	0.93	0.34
G 10613 x Sprite	F ₂	137:58	3:1	2.34	0.13
G 10613 x Sprite	F ₁	24:0	1:0	0	1.0
G 10613 x Sprite	BCS	13:7	1:1	1.8	0.19

Conclusion: These results make it difficult to conclude with certainty the nature of inheritance in these two genotypes, especially in G 9836. That said, it is probable that a recessive gene(s) conditions ALS resistance in G 9836 and that in G 10613 is conditioned by a dominant gene(s). The segregation ratios observed could reflect two genes that are linked. More studies are needed before firm conclusions about the nature of inheritance in these genotypes can be drawn.

References:

CIAT 2003. Annual Report, Bean Program 2003. CIAT, Cali, Colombia.

Contributors: G. Mahuku, C. Jara, J. Fory, G. Castellanos, S. Beebe

3.2.2 Allelism test for angular leaf spot resistance genes from several potential sources

Rationale: Several source of ALS resistance have been identified. Last year, we elucidated the nature of ALS resistance in some of these sources. It is important to establish the allelic relationships between these genes, and avoid using the same resistance gene that might be found in different genotypes. This study was carried out to test the independence of the resistance gene(s) in these potential sources of resistance.

Materials and Methods: Forty-five crosses were made between the different combinations of sources of resistance and the plants advanced to F₂ (Table 78). Because of the quantity of the populations involved, lack of greenhouse space, and the need to rapidly get information, we decided to first evaluate 100 individual plants from each cross, and in cases where a conclusive result was not obtained, to increase the number of F₂ plants with another 100 plants, until a conclusive result is obtained. During the course of this year, populations for 6 populations have been evaluated. Plant establishment, inoculum production, inoculations and disease evaluations were as described previously (CIAT 2003).

Table 78. Crosses for to test the independence of angular leaf spot resistance genes

	MEX 54	Cornell	MAR 1	MAR 2	AND 277	G 10613	G 10474	G 10909	G 4691
G 5686	X	X	X	X	X	X	X	X	X
MEX 54	-	X	X	X	X	X	X	X	X
Cornell		-	X	X	X	X	X	X	X
MAR 1			-	X	X	X	X	X	X
MAR 2				-	X	X	X	X	X
AND 277					-	X	X	X	X
G 10613						-	X	X	X
G 10474							-	X	X
G10909								-	X

Results and Discussion: Pathotypes that had an R x R reaction with the two genotypes involved in the cross were used for evaluations (Table 79). These results reveal that Mexico 54 carries different ALS resistance gene (s) from the one in G 10909 and probably Cornell 49242. A lack of segregation in Mexico 54 x G 10613 revealed that the gene conditioning resistance to pathotype 31-39 occupies the same locus in both genotypes. Allelism studies by Caixeta et al. (2002) using pathotype 31-55, revealed that Mexico 54 carried three ALS resistance genes *Phg-2*, *Phg-5*, and *Phg-6*. It is possible that one of these genes is the same as the one in G 10613. The segregation ratios observed in the G 10474 x Mexico 54 cross suggest the presence of as many as three resistance genes but there is a need to carry out progeny testing to confirm segregation. Inheritance studies have revealed that G 10474 carries a single dominant gene while Mexico 54 has three resistance genes, and one of them is recessive (Mahuku et al., 2003). In the cross MAR 1 x G 10474, no segregation was observed, revealing that the resistance genes in these two genotypes occupy the same loci. However, given the resistance spectrum displayed by these two genotypes, it appears that G 10474 contains a different allele that that found in MAR 1. Looking at the pedigree of MAR 1, the resistance source is derived from Cornell 49242. Allelism test involving G 10474 x Cornell 49242, once done, will confirm this conclusion. The segregation ratio of the G 10474 x G 10613 (63R: 1S) also suggest three independent genes segregating, but

this is pending progeny testing. A similar result was obtained in the Mexico 54 x G 10474 population, while Mexico 54 x G 10613 showed no segregation.

Table 79. Test for the independence of the resistance genes in F₂ populations derived from crossing different sources of angular leaf spot resistance

Cross	Race	Observed (R:S)	Expected	X ²	P	Conclusion
G10613*G10474	15-59	118:2	63:1	0.008	0.93	Three genes segregating
MAR1*G10474	7-7	117:0	1:0	0.000	1.00	A gene occupying the same loci
MEX54*CORNELL 49292	31-7	102:10	57:7	0.460	0.50	3 genes, 2 dominant, 1 recessive
MEX54*G10474	1-7	92:2	63:1	0.195	0.66	Three dominant genes
MEX54*G10613	31-39	109:0	1.0	0.000	1.00	A gene occupying the same loci
MEX54*G10909	7-35	72:21	3:1	0.290	0.59	Two independent genes

Conclusion:

More information regarding the relationship between the different sources of resistance will be obtained when the studies of independence are completed, and with progeny testing of the G 10474 x G 10613 and Mexico 54 x G 10474 crosses. However, it appears that G 10613 shares resistance loci with Mexico 54, while MAR 1 shares a resistance locus with G 10474.

References:

- Caixeta, E.F., A. Borém, N.G, de Moraes Silvia, R.C. Rocha, R.C., E.G. de Barros, and M.A. Moreira. 2002. Teste de alélismo para genes do feijoeiro que conferem resistência ao fungo *Phaeoisariopsis griseola*. VII Congresso Nacional de Pesquisa de Jeijão. Universidade Federal de Vicosa, Vicosa-MG, Brazil. Setembro 8 a 12 de 2002.
- CIAT 2003. Annual Report, Bean Program 2003. CIAT, Cali, Colombia annual
- Mahuku, G., Jara, C., Cajiao, C., and Beebe, S. 2003. Sources of angular leaf spot (*Phaeoisariosis griseola*) in common bean core collection, wild *Phaseolus vulgaris* and secondary gene pool. *Euphytica* 130: 303-313
- Mahuku, G., C. Jara, H. Teran, and S. Beebe. 2003b. Inheritance of angular leaf spot resistance in selected common bean genotypes. *Ann. Rep. Bean Improv. Coop.* 46:151-152.

Contributors: C. Jara, J. Fory, G. Castellanos, G. Mahuku, S. Beebe

3.2.3 Inheritance of anthracnose resistance in the Andean germplasm accession G 19833

Rationale: Previous characterizations of resistance genes in G 19833 (Bean annual report 2003) revealed that this contains dominant and recessive genes for resistance against several Andean and Mesoamerican pathotypes of *C. lindemuthianum*, including 3481, a pathotype that overcomes the genotype G 2333, that contains three resistance genes (*Co-4*², *Co-5*, *Co-7*). We report further resistance gene characterization using another widely distributed *C. lindemuthianum* pathotype 65. In addition, this race was selected in order to confirm whether G 19833 carries an allele of the *Co-1* locus, the only anthracnose resistance loci described in Andean genotype.

Materials and Methods: 200 F₂ plants from the G 19833 x La Victorie, were inoculated with *C. lindemuthianum* race 65 under greenhouse conditions. Plant establishment and handling, inoculum production, inoculation and disease evaluations were done as described previously (CIAT 2003).

Results and Discussion: Of the 200 F₂ inoculated with pathotype 65, 170 were resistant while 30 were susceptible. Chi-square (X^2) analysis revealed a segregation ratio of 57:7, suggesting that resistance to pathotype 65 is probably a result of three resistance genes, two dominant and one recessive.

Conclusion: These results suggest that G 19833 contains three independent resistance genes. However, we need to test the F₁ and backcross population to resistant and susceptible parents to confirm the presence of three resistant genes. If resistance genes are linked, this would confound conclusions.

References:

CIAT 2003. Annual Report, Bean Program 2003. CIAT, Cali, Colombia.

Contributors: G. Mahuku, C. Jara, J. Fory, G. Castellanos, H. Terán, S. Beebe

3.2.4 Allelism test for anthracnose resistance genes in the germplasm accession G 19833

Rationale: G 19833 has been highly resistant to *C. lindemuthianum* isolates known to infect genotypes that carry the only known anthracnose resistance gene of Andean origin (*Co-1*). Several alleles of this resistance gene have been characterized in Widusa (*Co-1*⁵), Michigan Dark Red Kidney (*Co-1*); Perry Marrow (*Co-1*³) and Kaboon (*Co-1*²). This study was carried out to test the independence of the resistance gene(s) in G 19833 from the *Co-1* gene and establish if the resistance gene(s) in G 19833 were the same or different from the *Co-1* alleles in the cultivars Michigan Dark Red Kidney, Kaboon, Widusa and Perry Marrow (Melotto et al, 2000). Identifying another resistance loci in the Andean gene pool would be useful to diversify the Andean resistance genes to use in breeding programs and to avoid the dependence on a single multi-allelic gene.

Materials and Methods: Two hundred F₂ plants per population derived from crossing G 19833 x Kaboon, G 19833 x Perry Marrow, G 19833 x Michigan Dark Red Kidney (MDRK) and G 19833 x Widusa were inoculated independently using two *C. lindemuthianum* races (race 65 and 521) (Table 80). All bean varieties used in the crosses are resistant to these two races. Inoculum production, plant handling, inoculations and disease evaluations were done as described previously (CIAT, 2003). A plant with no visible symptoms or with only a few, very small lesions mostly on the primary leaf veins was scored as resistant (rating 1 to 3). A plant with numerous small or enlarged lesions, or with sunken cankers on both the lower sides of leaves and the stems was recorded as susceptible (rating 6.1 to 9). A plant with a rating score of (3.1 – 6) was considered as intermediate.

Table 80. Gene pool, described anthracnose resistance genes and disease reaction of bean cultivars inoculated with different races of *C. lindemuthianum*.

Genotype	Gene Pool	R-gene	Anthracnose race	
			65	521
MDRK	A	<i>Co-1</i>	R	R
Perry Marrow	A	<i>Co-1³</i>	R	R
Kaboon	A	<i>Co-1²</i>	R	R
Widusa	A	<i>Co-1⁵</i>	R	R
G 19833	A	?	R	R

Results and Discussion: Inoculation of the G 19833 x MDRK, Perry Marrow and Kaboon with race 521 revealed that three independent resistance genes were segregating in this population (Table 81). A similar result was observed when the same population was inoculated with race 65 ($X^2 = 0.12$; $P = 0.72$) These results reveal that G 19833 carries three resistance genes that condition resistance to *C. lindemuthianum* races 521 and 65. A similar result was observed in another background (G 19833 x Perry Marrow (*Co-1³*)). However, when G 19833 was crossed with Widusa (*Co-1⁵*) and inoculated with race 65, a segregation ratio of 15:1 ($P = 0.88$) was observed, indicative of two independent resistance genes (Table 81).

Table 81. Test for the independence of the resistance genes in F₂ populations derived from crossing G 19833 with Kaboon, MDRK, Widusa and Perry Marrow

Cross	Race	Obs (R:S)	Esp	X ²	P	Conclusion
G 19833 x MDRK	65	198: 2	63: 1	0.12	0.72	3 dominant and independent genes
G 19833 x MDRK	521	194: 6	61: 3	1.27	0.26	3 genes,2 dominant; 1 recessive
G 19833 x PM	65	195: 5	63: 1	1.14	0.29	3 dominant and independent genes
G 19833 x PM	521	193: 7	61: 3	0.63	0.43	3 genes,2 dominant; 1 recessive
G 19833 x KAB	65	188: 12	15 : 1	0.02	0.88	2 dominant and independent genes
G 19833 x KAB	521	195: 5	63: .1	1.14	0.29	3 dominant and independent genes
G 19833 x Widusa	65	187: 13	15 : 1	0.02	0.88	2 dominant and independent genes

Conclusion: The segregation ratios observed reveal that G 19833 may carry three resistance genes that are different from the gene carried by MDRK (*Co-1*), Perry Marrow (*Co-1*³), Kaboon (*Co-1*²) and Widusa (*Co-1*⁵). There is a need to test F₂ derived families of all crosses, to confirm that susceptible plants are segregating, and to be able to conclusively and confidently describe another Andean locus for anthracnose resistance in the Andean genotype G 19833.

References:

- CIAT 2003. Annual Report of the Bean Program 2003. CIAT, Cali, Colombia
- Melotto , M., and Kelly, J.D. 2000. An allelic series at the Co-1 locus conditioning resistance to anthracnose in common bean of Andean origin. *Euphytica* 116: 143-149.

Contributors: G. Mahuku, C. Jara, J. Fory, G. Castellanos, J.B. Cuasquer, H. Teran, S. Beebe

3.2.5 Inheritance of resistance to *Pythium* root rot and allelic relationship of resistance genes among resistant bean genotypes

Rationale: Last year we showed that resistance in three important sources (RWR 719, AND 1062 and MLB-49-89) against *Pythium* root rot was controlled by single dominant genes, which were simply inherited. This information is useful in designing effective strategies for cultivar improvement. Other potential resistant sources include AND 1055, SCAM 80-CM/15, RWR 1092 and MLB-40-89A. Because they consist of small, medium and large seeded materials, their utility is influenced by the genetic background (gene pool) of varieties to be improved. Small (e.g. RWR 719) or large (AND 1062) seeded types are better suited in the improvement of small or large seeded types respectively. The objective of this study was therefore to determine the nature and mode of inheritance of resistance in additional resistant lines (AND 1055 and SCAM 80-CM/15). To efficiently use the resistant genotypes, we also studied their allelic relationships.

Materials and Methods: More breeding populations (F₁, F₂, and F₁ backcrosses to resistant and susceptible parents) were generated for the three *Pythium* root rot resistant lines evaluated last year (RWR 719, AND 1062 and MLB-49-89A) using different susceptible parents (GLP 585, CAL 96 and Urugazi). Resistant cultivars AND 1055 and SCAM 80 –CM/15 were also used to generate breeding populations by crossing them to the four susceptible genotypes. Sixty seeds from each parent, 60 F₁, 300 F₂, 90 from backcross to susceptible parent (BCs) and 90 from backcross to resistant parent (BCr) were evaluated using *P. ultimum* as described under 2.1.1 above. Resistant (R) phenotype was assigned to plants with no or limited symptoms (score 1-3), whereas plants graded 5 or greater were considered to be susceptible (S). The data obtained was tested for goodness of fit to expected theoretical ratios with chi-square test.

Allelic relationships for resistance to *Pythium* root rot was determined in seven resistant genotypes, RWR 719, MLB-49-89A, AND 1062, AND 1055, SCAM 80-CM/15, RWR 1092 and MLB 40-89A. Twenty-one sets of crosses were made between the resistant cultivars to generate F₁ and F₂ populations. Ninety seed from each of the latter were evaluated against *P. ultimum* as already described above.

Results and Discussion: All the five cultivars, RWR 719, AND 1062, MLB-49-89A, AND 1055 and SCAM 80-CM/15 were resistant to *P. ultimum*. In contrast and as expected GLP 2, GLP 585, CAL 96 and Urugezi were susceptible under similar conditions. All F₁ families were resistant. Chi-square values for all resistant-susceptible combinations (Table 82) showed a good fit for segregation ratio of 3:1 (resistant to susceptible) in F₂, 1:1 in all F₁ backcrossed to susceptible cultivars (test cross population), and 1:0 in F₁ backcrossed to the five resistant genotypes. These results confirmed previous observations that resistance in AND 1062, RWR 719 and MLB-49-89A was controlled by a single dominant gene in each cultivar. Similar results were also observed for AND 1055 and SCAM 80-CM/15.

Table 82. Segregation for reaction to *Pythium ultimum* among F₂ plants, and test cross generations derived from crosses between four susceptible and five resistant bean genotypes, Kawanda, Uganda, 2004.

Cross	Number of plants segregating for <i>Pythium</i> reaction and X ² values								
	F ₂ ^x			BCs			BCr		
	R	S	X ^{2y}	R	S	X ²	R	S	X ²
RWR719 x GLP 585	217	84	1.364 ^{ns}	41	49	0.722 ^{ns}	86	4	0.00
RWR 717 x CAL 96	228	71	0.296 ^{ns}	40	49	0.911 ^{ns}	88	1	0.00
RWR 719 x Urugezi	218	81	0.647 ^{ns}	48	42	0.411 ^{ns}	90	0	0.00
MLB-49-89A x GLP 585	212	87	2.485 ^{ns}	44	46	0.055 ^{ns}	81	9	0.00
MLB-49-89A x CAL 96	215	84	1.410 ^{ns}	42	47	0.322 ^{ns}	90	0	0.00
MLB-49-89A x Urugezi	223	76	0.021 ^{ns}	42	47	0.260 ^{ns}	90	0	0.00
AND 1062 x GLP585	210	81	1.471 ^{ns}	42	48	0.411 ^{ns}	88	2	0.00
AND 1062 x CAL 96	206	75	1.680 ^{ns}	43	46	0.084 ^{ns}	90	0	0.00
AND 1062 x Urugezi	210	90	3.871 ^{ns}	48	41	0.543 ^{ns}	90	0	0.00
AND 1055 x GLP2	216	84	1.364 ^{ns}	42	47	0.260 ^{ns}	90	0	0.00
AND 1055 x 585	233	67	1.213 ^{ns}	45	45	0.011 ^{ns}	87	3	0.00
AND 1055 x CAL 96	221	78	0.169 ^{ns}	38	45	1.072 ^{ns}	88	1	0.00
AND 1055 x Urugezi	218	81	0.770 ^{ns}	39	51	1.611 ^{ns}	88	2	0.00
SCAM 80-CM/15 x GLP 2	182	74	8.050 ^{ns}	53	36	2.986 ^{ns}	90	0	0.00
SCAM 80-CM/15 x GLP 585	222	77	0.067 ^{ns}	43	46	0.134 ^{ns}	90	0	0.00
SCAM 80-CM/15 x CAL 96	214	85	1.882 ^{ns}	40	49	0.911 ^{ns}	90	0	0.00
SCAM 80-CM/15 x Urugezi	221	78.	0.188 ^{ns}	43	46	0.167 ^{ns}	90	5	0.00

^x Expected ratio for F₂, BCs and BCr is 3:1, 1:1 and 1:0 respectively.

In allelic studies, all parents were resistant to *P. ultimum*. Similarly, all F₁ families were resistant. There was no resistant-susceptible segregation in F₂ populations. These results imply that the seven cultivars have a common locus with a gene(s) conditioning resistance to *Pythium* root rot and inherited as a dominant character.

Contributors: R. Otsyula (graduate student), R. Buruchara, S. Sebuliba, P. Kimani

Collaborators: G. Mahuku, M. Blair.

3.2.6 Identifying and developing molecular markers linked to ALS resistance genes

Rationale: The emphasis in 2003 was to test and validate AFLP-derived markers that were identified in 2002 for G 10474, G 10909, Mexico 54 and MAR 1, and where possible, develop protocols for their use in marker assisted selection breeding programs. Our approach has been to first convert polymorphic AFLP markers to SCARs, then evaluating the potential SCAR markers on the entire F₂ segregating populations, so as to have markers that are useful to our NARS partners, as well as reducing the cost of marker development. This year, we concentrated on further refining these markers; identifying new markers and validating identified markers to establish their utility for MAS.

Materials and Methods:

OPE4₇₀₀ marker: Previous studies identified a RAPD marker OPE4₇₀₉ that is tightly linked (in coupling) to the resistance gene in Mexico 54 (0 cM). For easy of use of this marker, we cloned and sequenced the 700bp fragment and designed longer primers for specificity. These primers were tested in the entire F₂ population and used to amplify several parents that are routinely used in our breeding program (G 10474, G 10613, MAR 1, VAX 6 and G 10909), and genotypes belonging to the angular leaf spot differential series. For eventual mapping of this marker, both the OPE4₇₀₉ SCAR marker and RAPD primer were used to amplify the DOR 364 x G 19833 RIL population.

SCAR PF 11: An AFLP-derived SCAR marker was identified for Mexico 54. Subsequent tests and validation on the parents and respective bulks revealed that it was co-dominant. The SCAR was tested in 166 F₂ plants, differential varieties and breeding parents.

SCAR PF9 260 G1: The fragment of an AFLP marker linked in coupling with the resistance gene in G 10474 (E-AAC/M-CAT) that was previously identified (CIAT 2003), was cloned, sequenced and specific primers developed. The marker was used to amplify parental DNA, and DNA extracted from a bulk of 10 resistant and 10 susceptible individuals. Once polymorphism was confirmed, the marker were tested on 10 resistant and 10 susceptible individuals, before being evaluated on 246 F₂ individuals obtained from a G 10474 x Sprite cross, (111 inoculated with pathotype 7-35 and 135 inoculated with pathotype 63-63). The distance of the marker from the resistance gene was estimated using the program MAPMAKER. Validation of the SCAR marker outside the mapping population was done by amplifying DNA from genotypes representing the ALS differential series (constituting of 6 Mesoamerican genotypes and 6 Andean genotypes) and 14 additional genotypes that are currently being used as parents for the improvement of ALS resistance.

Results and Discussion: The SCAR-OPE4₇₀₀ was dominant and linked in coupling to the resistance gene in Mexico 54 (Figure 58). The marker was present in some susceptible F₂ plants and in all resistant F₂ plants (Figure 58). This is not surprising, as previous inheritance studies revealed that a single recessive gene conditioned resistance of Mexico 54 to race 31-55 of *P. griseola* (Mahuku et al., 2003). The marker was not present in any differential variety except Mexico 54 (Figure 59B).

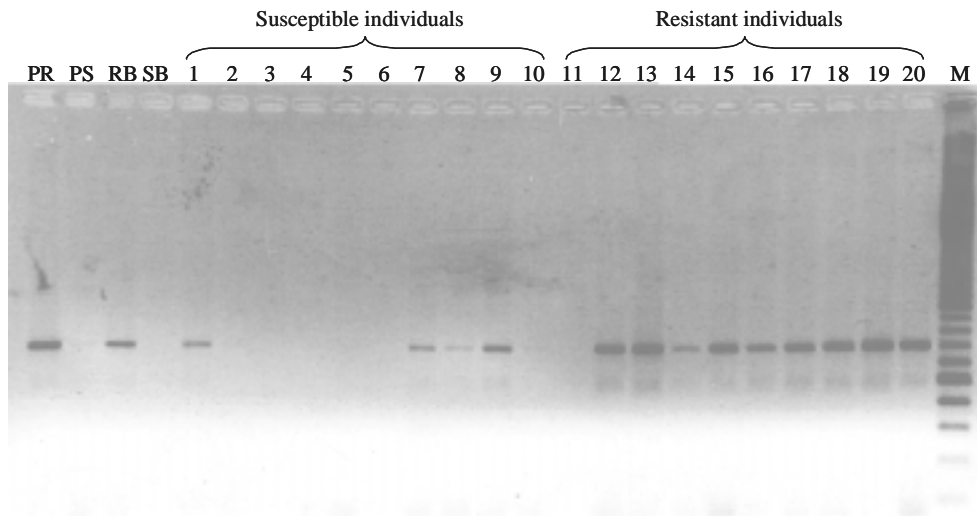


Figure 58. PCR amplification of F₂ individuals of a Mexico 54 x Sprite cross using the OPE4₇₀₉ SCAR marker. PR is resistant parent Mexico 54, PS is susceptible parent Sprite, RB is resistant bulk, SB is susceptible bulk and M is the 100 bp molecular size marker.

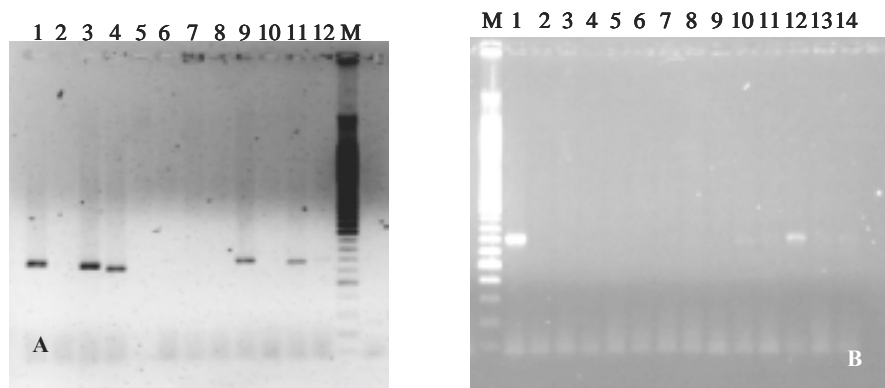


Figure 59. PCR amplification of sources of angular leaf spot resistance and parents used in improvement of ALS resistance in bean using the OPE4₇₀₉ SCAR marker. (A) From left to right, lanes 1–12 are Mex 54, Sprite, G10474, G10909, Mar 2, AND 277, AND 279, G 9603, G 4032, G 3991, G 5653, Mar 3. Lane M is the molecular size marker. (B) Mex54, Sprite, Timoteo, G11796, Bolon Bayo, Montcalm, Amendoim, G5686, PAN72, G5828, Flor de Mayo, Mex 54, BAT332, Cornell]

Amplification of other sources of ALS resistance including genotypes normally used in our breeding program, revealed the band in G 10909, G 10474, G 4032, G 5653 and MAR 2 (Figure 59A), but the fragment was smaller than the one in Mexico 54, revealing that this marker can be used in crosses involving Mexico 54 and these genotypes. Similar results were observed for MAR 1 and DOR 364.

On the cross of G 10909 and Sprite, the SCAR marker was co-dominant (Figure 60) and could distinguish between homozygous and heterozygous individuals. This marker is currently being evaluated on the entire G 10909 x Sprite mapping population to ascertain the distance of the marker from the resistance gene. However, results from this study reveal that this is another useful marker when G 10909 is used as a parent in ALS improvement.

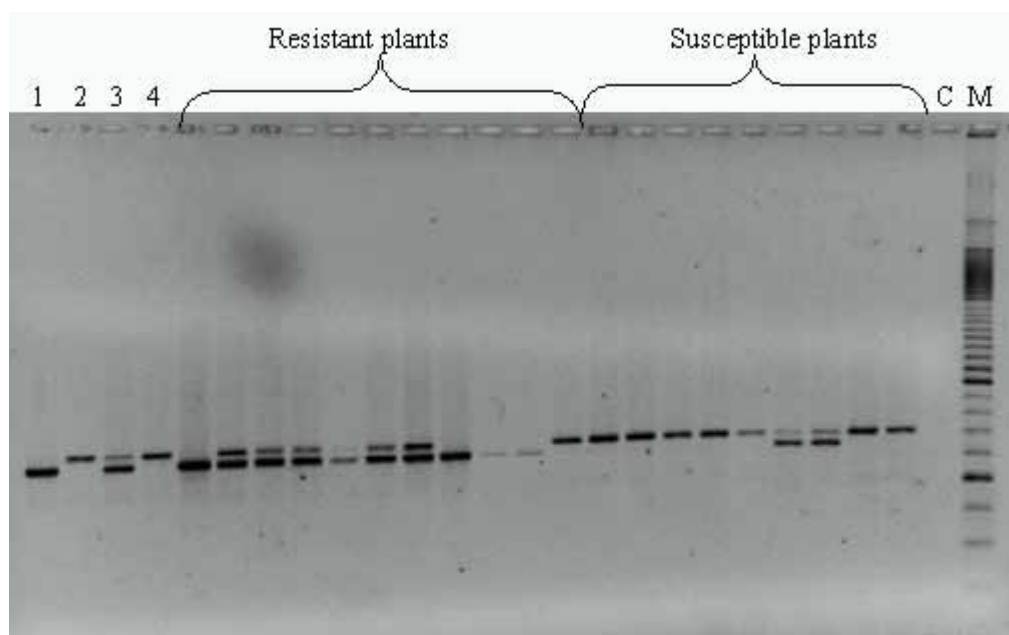


Figure 60. PCR amplification of F_2 individuals of a G 10909 x Sprite cross using the OPE4₇₀₉ SCAR marker. Lane 1 is G 10909, Lane 2 is Sprite, Lane 3 Resistant bulk and Lane 4 is susceptible bulk., C is negative control and M is 100 bp molecular size marker.

SCAR PF 11: An AFLP derived SCAR marker (PF 11) was identified linked in coupling to the resistance gene in Mexico 54. When evaluated on F_2 segregating population, the marker was co-dominant (Figure 61). This marker is currently being evaluated in the entire F_2 mapping population, and outside the mapping population to establish its suitability for MAS.

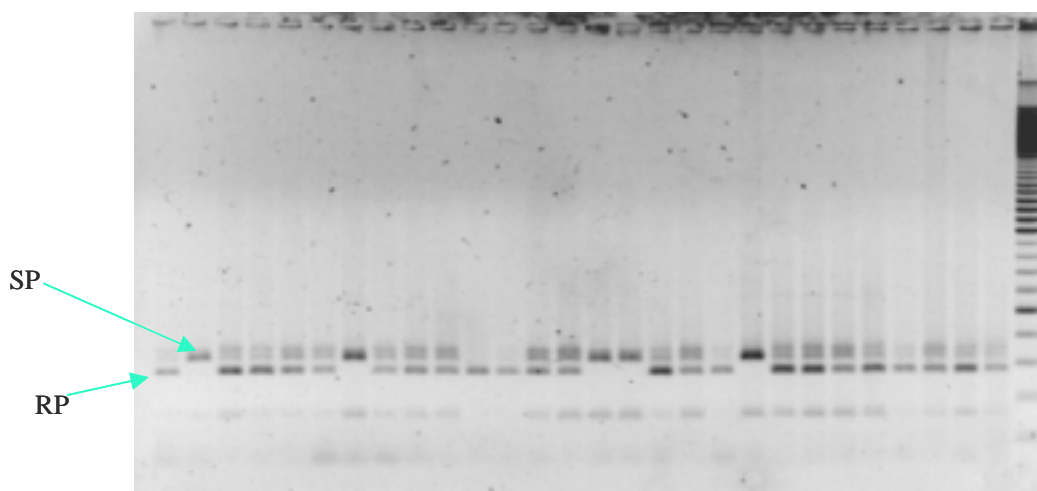


Figure 61. PCR amplification of F₂ plants from a Mexico 54 x Sprite cross using the AFLP-derived SCAR marker PF11. RP is resistant parent, Mexico 54, SP is susceptible parent, Sprite. The rest are individual F₂ plants that are either homozygous susceptible, homozygous resistant or heterozygous resistant.

SCAR PF9 260 G1: A second co-dominant SCAR marker was developed for G 10474. Analysis showed that this marker is 3.0 cM from the resistance gene. Amplification of susceptible and resistant individuals and parents produced a 280 bp band in the resistant parent and individuals and a 300 bp fragment in the susceptible parent and individuals (Figure 62). Evaluation of the differential varieties showed that this marker was present in some Andean genotypes and absent from others (Figure 62). However, it was largely absent from Mesoamerican differential genotypes, showing that this marker can be used to introgress the G 10474 gene into Mesoamerican genotypes. However, a parental survey should first be done to verify the utility of this marker in the parents that are being used before it is deployed in MAS involving G 10474. We are in the process of developing a protocol for the use of this marker in MAS.

Conclusion: A RAPD marker OPE4700, linked in coupling with the resistance gene in Mexico 54 was successfully converted to a SCAR marker. Validation of this marker showed that it was present in some genotypes, albeit with a different fragment size, revealing that it can be used to introgress this gene into Andean and Mesoamerican genotypes. The SCAR was polymorphic in the G 10909 mapping population, being co-dominant. Studies are underway to determine the location of the marker relative to the resistance genes are in progress. Another marker, PF11 was identified for Mexico 54 and successfully converted to a co-dominant SCAR. A third marker (PF9) located at 3.0 cM from the resistance gene in G 10474 was identified. The protocol for the use of this marker is currently being developed.

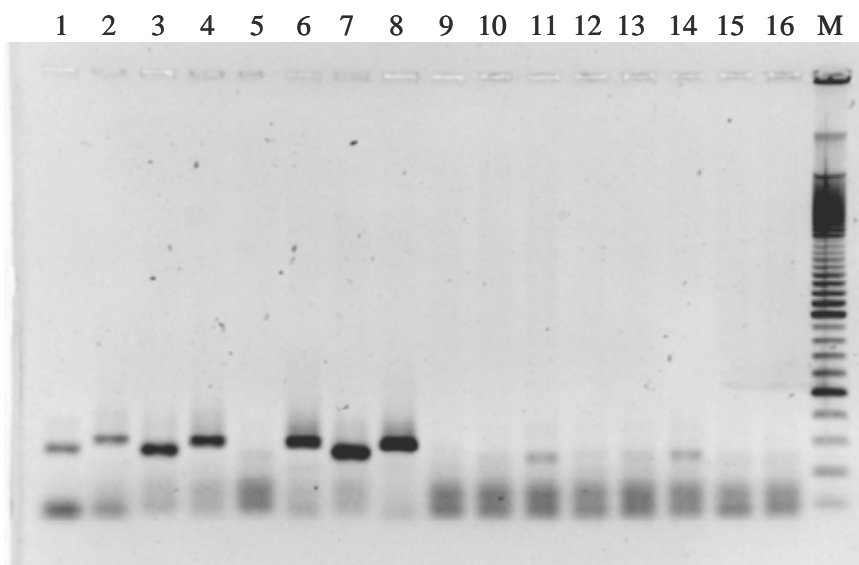


Figure 62. Amplification of the angular leaf spot differential genotypes using the AFLP-derived SCAR marker PF9 that is linked to the resistance gene in G 10474. Lanes 1-16 are G10474, Sprite, Bulk R, Bulk S Timoteo, G11796, Bolon Bayo, Montcalm, Amendoim, G5686, PAN72, G5828, Flor de Mayo, Mex 54, BAT332, Cornell.

References:

CIAT 2003. Annual Report, Bean Program 2003. CIAT, Cali, Colombia.

Mahuku, G., Jara, C., Cajiao, C., and Beebe, S. 2003. Sources of angular leaf spot (*Phaeoisariosis griseola*) in common bean core collection, wild *Phaseolus vulgaris* and secondary gene pool. *Euphytica* 130: 303-313

Contributors: M.A. Henriquez, C. Montoya, G. Mahuku, H. Terán, S. Beebe

3.2.7 Development of SCAR markers for Apion resistance

Rationale: The bean pod weevil (*Apion goodmani* Wagner) is a destructive insect pest that damages beans grown in Mexico and Central America. Resistance is controlled by two possible mechanisms – either antibiosis involving a hypersensitive response that encapsulates the oviposition site – or antixenosis that affects the preference of oviposition sites. Epistasis between two independent genes, *Agr* and *Agm*, has been suggested to control the hypersensitive response. The fact that a few genes control resistance may explain why it has been relatively easy to transfer resistance from Mexican landraces where it is found to new breeding lines with Central American grain types. The objective of this research was to create additional SCAR markers linked to the genes controlling resistance in the recombinant inbred line (RIL) population derived from the cross Jamapa x J117.

Methodology:

Plant material: Plant material consisted in susceptible and resistant bulks (4 lines each) selected from 104 F₅-derived recombinant inbred lines (RILs) of the cross Jamapa x J117. Jamapa is a susceptible cultivar released in Mexico and J117 is a resistant landrace. The population has been evaluated in Mexico for Apion resistance over five seasons.

RAPD cloning: RAPD bands were purified from 1% low melting point agarose gels using Wizard PCR prep purification system (Promega). The purified insert DNA was cloned into the PGEM-T easy vector system for further analysis. Several recombinant clones were picked per ligation reaction, checked with *EcoRI* digestions, and their inserts sequenced using standard techniques, T7 and Sp6 primers, Big Dye sequencing kits and an ABI377 DNA sequencer.

SCAR primer design and CAPs assays: Specific primers were designed for each unique cloned RAPD sequence using Primer 3.0 software and these were tested for their ability to amplify SCAR products. Any monomorphic SCAR products were digested with frequent cutting restriction enzymes (*AluI*, *CfoI*, *HaeIII*, *Hsp92II*, *MboI*, *RsaI* and *Sau3AI*) to convert the markers into CAPS (Cleaved Amplified Polymorphisms).

Results and Discussion:

A total of seven RAPD bands, U1₁₄₀₀R, F10₅₀₀S (on linkage group b01), M12₈₀₀S (b07), C1₈₀₀S (b08), B1₁₄₀₀R, R20₁₂₀₀CS (b11) and W6₈₀₀R (unlinked), that were polymorphic from the parental survey and which were significantly associated with the resistance phenotype were selected for cloning. This brings to a total of nine the bands that have been targeted including W9₁₃₀₀S and Z4₈₀₀R which were converted to SCARs last year. BLAST searches identified homologies for several of the nine cloned RAPD bands (Table 83). Several clones had homologies to retrotransposons from a range of dicotyledonous species. This is a common feature of cloned RAPD bands. Two of the clones were similar to gene sequences from soybean: 1) Z4₈₀₀R with similarity to an unknown gene and 2) F10₅₀₀S with similarity to a seed coat peroxidase.

Table 83. Development of SCAR and CAPS markers from RAPD bands that were significantly associated with *Apion godmani* resistance in common bean.

RAPD band	Linkage group	Aprox. Size	Blastx results	No. of primer sets	SCAR polym	CAPS polym.
W9 ₁₃₀₀ S	b01	1300	Retrotransposon	1	-	+ AluI
Z4 ₈₀₀	b01	800	Unknown gene	1	-	-
U1 ₁₄₀₀ R	b01	1400	Glycine max NS	1	-	-
F10 ₅₀₀ S	b01	500	Peroxidase Glycine max	4	-	-
M12 ₈₀₀ S	b07	800	NS	1	-	-
C1 ₈₀₀ S	b08	800	NS	1	-	+ RsaI
B1 ₁₄₀₀ R	b11	1400	Retrotransposon Cicer	2	-	+ TaqI
R20 ₁₂₀₀ CS	b11	1200	Retrotransposon Arabidopsis	2	-	+ AluI, MboI
W6 ₈₀₀ R	unlinked	800	NS	2	+	Na

SCAR and CAPS development is also summarized in Table 83. A total of 15 primer sets were designed for the nine RAPD band sequences and these were tested on the population parents and on the bulks. Most of the PCR products of these primer sets, except those derived from W6₈₀₀R, were monomorphic as SCARs. A single SCAR (W6₈₀₀R) showed a polymorphic fragment with clear positive and negative signals in PCR amplification (Figure 63). All monomorphic SCARs were tested with frequently-cutting restriction enzymes (all with 4 bp recognition sites). CAPS polymorphisms were revealed for four of the PCR fragments (W9₁₃₀₀S, C1₈₀₀S, B1₁₄₀₀R and R20₁₂₀₀CS) when digested with different restriction enzymes, two of the fragments being polymorphic with *AluI* digestion while one each was polymorphic with *RsaI* or *TaqI* digestion. All the polymorphic SCAR and CAPS markers genetically mapped to the same locations as the original RAPD bands from which they were derived.

Unfortunately we were not able to make a polymorphic marker for the peroxidase gene that we found in the cloning process (F10₅₀₀S). The peroxidase represents an interesting candidate gene for providing insect resistance because peroxidases have been involved in hypersensitive response and have been shown to be up-regulated by wounding. Given that *Apion godmani* is a pod borer whose main site of action is at developing seed within the pod placenta and that beans resist the pod borer through a modified hypersensitive response, the peroxidase may be one of the mechanisms of resistance to this pest. Therefore, we will continue to pursue this mechanism of resistance and try to genetically map the peroxidase gene. Among other results worth highlighting is the potential of the new markers to dissect the inheritance of resistance and to help with marker assisted selection.

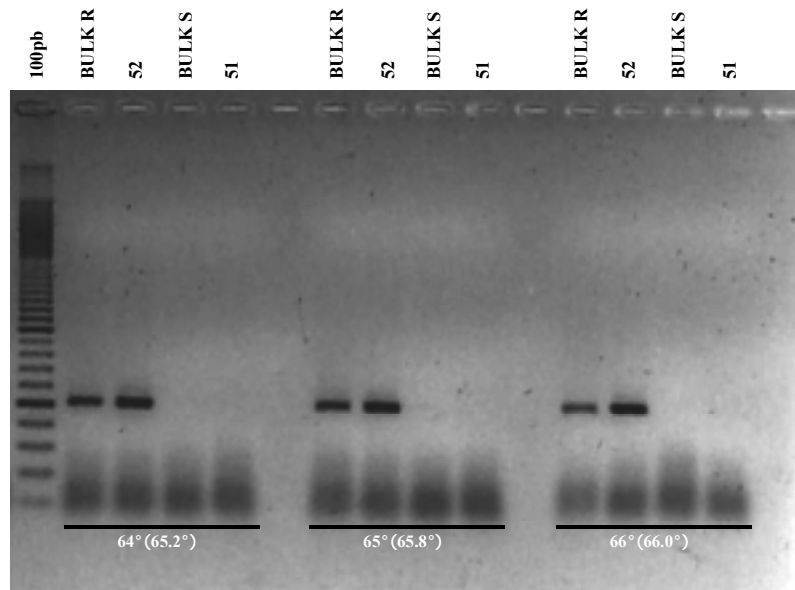


Figure 63. Dominant SCAR for resistance based on the W68C RAPD showing amplification in the resistant parent no. 52 and in the resistant bulk at a range of annealing temp. gradient = 55° -66°C.

Future Plans:

- The peroxidase gene markers will be converted into polymorphic SNP markers so as to genetically map this gene in the bean genome.
- QTL analysis will be carried out when phenotypic data is available for the entire set of recombinant inbred lines which is expected for 2005.
- We will test the ability of the markers to be used in marker assisted selection.

Contributors: MW Blair, C Muñoz, HF Buendia, (SB-2), C. Cardona (IP-1)
R. Garza (INIFAP-Sta. Lucia de Prias, Texcoco, Mexico).

3.2.8 Evaluation of geminivirus resistance sources for SCAR and microsatellite polymorphisms

Background: Bean golden yellow mosaic virus (BGYMV) is an important disease of tropical lowland bean production areas caused by a member of the Geminiviridae family. Symptoms include intense yellowing, pod deformation, stunting and flower abortion that cause important and often devastating yield losses. BGYMV is transmitted by the sweet-potato white fly (*Bemisia tabaci*) a widespread and cosmopolitan pest that is often found on a wide range of horticultural crops as well as tobacco, soybean and common beans. The disease is endemic in Central America and the Caribbean. Breeding for resistance to the virus has been the most effective strategy for controlling the disease since pest control is expensive and impractical given the rapid lifecycle of the insect and the repeated development of insecticide resistance. A few resistance genes have been identified in common beans (*P. vulgaris*) and these function by attenuating symptoms and yield losses when the plant is infected. In the case of a few related species (*P. acutifolius* and *P. coccineus*) there appears to be immunity. Most of these resistance genes remain under-utilized or have only been bred into a limited pool of advanced breeding materials or cultivars. For example several BGYMV resistance genes originated in the Mesoamerican gene pool and these are only now beginning to be transferred to the Andean gene pool. Given this, there is an important role for marker assisted selection to play in encouraging the use and effecting the transfer of BGYMV resistance genes. Pyramiding of resistance genes is important for the greatest protection from the disease's symptoms. Our objectives for this study was to screen all the sources of geminivirus resistance for polymorphic microsatellites from the linkage groups which are thought to be involved in resistance and to evaluate all the SCARs developed for geminivirus resistance against this same panel of genotypes.

Methodology

Plant material and DNA extraction: A panel of genotypes was constructed with all the known sources of resistance to BGYMV (Table 84). A total of 16 genotypes were included and represent the parents of six populations that have been used to determine the genetic control of resistance (two at CIAT and four elsewhere). A miniprep DNA extraction technique was used.

Marker genotyping: Microsatellites were selected from linkage groups b04, b06, b07, b08, and b10 based on central CIAT map for the DOR364 x G19833 population and previous reports that suggested that these regions of the genome were important in virus resistance in common beans. The second set of markers consisted of SCARs related with virus resistance developed by other authors, including SR2 (CIAT, unpublished), SW12 (Miklas et al., 2000) and SAS 8 (Larsen et al., 2004). Microsatellites were run on 4% PAGE gels while SCARs were run on 1.5% agarose gels.

Table 84. Evaluation of SCAR markers on the geminivirus parental survey.

No.	Genotype	Gene pool ¹	BGYMV reaction	SAS8	SCAR ⁴		SW 12
					SR 2		
					530 (R)	570 (S)	
1	Morales	Meso	S	+	+	-	-
2	G35172	<i>P.coccineus</i>	R	-	-	+	-
3	Arroyo loro	Meso	S	+	-	+	+
4	X 015741	Meso	S	-	-	+	-
5	Bulk R1	--	R	+	-	+	+
6	Bulk S1	--	S	+	-	+	+
7	A55	Meso	S	+	-	+	NA ³
8	G122 ²	Andean	--	-	-	+	+
9	Montcalm ²	Andean	--	+	-	+	+
10	DOR476	Meso	R	+	+	-	+
11	SEL 1309	Meso	S	-	-	+	+
12	Bulk R2	--	R	-	+	-	+
13	Bulk S2	--	S	-	-	+	+
14	G19833	Andean	S	-	-	+	-
15	DOR364	Meso	R	+	-	+	+
16	XAN 176	Meso	S	+	-	+	-
17	DOR 303	Andean	S	+	-	+	+
18	IJR	Andean	S	-	-	+	-
19	Raven ⁴	Meso	S	+	-	+	+
20	I 9365-31	Meso	--	-	-	+	-

¹ Meso = Mesoamerican, R: Resistant, S: Susceptible

² BCTV-resistant (G122) and partially resistant (Montcalm) checks

³ new allele observed

⁴ BCMV resistant check

Results and Discussion:

Among the SCAR markers, SR2, which is linked to the *bgm-1* gene, was co-dominant as expected, showing a resistant associated band (530 bp) and a susceptible associated band (570 bp) (Figure 64). The genotypes Morales and DOR476 had the resistant associated band, as did the BGYMV resistant bulk R2. All the other genotypes and bulks had the susceptible associated band for this marker. Since the *bgm-1* gene is known to have originated in a specific Durango landrace it is only found in genotypes derived from this original source through many of the CIAT breeding lines that were bred to contain this resistance gene which provided the best levels of control for severe yellowing symptom caused by BGYMV.

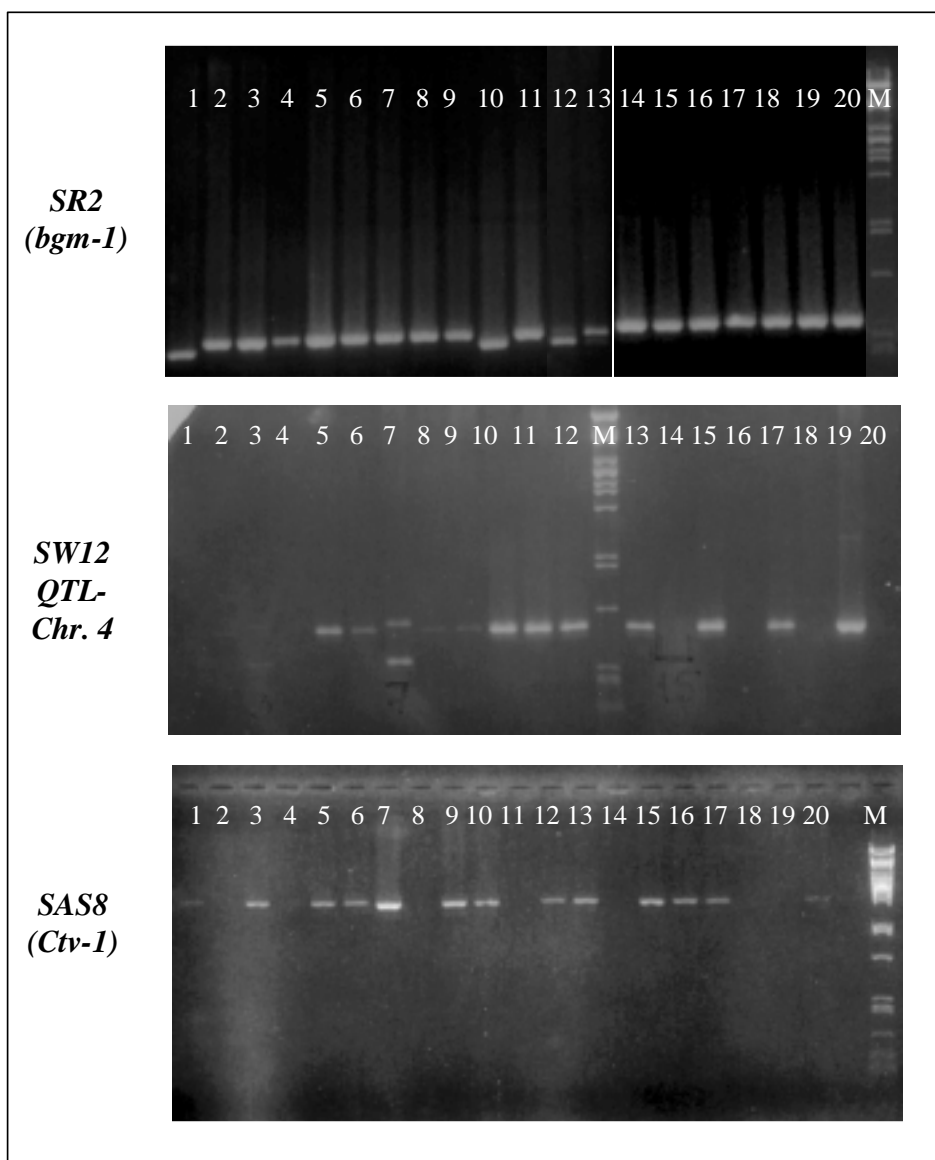


Figure 64. Parental survey of geminivirus resistance sources.

The SW12 marker, linked to a QTL for BGYMV resistance on linkage group b04 was dominant and present in the genotypes Arroyo Loro, DOR303, DOR364, DOR476 and SEL1309 and Raven most of which are genotypes that have been bred for BGYMV resistance (Figure 64). The same band was also present in both the resistant and susceptible bulks R1, S1, R2 and S2 (data not shown). Light bands were amplified for G122 and Montcalm, two Andean genotypes that have not been improved for BGYMV and would not be expected to have the band. A new banding pattern (allele) with two bands, one higher than the expected band and one lower than the expected band, was observed in A55.

The SAS8 marker developed for the *Ctv-1* gene for resistance to beet curly top virus was dominant and was present in Morales, Arroyo Loro, A55, Montcalm, DOR476, DOR 364, XAN176, DOR303 and Raven. This marker was reported by Larsen et al. (2003) to amplify a band in all Mesoamerican genotypes and to not amplify a band for all Andeans. This seems to be the case in our survey where most of the positive genotypes are typically Mesoamerican and where the two positive Andean genotypes, Montcalm (S Phaseolin) and DOR303 (Pedigree A25 x Redcloud), are the result of Andean x Mesoamerican crosses.

In the microsatellite survey, the parental combinations varied in their level of polymorphism (Table 85). As expected the Andean x Mesoamerican cross DOR364 x G19833 was the most polymorphic. The cross DOR303 x IJR was almost as polymorphic as DOR476 x SEL1309, while the population Arroyo Loro x X0157-4 (G35172) had the lowest polymorphism rate. The number of microsatellite per linkage group varied from 5 to 12 and the relative polymorphism in different parts of the genome varied as well.

Table 85. Number of polymorphic microsatellite markers in each linkage group for each population and overall percentage population polymorphism.

Population	Number of polymorphic markers					% polymorphism on each population	
	Linkage Group	b04	b06	b07	b08		b10
	No. of markers tested	n = 11	n =12	n=9	n = 5	n = 5	
Arroyo Loro x X0157-4 (G35172)		2	2	2	2	1	23
DOR 476 x SEL 1309		2	7	7	2	2	49
DOR 364 x G19833		8	9	8	5	5	83
DOR 303 x IJR		4	4	5	2	2	41

Future work:

- Based on parental polymorphism and bulked segregant analysis, we will select microsatellite markers for mapping on the populations represented by this survey.
- QTL analysis on the selected populations.

Collaborators: MW Blair, LM Rodriguez, HF Buendia (SB2-CIAT), J. Beaver (UPR).

Progress towards achieving milestones:

Strategy developed for stable angular leaf spot resistance / markers for marker assisted selection developed for various biotic constraints

- Angular leaf spot resistance genes were identified and characterized in two genotypes that are potential sources of ALS resistance.
- The germplasm accession, G 19833 was identified as having 2 or 3 resistance genes for anthracnose. One of these genes appears to be an allele of the *Co-1* locus, while the other appears novel.
- Two AFLP markers for G 10474 and Mexico 54, and the RAPD marker OPE4₇₀₉ were successfully converted to SCAR markers and protocols for their use in MAS were developed.
- Nature of resistance to *Pythium* root rot and its inheritance in five major sources of resistance that have been used in crosses is better understood. One major gene at the same locus confers resistance in all sources studied.
- Several markers for resistance to *Apion godmani* have been developed and will be adapted for MAS.

Activity 3.3 Developing integrated disease and pest management components

Highlights:

- Diffusion of technology activities within the DFID-funded project on Sustainable Management of Whiteflies initiated.
- The second phase of the Tropical Whitefly IPM Project has demonstrated the importance of adopting IPM measures to recover common bean production in whitefly-stricken regions.
- Three potential biocontrol agents were identified and tentatively classified as *Paenibacillus polymyxa*, *Bacillus subtilis* and *Gluconobacter* spp. The antimicrobial compound is possibly proteinaceous in nature and one of the bacteria produces a heat resistant compound.
- Preliminary results showed *Calliandra calothyrsus* to be the best source of green manure for control of soil pathogens and to increase yields.
- Some of the *Pythium* species pathogenic to beans induced symptoms on and affected sorghum, millets, field peas and maize major crops grown in association with beans in south western Uganda.
- Some of the components useful in the integrated management of bean root rots were effective in reducing root damage and in increasing yield parameters on sorghum, millets, field peas and maize in bean based cropping system.

3.3.1 Management strategies for whiteflies

Rationale: Whiteflies have become the target of excessive pesticide use by snap bean and dry bean farmers in the Andean zone. A management system for whiteflies that contributes to reducing pesticide use has been developed and tested with farmers in Colombia and Ecuador (see 2002 and 2003 Annual Reports). In 2004 we tested other alternatives to further reduce the need for toxic insecticides and initiated diffusion of technology activities at both sites in Colombia and Ecuador.

Materials and Methods: Two large-scale trials were conducted in areas of the Pradera reference sites where *T. vaporariorum* is still the predominant species. We compared different approaches for whitefly control based upon judicious and less detrimental use of chemicals. Seed treatments and drench applications of novel systemic insecticides were compared with the timing of foliar applications of conventional (less costly) products, in some cases with applications based upon pre-established action thresholds developed in previous experiments (see 2002 and 2003 Annual Reports). These treatments were compared with farmers' practices. These trials were used as demonstration plots for farmers in the area.

Results and Discussion: As in previous trials, and as compared with farmers' practices, alternative management strategies based on judicious timing of applications and use of action thresholds resulted in yields that did not differ from those obtained by farmers with their traditional management approaches (Table 86). Crop appearance, damage (sooty mold) levels, and final produce quality (as judged by farmers attending field days) did not differ either. Use of

systemic insecticides as seed dressing and proper timing of foliar applications resulted in higher benefit/cost ratios with 60-70% less applications made per cropping cycle.

Table 86. Yields (tons ha⁻¹) and economic returns obtained with different approaches for control of the greenhouse whitefly *Trialeurodes vaporariorum* in Pradera, the reference site

Treatment	Yield (tons ha ⁻¹)		Benefit/cost ratios	
	Trial 1	Trial 2 ^a	Trial 1	Trial 2 ^a
Seed treatment with imidacloprid followed by two foliar applications of conventional insecticides at pre-established action thresholds	11.1a ^b	11.9	1.43	1.77
Seed treatment with imidacloprid followed by three foliar applications of conventional insecticides at pre-established crop growth stages	10.7a	11.5	1.38	1.62
Farmers' practices (6-7 foliar applications of conventional insecticides)	9.3a	11.9	1.14	1.65

^aUn-replicated demonstrative trial. No statistical analysis performed

^b Means followed by the same letter are not significantly different at the 5% level by LSD.

These trials were used to initiate diffusion of technology activities in the area. A field day was organized in collaboration with ICA and the Municipal Technical Assistance Unit. Attendance was good (76 people, 15 of them women). Farmers were informed on the purposes of the demonstration plots and received training on whitefly biology and safe management of insecticides. Farmer's schools activities were initiated with 12 farmers who received training on whitefly sampling, safe management of pesticides and use of action thresholds for rational whitefly control. Diffusion activities will be strengthened if the second phase of the special project on whiteflies is approved.

Contributors: J. M. Bueno, M. Castaño, F. Morales, C. Cardona

3.3.2 'Recovery of common bean production in the Valley of Zapotitán' Project

Until 1985, the Valley of Zapotitán was the main common bean production area to satisfy the demand of the capital city of San Salvador during the months of April, May and June, at the end of the prolonged dry season (November-March). The increasing incidence of *Bean golden yellow mosaic virus* (BGYMV), transmitted by the whitefly *B. tabaci*, gradually led to the abandonment of common bean production in this valley during the dry season. Although common bean is produced throughout Central America, the Salvadoran market demands a unique red-seeded bean type ('Rojo de Seda') only produced in this country. Thus common bean imports from neighbouring countries, did not satisfy the consumers and common bean prices and consumption fell (from 12 to 8 kg per capita) since 1985. In 1990, the collaborative project (PROFRIJOL) between CENTA and CIAT, led to the selection of a BGYMV-tolerant common bean variety (CENTA-Cuzcatleco). However, the commercial characteristics of this new variety were not adequate and, consequently, its market price was relatively low. Moreover, the BGYMV resistance of CENTA-Cuzcatleco has been breaking down even during the rainy months of the year, which has further contributed to its rejection by local farmers due to its high

protection costs. Hence, the TWFP and CENTA initiated activities towards the identification and validation of new improved common bean genotypes for the San Salvador market.

Research plan: A promising red-seeded common bean line possessing high levels of BGYMV resistance and adequate commercial characteristics was identified in field trials of materials developed by Dr. Juan Carlos Rosas, breeder of the Pan American School (Zamorano) in Honduras using parental materials selected through the PROFRIJOL project. The line selected, EAP 9510-77, was planted in September 2001, in five plots of 2,000 sq/m each, to cover the five districts of the Valley of Zapotitán. Half of the area was planted to the local susceptible common bean landrace, ‘Rojo de Seda’, and the other half with the new EAP line. The plots were planted and evaluated with local farmers in each district. The treatments consisted of minimum inputs: seed treatment (imidacloprid) and herbicide (Prowl). Yield was estimated per plant and per plot (Table 87).

Table 87. Comparative yield (kg ha⁻¹) of a new virus-resistant breeding line and the preferred local common bean landrace in the valley of Zapotitán, El Salvador

Zone	1	2	3	4	5	Average
Year	2001	2001	2002	2002	2003	
Virus rating	8	8	4	4	6	6
Rojo de Seda	120	150	350	408	230	251.6
EAP 9510-77	810	890	1,250	1,400	910	1,052

A demonstration plot was planted in 2001 in order to show farmers the superior yielding capacity of the new line EAP 9510-77, as compared with the previous cultivar CENTA-Cuzcatleco (DOR 364) and the preferred landrace ‘Rojo de Seda’ (Figure 65). DOR 364 was a CIAT-bred, virus-resistant cultivar released over a decade ago, and although its seed color was more purple than red, it was widely planted in various Central American countries. This cultivar is on its way out because of its increased susceptibility to BGYMV and dark red colour. The EAP line has a combination of different sources of BGYMV-resistance and better seed color. Given the clear preliminary results obtained in the first series of evaluation sites, which demonstrate that it is possible to grow common bean during the dry season (November-March) in the Valley of Zapotitán using minimum inputs, line EAP 9510-77 was evaluated at the national level by CENTA with complementary funding from DFID/PROFRIJOL/CRSP-USAID

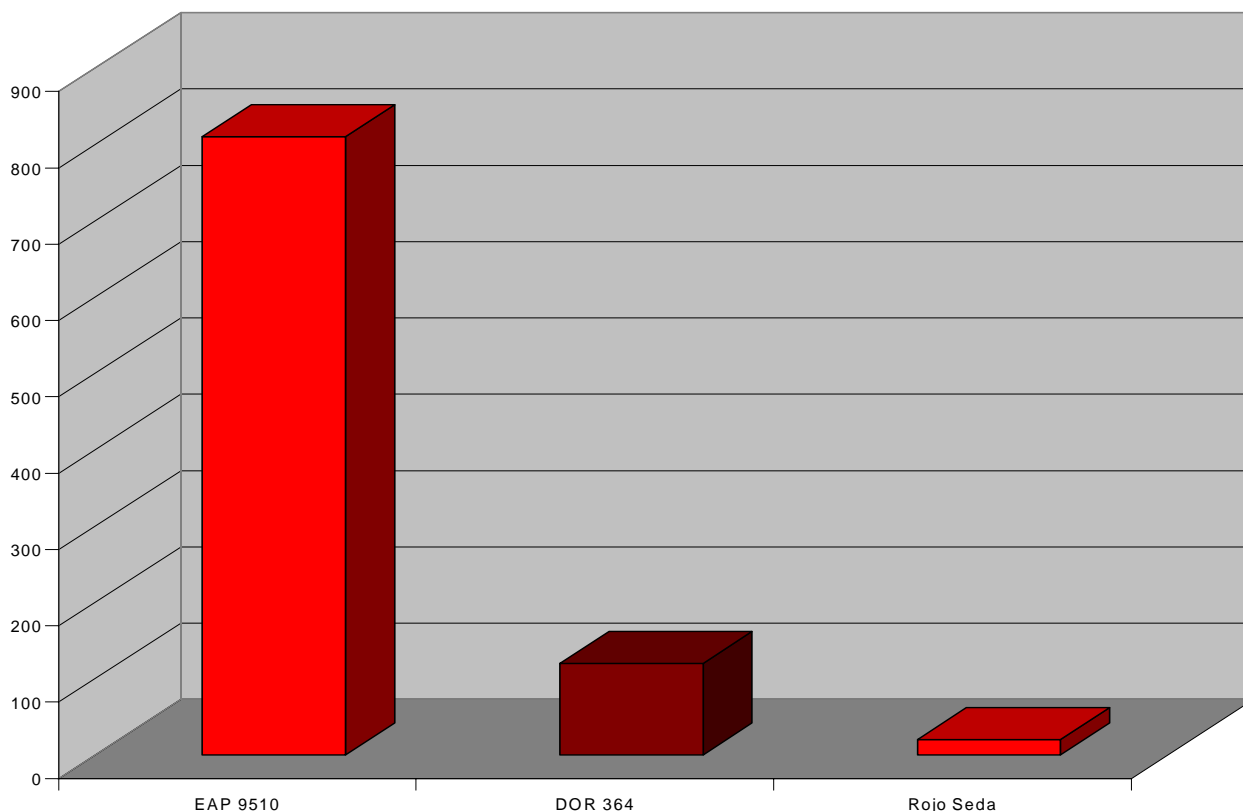


Figure 65. Yield of the new BGYMV-resistant EAP line and the preferred landrace ‘Rojo de Seda’.

Principal national scientist : Ing. Carlos Atilio Perez (CENTA).

Collaborators: Agents (3) of the Zapotitán Extension Agency (CENTA) under the coordination of Ing. Mario Aragón.

Evaluation of the new line EAP 9510-77

A case study was conducted with 60 farmers in the western (6), central (23), para-central (22), and eastern (9) regions, during the second semester of 2003. Only 3 of the 60 farmers interviewed were women, which reflects the cultural characteristics of farming in Latin America. The age range of the farmers interviewed was 30-81 years, with 60% of the farmers being older than 50 years. This finding illustrates the migration of young people from rural to urban areas in search of jobs in commerce, industry and maquila, all activities that show positive growth in recent years, as well as an increase in minimum wages. Interestingly, 92% of the farmers interviewed were literate, although only 22% reached secondary school. Over 70% of the farmers owned their farms and 58% lived in the farm. 75% of the farmers do not have access to credit and most farmers have incomes between US \$ 1.50 and 3.00/day.

The area of the validation plots varied according to the capabilities and willingness to collaborate of the participating farmers, from 200 m² to 1,750 m² for the new line, and from 200 m² to 2,598 m² for the local check (red-seeded cultivar chosen by the farmer).

Farmers also differ in relation to the cropping system used: monoculture (42%), association (20%) and relay (38%). The most popular common bean cultivars are: Rojo de Seda (30%), followed by two BGYMV-resistant cultivars (CENTA 2000 and DOR 585). 80% of the participating farmers registered higher yields with the new improved common bean EAP line. Only in the central region approximately 20% of the farmers concluded that they preferred their traditional bean cultivar. 62% of the farmers manifested that the new line had superior disease resistance qualities as compared to their own cultivars. 33% could not tell any difference (mainly those that already grow virus-resistant cultivars, such as CENTA 2000 and the DOR lines), and 5% concluded that the new material was more susceptible. However, it was later shown that the susceptibility of the new line was to 'web blight', a fungal disease present in isolated areas of El Salvador. 83% of the farmers considered that the commercial characteristics of the EAP line as excellent. The remaining 7% thought that their local material was better (mainly the local landrace 'Rojo de Seda' which is highly susceptible to BGYMV and cannot be grown in the dry season even under heavy chemical protection).

The most important result of this survey is that 87% of the farmers that planted the new improved bean line were willing to adopt it. This figure was almost 100% in areas affected by the whitefly-transmitted BGYM virus. Of all the seed obtained by the collaborating farmers, 37% was used for household consumption, 32% was saved as seed for the next planting, and 27% was sold to generate income.

Table 88 shows the statistical analysis of the different variables evaluated in order to determine the level of acceptance of the new line EAP 9510-77. Table 89 shows the superior yielding capacity of the new material EAP 9510-77 in the selected regions where it was evaluated, in relation to the local cultivar.

The line EAP 9510-77 was officially released in November 2003 as the new variety 'CENTA San Andres'. In the District of Zapotitán, the TWFP has financed two field days for 83 farmers (including 18 women), and 18 technicians, in order to promote the new variety.

Responsible scientist: Ing. Carlos Atilio Pérez C. (CENTA)

Table 88. Main variables that determine the adoption of a new bean cultivar

Variable	Coefficient	Standard Error	t-Statistic	Probability
Intercept	0.141624	0.260788	0.543063	0.5895
Growth Habit	0.14294	0.120277	1.188416	0.2403
Vegetative Cycle	0.115406	0.075519	1.528176	0.1328
Yield	-0.115342	0.087253	-1.321933	0.1922
Disease Resistance	-0.166001	0.099686	-1.665248	0.1021
Pest Resistance	0.101755	0.097583	1.042755	0.3021
HumidityTolerance	0.053299	0.049807	1.070111	0.2897
Market Price	-0.057198	0.054633	-1.04696	0.3002
Acceptance	0.693283	0.156329	4.434778	0.0001
R2	0.376418	Mean dep. var.		0.881356
Adjusted R2	0.276645	S.D. dep. var.		0.326145
St. Error Regress.	0.277387	F value		3.772743
Residual S.C.	3.847183	Probab (F)		0.001584

Model: Varietal Adoption = 0.141624 + 0.14294 contall + 0.115406 cveg-0.115342 rend-0.166001 resenf + 0.101755 respla + 0.053299 tolhum-0.057198 sale + 0.693283

Table 89. Yield results (kg ha⁻¹) of the validation trials of EAP 9510-77 in 4 regions of El Salvador

Region	EAP 9510-77	Local cv.	Yield Difference	Percentage
West	1815	1312	503	27.7
Central	1259	951	308	24.5
Para-Central	1088	875	213	19.6
East	1171	901	270	23.0
National Ave.	1240	952	288	23.2

3.3.3 Identification of potential biocontrol bacterial agents

Rationale: Because of the negative effects that synthetic chemicals have on the environment, it is apparent that the use of antagonistic microorganisms may be a good alternative in controlling diseases caused by pathogens with large pathogenic variability. If this is to be a viable and reliable alternative, it is important to understand why, when and how these microorganisms and their products affect the development of pathogens. Several bacteria that exhibit a biocontrol effect on some common bean pathogens have been isolated in our laboratory. Preliminary experiments revealed the antagonistic effects of these bacteria. Three bacteria have been of particular interest. We report the identification of these bacteria.

Bacteria identification:

Bacteria 1: The bacterium was isolated from the phyloplane of common bean leaves. The bacterium is gram positive, non-motile, with large spores and produces acid in the presence of manitol, maltose and cellobiose, does not utilize urea, has the ability to utilize catalase and oxidase. Based on the biochemical and morphological analysis, this bacterium was identified as a *Bacillus*. Analysis of the partial sequence of the 16S rDNA gene revealed that this bacterium was 98% similar to *Paenibacillus polymyxa*. Based on sequence analysis of the partial 16S ribosomal gene, morphological and biochemical tests, bacterium 1 was tentatively classified as *Paenibacillus polymyxa*.

Bacterium 2: The bacterium was isolated as a contaminant from petri plates of V8 juice medium. Morphologically, this bacterium is irregular in shape, convex, translucent with colonies that are ≤ 1 mm. It is gram positive with small *Bacillus* type spores. Based on morphological and biochemical tests, this bacterium was identified as *Bacillus subtilis*. This identification was confirmed following partial sequence of the 16S rDNA gene and blast sequence search that showed that the sequence of this bacterium was 98% similar to that of *Bacillus subtilis*.

Bacteria 3: The bacterium was isolated from the phyloplane of *Morinda citrifolia*. Morphological tests revealed that this bacterium is a gram-positive cocos with circular colonies < 1 mm, transparent and convex. Partial analysis of the 16S rDNA sequences revealed that this bacterium is 100% similar to *Gluconobacter* spp. This bacterial has been tentatively labeled as *Gluconobacter* spp.

Conclusion: Further identification and classification of the bacteria by an independent bacteriologist is under way. Meanwhile, characterization of these bacteria and establishment of their biocontrol activity and range is under way.

Contributors: C. Jara, G. Castellanos, M.A. Henriquez, G. Mahuku

3.3.4 *In vitro* inhibition of *Colletotrichum lindemuthianum* by three potential biocontrol bacterial species (*Paenibacillus polimixa*, *Bacillus subtilis* and *Gluconobacter spp.*)

Rationale: Biological control is an alternative sound strategy for the management of plant pathogens because it is environmentally safe while promoting build up of natural enemies, thus creating a sustainable production system. For this reason, we are involved in studies to identify and evaluate the efficacy of potential biological control agents. We report the effect of cell-free culture filtrates of three potential biocontrol bacteria on mycelial growth and germination of *Colletotrichum lindemuthianum* conidia.

Materials and Methods: Three potential bacterial biocontrol agents (tentatively classified as *Paenibacillus polimixa* (B1); *Bacillus subtilis* (B2); and *Gluconobacter spp.* (B3)) were used in this study. The bacteria were grown on either PDA or nutrient agar, unless otherwise specified.

Inhibition of *C. lindemuthianum* growth

To establish the effect of the bacterium on the growth of *C. lindemuthianum*, bacterium from a 48 hr culture on PDA was inoculated onto PDA medium in a circle at different distances (2, 3, 4, and 6 cm) diameters from the center of the petri plate. A plug of mycelium (4 mm diameter) cut from the edges of an actively growing *C. lindemuthianum* isolate was placed in the center of each plate. To establish the nature of the potential antifungal compound, the fungus was inoculated immediately after culturing the bacteria (0 hrs), and at varying times 24, 48 72 and 96 hrs after culturing the bacteria. There were five plates for each treatment and the experiment was repeated. Radial growth of the fungus was evaluated 7, 14 and 21 days after culturing. Control plates contained the fungus on the same media, and inoculated at the same time but without the bacteria.

Preparation of cell free culture filtrates

Cell-free culture filtrates of the bacteria were produced by culturing the bacteria in 250 mL of nutrient broth (Difco) in 750 mL flasks and incubating at 28°C with shaking at 200 rpm until an OD₆₀₀ of 1.1 was reached. The culture filtrate was centrifuged at 7000 g to remove bacterial cells and then the fluids were passed through a 0.22 µm pore-size nylon membrane to remove residual bacterial cells. The cell-free culture filtrate either heat inactivated by 100 C° for five minutes or not heated were used to prepare medium for culturing *C. lindemuthianum* conidia and test inhibition of conidial germination.

Conidia germination assay

Cell-free culture filtrates were mixed with autoclaved and cooled PDA agar to a final concentration of 60% (v/v). *C. lindemuthianum* conidia suspension (10⁶ conidia ml⁻¹) in sterile distilled and deionized water was plated on to PDA medium amended or non-amended PDA medium (control) with cell-free culture filtrates. Inoculated plates were incubated at 24°C and evaluated for the growth and development of *C. lindemuthianum*.

Results and Discussion:

All bacteria were effective in inhibiting the growth of *C. lindemuthianum* (Tables 90, 91, and 92), however, *Gluconobacter* spp. and *Paenibacillus polimixa* were the most effective. *C. lindemuthianum* spores plated on medium containing cell-free culture filtrates did not germinate, where as on control plates (lacking bacterial filtrates), normal fungal growth was observed (data not shown). The antimicrobial compound is diffusible, and was more potent with increased time that the bacteria was allowed to establish before inoculating the fungus (Tables 90-92). The rate of fungal growth inhibition dependent on the distance that *C. lindemuthianum* was from the bacteria. This was more evident for *B. subtilis* and *Paenibacillus polimixa*. This might reflect the nature of the antimicrobial compound, which in turn, might determine the rate of diffusion through the medium. Conversely, this might also reflect the rate of antimicrobial production, with *Gluconobacter* producing and reaching high concentrations faster than the other bacteria. The compound produced by *Gluconobacter* appears to be in high concentrations and diffuses through the medium rapidly. More studies are under way to optimize the production media and culturing conditions, as a means of verifying this assertion.

Table 90. Radial growth of *Colletotrichum lindemuthianum* challenged with the potential biocontrol bacteria *Paenibacillus polimixa* inoculated at different times and distance.

Time (hrs)	Distance of bacteria from center of plate (cm)				
	2	3	4	6	Control
0	0.28	0.41	0.92	1.54	4.54
24	0.10	0.26	0.45	1.29	4.45
48	0.10	0.1	0.24	1.08	6.71
72	0.10	0.1	0.16	0.47	4.58
96	0.10	0.1	0.20	0.48	5.50

Table 91. Radial growth of *Colletotrichum lindemuthianum* challenged with the potential biocontrol bacteria *Bacillus subtilis* inoculated at different times and distance.

Time (hrs)	Distance of bacteria from center of plate (cm)				
	2	3	4	6	Control
0	0.80	1.14	0.97	2.17	6.80
24	1.31	1.16	1.25	1.71	4.50
48	0.59	0.54	0.29	1.17	4.43
72	0.41	0.54	0.49	1.30	5.14
96	0.41	0.44	0.30	1.24	4.80

Table 92. Radial growth of *Colletotrichum lindemuthianum* challenged with the potential biocontrol bacteria *Gluconobacter* spp. inoculated at different times and distance.

Time (hrs)	Distance of bacteria from center of plate (cm)				
	2	3	4	6	Control
0	0.13	0.13	0.23	0.32	4.54
24	0.10	0.10	0.10	0.10	7.5
48	0.10	0.10	0.10	0.10	6.71
72	0.10	0.10	0.10	0.10	4.58
96	0.10	0.10	0.10	0.10	5.60

Heating the culture filtrate destroyed the activity of the antifungal compound, produced by *B. subtilis* and *Paenibacillus polymixa* but not that produced by *Gluconobacter*. The antimicrobial compounds seem to be different. For B1 and B2 it appears that the antifungal compound is proteinaceous in nature; whereas the antimicrobial compound produced by B3, is either a heat resistant protein or some other type of compound. Further tests are needed to definitely identify the antimicrobial compounds in these bacteria.

Conclusion: Three bacteria with potential to manage fungal pathogens have been identified. Preliminary results have revealed at least two compounds; a heat susceptible and a heat stable compound. It is probable that one of these compounds is proteinaceous in nature. However, this assertion needs to be confirmed. There is a need to optimize culturing conditions, and to test the efficacy of these compounds on a diverse range of plant pathogens.

Contributors: C. Jara, G. Castellanos, G. Mahuku

3.3.5 Integrated soil fertility/Pest & disease management approaches to address root-rot problems in common beans

Rationale: Consensus about societal demands for agricultural sustainability and biodiversity conservation has been reached in the past decade (UNCED,1992). New approaches to continuing problems, like soil degradation and soil pest and diseases, are then needed in order to achieve agricultural sustainability. Our overall working hypothesis in this study is that combining soil fertility and pest management approaches would provide a unique opportunity to exploit synergies allowing a better control of soil fertility, pest and disease limitations to crop productivity than either approach alone.

The management of organic matter is crucial to the activities of the soil biota. Use of green manures can have a multi-faceted beneficial effect on crop productivity arising from (i) protection of the soil from erosion; (ii) increased nutrient cycling; (iii) synchronized nutrient release and uptake by the plants; and (iv) increase in soil biological activity and diversity of

microorganisms, which in turn can lead to minimized damage and loss from soil borne pathogens, and increased activity of beneficial microorganisms. However, different sources of green manure can have different effects on the balance between populations of harmful and beneficial organisms because they have different rates of decomposition and nutrient release as well as different impact on soil moisture and temperature that invariably affects relative population sizes. For this reason, it is important to evaluate the effect of different sources of green manure on three key functional groups of soil biota: 1) pathogens, 2) microregulators and 3) microsymbionts. We are studying the population dynamics of soil pathogenic fungi (*Fusarium*, *Sclerotium*, *Macrophomina*, *Rhizoctonia* and *Pythium*), soil nematodes (discriminated by feeding habit), soil microsymbionts (mycorrhiza, rhizobia) during cultivation of common bean in soils infested with pathogenic fungi. Evaluations were carried out by: a) directly identifying and quantifying different soil biota from functional groups mentioned above and b) indirectly, by evaluating the incidence of disease on susceptible plant genotypes, by plant infection test for native rhizobia symbiotic potential and AMF activity in soil through hyphal lengths. The relative position of these three groups in the soil food web suggests the potential for soil organic management to reduce soil pathogenic fungi populations and incidence in bean plants by changes induced in soil moisture and temperature, nutrient availability and interaction with other soil organisms.

Materials and Methods: An experiment was established in CIAT's Santander de Quilichao Research Station, using a plot that has a history of high incidence of root rot pathogens. The plots were planted with a root rot susceptible bean variety A 70. Immediately after planting, the plots were covered with three green manures treatments: (1) rapidly decomposing *Tithonia diversifolia* (TTH); (2) intermediate rate of decomposition but greater soil cover due to leaf morphology by *Cratylia argentea* (CRA); (3) slow decomposing *Calliandra calothyrsus* (CAL) at a rate of 6 ton ha⁻¹; and (4) control (no green manure added). The experiment was replicated five times. Soil samples (0-10 cm) collected during the cropping season included at least planting and harvesting time. Samples were collected within rows and between rows, to measure the effect of the rhizosphere of bean plants on the soil biota studied.

Results and Discussion:

Diversity of soil pathogenic fungi

Preliminary data revealed that plots receiving CRA had a significantly less fungal diversity ($P < 0.05$) than plots receiving the other sources of green manure or the control (Figure 66). No differences were observed between the other treatments and the control. However, since this is the second season after initiation of the experiment, it is still too early to draw sound conclusions.

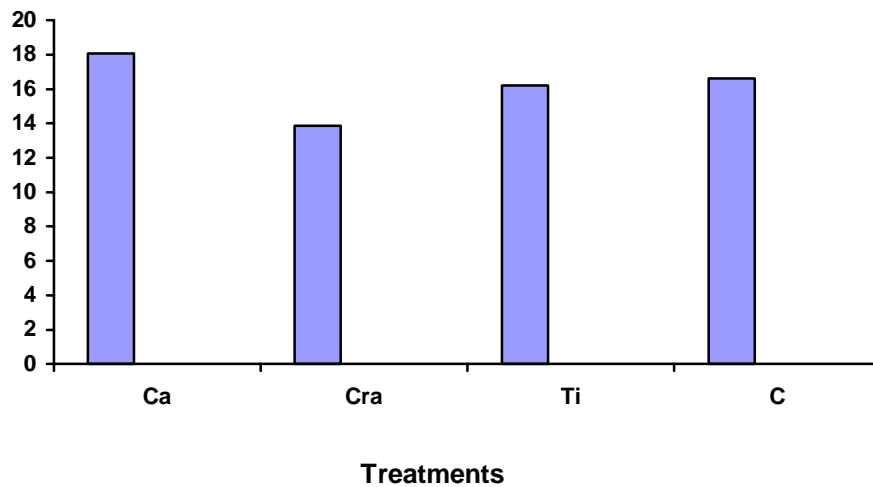


Figure 66. Diversity of soil-borne fungi in plots receiving or not receiving different sources of green manure. Value on Y-axis represents H, the Shannon Wiener diversity index.

The most frequently isolated fungus was *Aspergillus* (A) in all treatments, while *Macrophomina* (Ma) and *Rhizoctonia* (R) were the least isolated fungi (Figure 67). Other fungi that were isolated included *Fusarium* (F), *Penicillium* (P), *Humicola* (H) and *Mucor* (M) (Figure 67). The presence of *Penicillium* is interesting, as some species of this fungus are known to solubilize phosphorus. *Humicola* is a fungus that has been found to be involved in decomposing organic matter, and this was found in abundance in plots receiving *Calliandra*. Several fungi were isolated that are currently being classified. These were tentatively placed under the “unknown” group (D). It is possible that some of these fungi could be potential biological control agents. Although *Macrophomina* has been observed in the past in high frequencies and incidence on infected plants, this fungus was not detected in the soil samples analyzed thus far. It is possible that the method of analysis that is used leads to the exclusion of this fungus, or the high incidences observed under field conditions results from seed-borne inoculum.

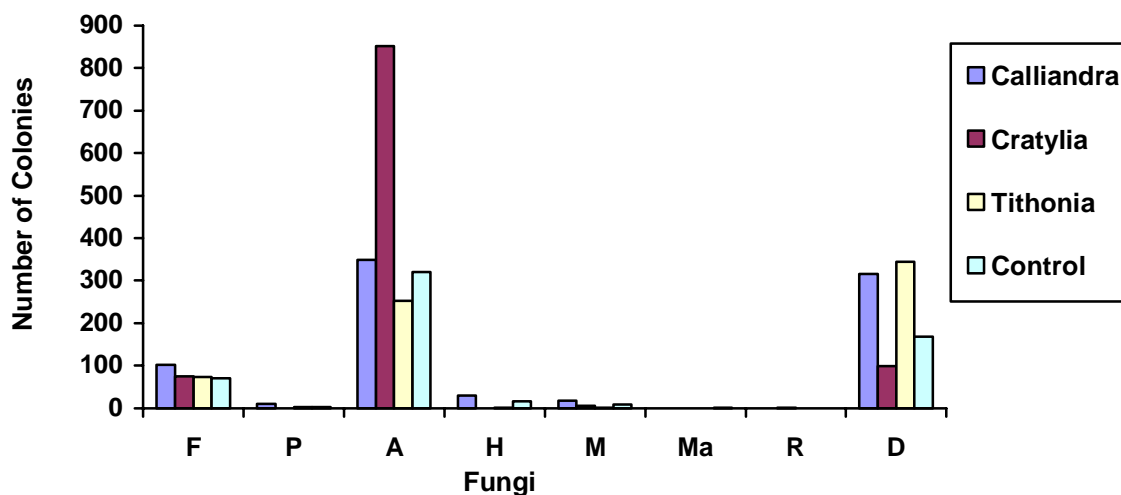


Figure 67. Frequency of different fungi isolated from plots receiving a slow (CAL), intermediate (CRA) and fast (TTH) decomposing green manure or the control.

Abundance of soil nematodes

Total number of soil nematodes was always higher in the row than between the rows highlighting the importance of the bean plant rhizosphere effect (Figure 68). On average greater number of nematodes were found when Tithonia pruning was applied to the soil and the overall order was TTH>CRA>CON=CAL . Taxonomic identification of nematodes and classification into feeding groups is on going and should help in the interpretation of abundance trends observed.

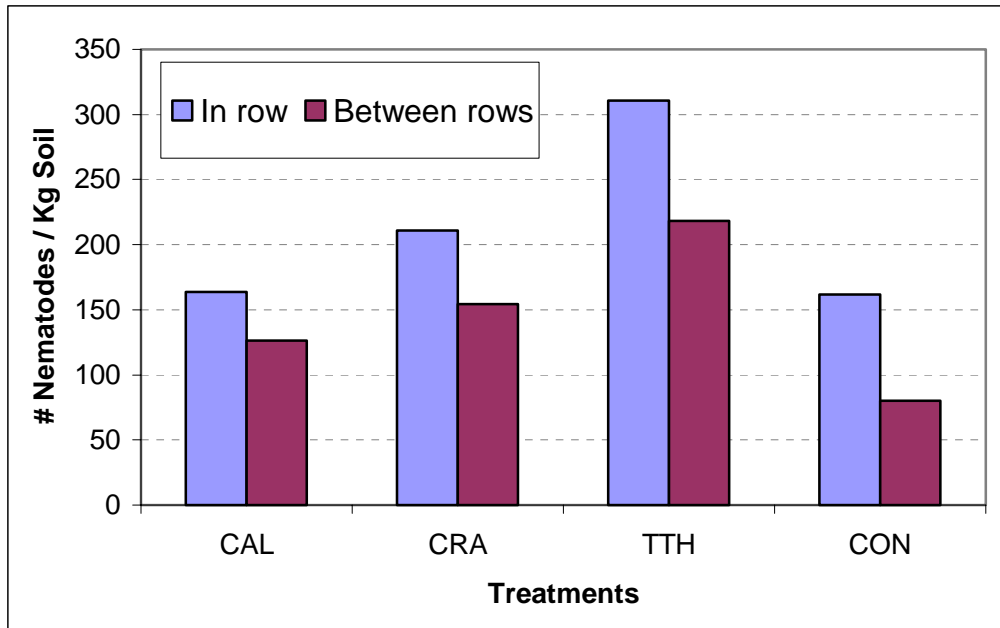


Figure 68. Total number of nematodes from plots receiving a slow (CAL), intermediate (CRA) and fast (TTH) decomposing green manure or the control.

Incidence of root rot pathogens: Significant differences were observed in the incidence of root rots in some treatments, when compared to the control (Figure 69). Application of *Calliandra*, and *Tithonia* significantly reduced disease incidence ($P < 0.05$), where a slight increase in disease incidence was observed in plots receiving *Cratylia*. Analysis of the samples collected from these plots revealed that most of the root rot symptoms were caused by *Macrophomina phaseolina* and *Fusarium solani*, while *Rhizoctonia solani* was occasionally isolated. Significant yield increases were observed for plots treated with *Calliandra* (10%) and lowest for plots receiving *Tithonia* (-29%) (Figure 69). Although a slight increase in yield was observed (1.2%) for plots receiving *Cratylia*, this was not significantly different from the control plots.

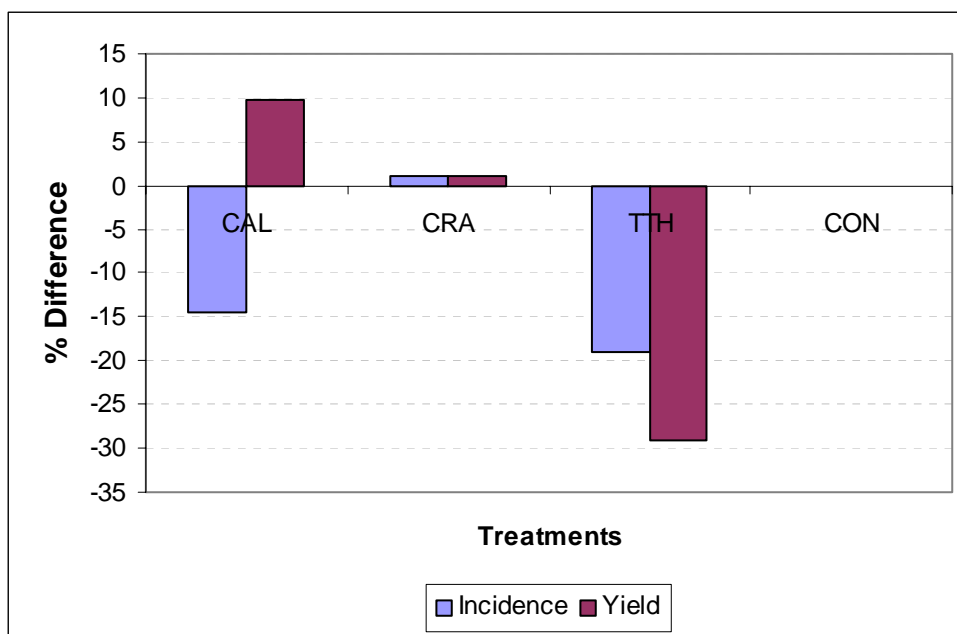


Figure 69. Incidence of root rots and yield of the bean genotype A 70, grown in plots with or without different types of green manures expressed as a percent of control treatment.

Conclusion: First results indicate that despite the relatively limited time of green manure treatments some initial trends can be identified. Compared with the control, application of *Calliandra* resulted in increased bean yield, reduced incidence of root rots and low nematode abundance. In the case of *Cratylia*, there were minor differences root rot incidence, yield and nematode abundance (in row) when compared to the control. Although disease incidence was low in plots receiving *Tithonia*, bean yield was also negatively affected. Taxonomic identification of nematodes would help to understand if high nematode populations in TTH were involved in reducing bean yield. In addition, the impact of treatments on the bean plant symbiosis with mycorrhiza and rhizobia needs to be included for a more complete explanation of yield differences encountered. Nevertheless, yield differences were likely also influenced by a combination of physico-chemical factors including differences in nutrient release by the three green manure sources.

While at this early stage application of *Calliandra* seems to offer the best results we need to examine how transient or cumulative these effects are and the mechanisms of action involved. The potential exists that unknown beneficial microorganisms are promoted in the soil by green manures and thus can potentially be used to manage root rot pathogens and/or for promoting plant growth. We are currently evaluating fungi that have tentatively been grouped under the “unknown” group for potential antagonistic effects, as well as *Penicillium* species for their ability to solubilize phosphorus.

Contributors: G. Mahuku, C. Jara, (IP-1), E. Barrios, L. Cortes, Asakawa N, Navia, J. (PE-2)

3.3.6 Pathogenicity of *Pythium* spp and effects of management options for root rots on crops grown in association with beans in southwest Uganda

Rationale: Bean is one of the crops grown under the intensive agricultural system in southwest Uganda. Others include sorghum, maize, sweet potatoes, Irish potatoes, bananas and peas. Crop rotation in the strict sense is rare. Dominance of crops in the field shifts according to season. Rotations commonly practiced include beans-maize-sorghum, beans-maize-beans and beans-Irish potato/maize-sweet potato (Edidah, 2003). Maize and sorghum are also intercropped with beans and/or Irish potatoes such that the bean crop appears in the field season after season. However, of all these crops, beans are most affected by root rots. In recent years this has resulted in the decline in bean production in the area. Given that some of the root rot causing pathogens (e.g. *Pythium* spp) are known to have a wide host range, some of the questions asked are: do crops grown in association or in rotation with beans play any role in the pathogen survival, inoculum density and severity of root rots in beans?; is bean the only crop in the system that is affected or is it simply a good indicator of the level of root rot pathogens?; to what extent are other crops in the system affected by bean pathogens?; what are the effects of management options for bean root rots on other crops? To address these questions, we initiated studies to characterize *Pythium* spp associated with major crops found in the bean based systems; to determine pathogenicity of some *Pythium* species on these crops; and to determine the effects of management options for bean root rot on crops grown in association with beans.

Materials and Methods:

Pathogenicity studies: Three *Pythium* species pathogenic to beans (*P. ultimum*, *P. chamaeophyon*, *P. pachycaule*) were artificially inoculated on three crops commonly associated with beans namely: sorghum, millets and maize. Autoclaved millet (100 g) was mixed with 200 ml of water in a 500-ml bottle and subsequently used to raise the fungi. After two weeks of incubation, the infested millet was mixed with pre-sterilized soil at a ratio 1:10 v/v in wooden trays. Maize, sorghum and millet were planted in two rows of twelve plants and replicated in three trays. Bean varieties CAL 96 and RWR 719 were used as susceptible and resistant checks respectively. Cumulative emergence and plant stand was recorded one week after germination. Three weeks after germination, plants were assessed for any root and shoot symptoms that may be associated with *Pythium* infection.

Effect of management practices: Four crops; beans (B), sorghum (S), maize (M), and peas (P) were subjected to four amendments i.e., farm yard manure (FYM), green manure (GM), inorganic fertilizer (NPK), fungicide (Metalaxyl + Mancozeb 63.5% WP) in farmers fields in Rubaya, Kabale district, southwest Uganda. Sorghum, maize and peas seed were obtained locally from farmers. A root rot susceptible bean variety (CAL 96) was used as a check. Farmyard manure and green manure (*Crotalaria*) were applied on a dry weight basis at a rate of 5t ha⁻¹ and their nutrient level determined. NPK fertilizer was applied at a rate of 50 kg of N ha⁻¹. Ridomil was applied as seed treatment (slurry) at a rate of 2.5 kg ha⁻¹. Qualitative data was obtained through field observations and photography. Quantitative data collected included: emergence, plant stand, disease incidence and severity at different times during the growing season, plant vigor and yield parameters (dry matter production). Disease severity was evaluated according to

a CIAT nine-point scale where 1 is resistant and 9 susceptible (Abawi and Pastor Corrales, 1990)..

Results and Discussion:

Pathogenicity studies

The different *Pythium* species invoked typical root rot symptoms on susceptible bean cultivar CAL 96 in screen house studies. As expected, cultivar RWR 719 was resistant. Sorghum exhibited severe stunting and purple color on leaves. These features were more pronounced with isolate KAK 5 B (*P. pachycaule*). Similarly, millet exhibited stunting as well as yellowing and drying of the leaf tips, unlike plants in un-inoculated control trays. Maize showed less pronounced effects characterized by reduced plant vigor and size.

Symptoms on roots of sorghum were comprised of red-black lesions and discolorations, reduced root mass and length. Millets displayed some lesions and reduced root mass. Maize exhibited little if any lesions on roots 3 weeks after emergence although root mass was relatively lower than in the control trays. *Pythium* was re-isolated from roots of all crops grown in infected soil.

These screen house results showed that *Pythium* species used had an effect on the different crops tested. The most affected crop was beans and then sorghum, millet and maize in that decreasing order. Maize exhibited an interesting reaction in that there was some reduction in both shoot and root mass but little necrosis on the latter. Stunting in crops is attributed to reduced capacity of roots (either due to damage or reduced amount) to support adequate water and food uptake. We can tentatively conclude from these preliminary observations that *Pythium* species pathogenic to beans cause damage to sorghum, millets and maize to varying degrees. Further investigation to elucidate these interactions is on-going.

Effects of management options on incidence and severity of root rots

The management options evaluated affected the crops in different ways. FYM and Metalaxyl/Mancozeb significantly reduced initial root rot infection on beans. High incidence of root rots was observed with GM and attributed to interactions between the root rot pathogens and soil micro-organisms. But FYM, GM and NPK enhanced root (mass) growth in beans, compared to control plots.

As in screenhouse studies, infected sorghum plants exhibited stunted growth, purple leaves, shoot death and dark-red to black root lesions (Figure 70). Significantly high incidence and severities were observed in control plots particularly 54 and 72 days after planting. Amendments reduced these effects and plant recovery was evident in plots amended with GM, FYM and NPK. Symptoms on maize were expressed as grey lesions on roots (Figure 71), stunting and poor establishment. However, incidence and severity were low indicating that maize was less affected (Figure 72A). As with sorghum, amendments and particularly FYM reduced severity (Figure 72B) and improved plant vigor and growth.



A



B

Figure 70. (A) Severely affected sorghum roots (control plots); (B) Sorghum root with prop root development in plots amended with NPK.



Figure 71. Maize roots showing root lesions

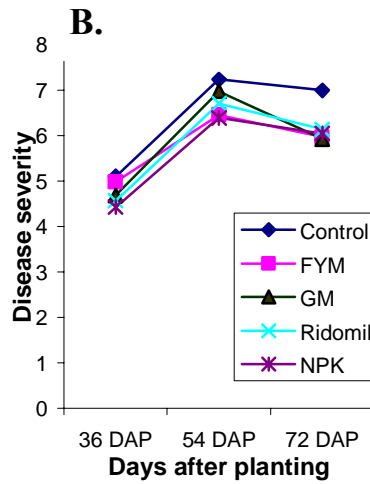
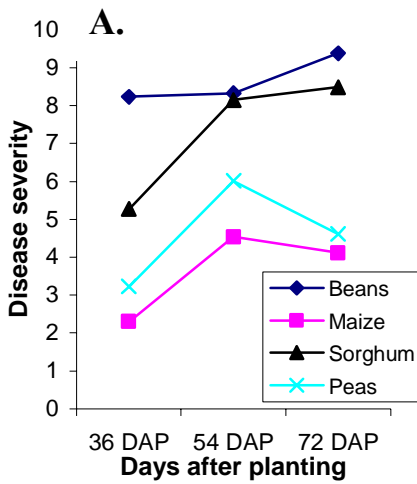


Figure 72. Disease severity in crops over the season (A.), and effects of different root rot management practices on root rots over the season (B.)

NPK, GM, FYM and ridomil (in sorghum) improved dry matter production (DMP) in both maize and sorghum (Table 93). Improved DMP in sorghum due to ridomil is probably due to its protective effect against *Pythium* species.

Table 93. The effect of different soil amendments on mean dry matter production (72 days after planting) for maize and sorghum. Rubaya, Kabale, 2004 season A.

Crop / Treatment	Dry matter (g)	
	Maize	Sorghum
Control	106.9	18.5
Farm yard Manure	128.3	42.7
Green Manure	138.4	38.9
Metalaxyl+Mancozeb 63.5% WP	112.5	46.1
NPK	163.2	48.8
L.S.D at P < 0.05 (32.20)		

Overall the different management options evaluated influenced severity of root damage and other growth parameters on crops grown in association with beans. This implies that the use these options do not only contribute in the management of bean root rots, but are also beneficial to other crops. Studies are underway to further define this contribution.

Contributors: R. Buruchara (IP-1), V. Gichuru, W. Ocimati (graduate students),
F. Opio (NARO)

Collaborators: N. Spence (CSL, UK), G. Tusiime (Makerere University)

Progress towards achieving output milestones:

- IPM measures have served to recover common bean production in an important whitefly-stricken production region of El Salvador.
- Some of the components useful in the integrated management of bean root rots were effective in reducing root damage and in increasing yield parameters on sorghum, millets, field peas and maize in bean based cropping system.

Output 4: Improved cultivars and management practices developed, evaluated and widely disseminated in partnership with NARS, regional networks, NGOs, and farmers

Activity 4.1 Supporting breeding programs in NARS, regional networks, farmers' associations, and CIALs with germplasm and technical knowledge

Highlights:

- A large number of breeding line nurseries and germplasm were distributed to bean network partners from CIAT-Headquarters
- Close collaboration between CIAT and breeding programs in the Andean region continued with exchanges of researchers and germplasm. Training programs were developed for researchers from CORPOICA and the Univ. Nacional in Colombia, PROMPEX-INIA in Peru and Univ. San Simon in Bolivia. One training project involved developing and confirming BCMV resistance in Peruvian dry beans, using marker assisted selection for the first time in Peruvian bean improvement. Another project involved selection of BCMV and anthracnose resistance in climbing beans using molecular markers.
- Lines bred for drought tolerance present as much as 50% yield advantage over elite cultivars under drought conditions in Nicaragua, confirming that tolerance mechanisms selected in CIAT-Palmira are effective in Nicaragua.
- Some top yielding cultivars across sites within SABRN (GCI-CAL-28-AR, AFR 708, CIM 9314 and CIM9314-2) combine acceptable market type (red mottled), high yield potential and resistance to ALS or FLS or both.
- The national bean research program in the southern highlands of Tanzania, this year released a CIAT-bred line DRK 124, calling it *Uyole 03* and another line selected from crosses generated by NRI on a collaborative project with Tanzania. Various nurseries and germplasm were distributed to bean network partners.
- Four new small red-seeded lines with tolerance to major diseases and better yield potential (up to 40%) compared to commercial cultivars were selected in three countries in Eastern Africa. Eight new small red lines perform significantly better than commercial checks in regional trials in two countries.
- Two new red mottled bean lines with improved yield potential over the best commercial checks and tolerant to major biotic stresses were identified in regional trials in four countries in East and Central Africa. An elite nursery of new red mottled bean lines was constituted for validation with farmers and other end-users in Eastern Africa.
- Five new red kidney bean lines show outstanding performance in regional trials and are selected in four countries in East and Central Africa. Thirteen new red kidney lines with better performance than the major commercial cultivar (Canadian Wonder) are selected in three countries.
- New releases of sugar bean become popular in south western Uganda as demand for sugar bean rises in east, central and southern Africa markets
- More than six new sugar bean lines with higher yield potential and combined resistance to angular leaf spot, anthracnose and rust identified in regional evaluations in East and Central Africa

- Sixty farmers from the Central and Eastern Highlands of Kenya, in collaboration with researchers, select 20 red mottled, 20 red kidney and 24 bean lines resistant to root rots and angular leaf spot from a genetically diverse germplasm pool. More than 120 farmers start bulking seed of their new red mottled and red kidney bean lines. Farmer's preference criteria for red mottled and red kidney bean cultivars identified.
- Farmers and researchers select 22 new climbing bean lines of major grain types preferred in the Central Highlands of Kenya and other areas in East and Central Africa from segregating populations. New climbing bean lines with farmer preferred traits distributed for wider evaluation and seed bulking in more than 15 districts in Kenya.
- 12 yellow, sugar, white-seeded bean cultivars show good adaptation to humid tropical lowlands (470masl)
- More than 14 agricultural NGOs, farmer associations and community based organization accelerate seed production and dissemination in lowland western Congo. Improved bean cultivars feature prominently in Kinshasa markets.
- Diffusion of improved bean cultivars to other countries in humid tropical lowlands of central and western Africa gains momentum.
- New bean lines of major market classes with high levels of tolerance to aluminium toxicity and acid low fertility soils identified. The Great Lakes region proves to be a potential source of germplasm with tolerance to low soil fertility conditions
- Five bean lines tolerant to drought identified in regional trials in eastern Africa. A regional drought nursery is constituted and distributed to five drought-prone countries in eastern Africa.

4.1.1 Distribution of seed from CIAT Headquarters

Tables 94 to 96 show a summary of Bean Breeding, Andean Breeding and other nurseries distributed from CIAT headquarters to partners and collaborators.

Table 94. Nurseries distributed by the Mesoamerican bean breeding section

Description	No. of nurseries	No. of lines	Purpose	Institution/ Collaborator	Country
Advanced lines	1	3	Participatory Breeding	CIAT-Malawi R. Chirwa	Malawi
	1	3	Participatory Breeding	CIAT-Nicaragua J. A. Beltrán	Nicaragua
Common bean lines Durango type	1	11	Research	MAFP - Brian Palmer	Timor-Leste
	1	35	Participatory Breeding	Crop Breeding Inst. B. Vivek/G. Makunde	Zimbabwe
Common bean lines tolerant to ALS	1	60	Participatory Breeding	ICTA – Julio Cesar Villatoro	Guatemala
	1	60	Participatory Breeding	EAP - Zamorano, Juan Carlos Rosas	Honduras
	1	5	Research	NBPGR- R.V. Singh	India
	1	6	Participatory Breeding	INTA - R. Valdivia	Nicaragua

Table 94. cont'd

Description	No. of nurseries	No. of lines	Purpose	Institution/ Collaborator	Country
Common bean lines tolerant to drought (2003)	1	89	Research	HAAS Feng Guojun	China
	2	85	Participatory Breeding	MAG Juan Carlos Hernández	Costa Rica
		72	Participatory Breeding	Univ. de Costa Rica Rodolfo Araya	Costa Rica
Common bean lines tolerant to drought (2001)	1	68	Local evaluation	CENTA Carlos Atilio Pérez	El Salvador
	1	95	Local evaluation	CENTA Carlos Atilio Pérez	El Salvador
Common bean lines tolerant to drought (2003)	1	89	Local evaluation	ICTA Julio Cesar Villatoro	Guatemala
	2	89	Local evaluation	EAP - Zamorano, Juan Carlos Rosas	Honduras
		6	Seed production	CIAT-Honduras Guillermo Giraldo	
	1	117	Research	Pantnagar Centre for Plant Genet. Resourc. Hari Har Ram	India
Early maturity lines	1	89	Research	SPII - A. Keshavarz	Iran
	1	55	Local evaluation	Crop Breeding Institute B. Vivek/G. Makunde	Zimbabwe
	1	38	Research	Univ. of Idaho S. P. Singh	USA
F ₂ /F ₅ Low fertility populations	1	3	Research	SPII - A. Keshavarz	Iran
F ₅ families Rojo de Seda type	1	36	Local evaluation	CENTA Carlos Atilio Pérez	El Salvador
F ₅ Families tolerant to drought (2004)	1	118	Participatory Breeding	INTA - R. Valdivia	Nicaragua
F ₈ families – Rojo de Seda type with recessive bc-3 gene	1	26	Local evaluation	CENTA Carlos Atilio Pérez	El Salvador
	1	26	Local evaluation	INTA - Aurelio Llano	Nicaragua
F ₈ Families tolerant to drought (2004)	1	5	Participatory Breeding	INTA - R. Valdivia	Nicaragua
High iron nursery	1	31	Research	EAP - Zamorano, Juan Carlos Rosas	Honduras
Interspecific F ₆ populations	1	23	Local evaluation	EAP - Zamorano, Juan Carlos Rosas	Honduras
RILS - BAT 881 x G 21212	1	3	Research	Univ. of Hannover W. Horst	Germany
RILS - DOR 364 x BAT 477	1	88	Research	Univ. of Leuven Ellen Luyten	Belgium
VIPADOGEN	1	86	Research	Pantnagar Centre for Plant Genet. Resourc. Hari Har Ram	India
Yield nursery DOR 364 x BAT 477	1	36	Yield evaluation	CIF “La Violeta”, Hernán Campos	Bolivia

Table 94. cont'd

Description	No. of nurseries	No. of lines	Purpose	Institution/ Collaborator	Country
Yield nursery (BAT 881 X G 21212)	2	36	Yield evaluation	INTA - Aurelio Llano	Nicaragua
		36	Yield evaluation	INTA - R. Valdivia	
Yield nursery (BRIBRI X SEA 5)	2	36	Yield evaluation	INTA - Aurelio Llano	Nicaragua
		36	Yield evaluation	INTA - R. Valdivia	

Table 95. Nurseries distributed by the Andean bean breeding and Germplasm Characterization section.

Description	No. of nurseries	No. of lines	Purpose	Institution/ Collaborator	Country
Anthracnose differentials	1	12	Biotic stress resistance evaluation	Univ. Nal. - Bogotá Gustavo Ligarreto	Colombia
BAT93	1	1	Nitrogen fixation evaluation	UNAM Gina Hernandez	Mexico
		1	Nitrogen fixation evaluation	LBMPS-Univ. Geneva Clive Pankhurst	Switzerland
		1	Nitrogen fixation evaluation	Gembloux Univ. Jean Pierre Baudoïn	Belgium
BNF/non-nod stocks DOR 364, BAT477	1	4	Nitrogen fixation evaluation	LBMPS-Univ. Geneva William Broughton	Switzerland
CAP, CAN lines x 3 reps	1	86	Yield evaluation	UAGRM Juan Ortube	Bolivia
Climbing bean germplasm nursery x 3 reps	1	41	Yield evaluation	UAGRM, Juan Ortube	Bolivia
Colombian varieties x 3 reps	2	40	Yield evaluation	FIDAR Jose Restrepo	Colombia
F ₂ populations	1	18	Line development	PROMPEX Angel Valladolid	Peru
F ₃ populations	1	8	Line development	PROMPEX Angel Valladolid	Peru
G 2333	1	1	Biotic stress resistance evaluation	Michigan State Univ Jim Kelly	USA
Germplasm accessions	1	21	Genetic studies	Univ. of Vienna Andrea Pedroza	Austria
		34	Transformation capacity	UNAM Jesus Arellano	Mexico
Mid-altitude climbing (MAC) lines x 3 reps	1	37	Yield evaluation	UAGRM, Juan Ortube	Bolivia
POP – bush ñuñas – advanced lines x 6 reps	3	78	Yield evaluation	PROMPEX Angel Valladolid	Peru
Red seeded BIF lines x 2 reps x 2 trials	4	68	PPB/PVS Yield evaluation	FIDAR Jose Restrepo	Colombia

Table 95. cont'd...

Description	No. of nurseries	No. of lines	Purpose	Institution/ Collaborator	Country
RIL parents	1	6	Abiotic stress tolerance evaluation	Michigan State Univ Karen Cichy	USA
RIL parents x 100 g.each	1	18	Nutritional quality evaluation	Cornell University Raymond Glahn	USA
RILs - BAT 93 X JALO	1	4	Genetic studies	Univ. of Vienna Andrea Pedroza	Austria
RILs - DOR 364 x BAT 477	1	4	Abiotic stress tolerance evaluation	INRA Jean Drevon	France
RILs - DOR 364 X G 19833	1	4	Genetic studies	Univ. of Vienna Andrea Pedroza	Austria
RILs - DOR 364 x G 19833	1	89	Biotic stress resistance evaluation	ARC- Grain Crops Inst. Diedre Fourie	South Africa
RILs - G 21078 x G 21242	1	102	Abiotic stress tolerance evaluation	USDA-Baylor Coll. Med. Mike Grusak	USA
RMA, DRK lines x 3 reps	2	23	Yield evaluation	UAGRM, Juan Ortube	Bolivia
RMA, DRK lines x 3 reps	1	23	Yield evaluation	PROMPEX Angel Valladolid	Peru
RMA, DRK lines x 2 reps	1	23	Line development	ARC-Grain Crops Inst. Merion Liebenberg	South Africa
VICARIBE lines x 3 REPS	1	130	Yield evaluation	UAGRM Juan Ortube	Bolivia
VIVA-Crema moteado x 3 reps	1	37	Yield evaluation	Univ. del Tolima Javier Osorio	Colombia
VIVA-Rojos x 3 reps	1	22	Yield evaluation	Univ. del Tolima Javier Osorio	Colombia
VIVA-Rojo moteado x 3 reps	1	29	Yield evaluation	Univ. del Tolima Javier Osorio	Colombia
XAN 159	1	1	Transformation capacity	Univ. of Hannover Hans Jorg Jacobsen	Germany

Table 96. Other nurseries distributed from CIAT headquarters.

Description	No. of nurseries	No. of lines	Purpose	Institution/ Collaborator	Country
ALS differentials (DIFALS)	1	12	Characterization of isolates of <i>P.griseola</i>	Univ. Nal. de Heredia Carlos Araya	Costa Rica
ALS differential lines (Mexico 54, Bolón Bayo)	1	2	Characterization of isolates of <i>P.griseola</i>	EAP-Zamorano Juan Carlos Rosas	Honduras
ANT differentials (DIFANT)	1	12	Characterization of isolates of <i>C. indemuthianum</i>	Univ. Nal. De Heredia Carlos Araya	Costa Rica
	1	12	Characterization of isolates of <i>C. indemuthianum</i>	Facultad de Ciencias Agron. de Gembloux, Jean Pierre Busogoro	Belgium
Bean for Empoasca (650 g)		5	Lab research	University Maryland, Dr. William O. Lamp	USA
Bean lines for virus evaluation	1	238	Virus evaluation	La Tupia, Pradera	Colombia
Diacol Calima line (2.7 kg)		1	Lab research	Institu fur Pflanzenwissenschaften, Entomologie, ETZ-Zentrum, Dr. A. Rott	Switzerland
ICA Pijao line (10 g)		1	Lab research	Institu fur Pflanzenwissenschaften, Entomologie, ETZ-Zentrum, Dr. A. Rott	Switzerland
Infested seed with <i>A. obtectus</i> (27.1 kg)		1	Lab research	Institu fur Pflanzenwissenschaften, Entomologie, ETZ-Zentrum, Dr. A. Rott	Switzerland

4.1.2 Distribution of germplasm within the ECABREN bean network

Table 97. Germplasm distribution from ECABREN bean network

Description of materials	No. of nurseries	No. of entries	Purpose	Recipient	Country
Red mottled, large whites, small whites, pinto, black and tan/yellow	1	10	Biofortification-trials in Denmark	Shankutala Thilsted	Denmark
Red mottled, red kidneys, small reds, large whites, small whites, carioca, pinto, purples, tan, yellow, brown, black (bush and climbers).	1	89	Mineral and protein analysis of Kisii field trials by students	Mwaura, Department of Food Science and Technology	Kenya
Drought lines, early maturity lines, rootrot resistant lines, low soil pH tolerant lines, and climbing bean selections	6	50	PhD (TSBF)	M. Mucheru, Kenyatta University	Kenya
Small reds, blacks, small whites, browns	1	10	International drought trial	Prof Nancy Karanja, Dept of Soil Science	Kenya
Ayewu, Gofta, Roba-1, Maharagi Soja, K 131, Ituri Matata, HRS 545	1	7	Biofortification Trials	Steve Beebe, CIAT	Cali, Colombia
1 Bush (KK 15) and 9 climbers	1	10	BNF trial (M.Sc. student)	Kamau Gicharu, Kenyatta University	Kenya
HarvestPlus Nursery 1 (Red mottled, red kidneys, small reds, large whites, small whites, carioca, pinto, purples, tan, yellow, brown, black (bush and climbers)	8	29 bush + 9 climbers	Biofortification	ISAR (Rubona), EARO (Melkassa) SARI (Arusha) INERA (Mulungu), ISABU(Bujumbura), CIAT-Malawi, Chitedze Agric. Res. Institute NAARI (Namulonge)	Rwanda, Ethiopia, Tanzania, DR Congo, Burundi, Malawi, (Uganda x 2)
International Drought trial (Small reds, blacks, small whites, browns)	4	36 entries (x 3 reps x 2 trials)	Regional evaluation	National program leaders (El Sadig, Musoni, Teshale and Ngulu)	Sudan, Rwanda, Ethiopia, Tanzania
Large whites, snap (bush)	2	35	Evaluations in Sudan	Gezira University	Sudan
Red mottled, red kidneys, small reds, pinto, Low Soil Fertility tolerant lines (Cal 143, CIM 9314-36, M'Mafutala, M'Sole, MLB 49-89A, AFR 708)	1	4 GLPs	HarvestPlus trials	Shankutala Thilsted,	Denmark
BSM tolerant lines (PAD 3, EXL 52,G 22501)	1	6	Low soil N & P tolerant lines	Annet Namayanja, NAARI, Namulonge	Uganda
VAX 6	1	3	BSM resistant lines	Annet Namayanja, Namulonge	Uganda
	1	1	CBB resistant line	Annet Namayanja, NAARI, Namulonge	Uganda
Drought lines Small reds	2	5	Maize-bean drought trial (with CYMMIT, Zimbabwe)	G. Makunde, Agric. Res. Council, Harare Charles Kapapa, Chitedze Agric. Res. Institute , Lilongwe	Zimbabwe, Malawi

Table 97. cont'd ...

Description of materials	No. of nurseries	No. of entries	Purpose	Recipient	Country
Small reds, blacks, small whites, browns	1	36 entries x 1 rep x 2 trials	Drought trials in Rift Valley	Prof. R.S Pathak, Egerton University	Kenya
Parental lines and commercial varieties , BSM , BILFA lines and root rot resistant lines (bush and climbers)	1	100	Development of populations for HarvestPlus CP	Matthew Blair, CIAT (13 May 04)	Cali, Colombia
Angular leaf spot differentials (G 5686, MEX 54, Montcalm, Balon Bayo, Flor de Mayo, G 11796, Don Timoteo, Cornell 49242, G 2858, Amendoim, PAN 72)	1	11	Trials in India	Dr. Sanjay Gupta, ICAR Division of Plant Breeding (13 May 04)	India
Red mottled, red kidneys, small reds, large whites, small whites, carioca, pinto, purples, tan, yellow, brown (bush and climbers)	1	29 bush (short & med. duration) + 10 climbers	Preliminary evaluation for adaptability.	Dr. Sanjay Gupta, ICAR Division of Plant Breeding (13 May 04)	India
Red mottled, red kidneys, small reds, large whites, small whites, carioca, pinto, purples, tan, yellow, brown (bush and climbers)	1	75 bush + 25 climbers	Regional trial	Dr. Jacob M Ngeve, IRAD Centre Agronomique (18 May 04)	Cameroon
Red mottled, red kidneys, small reds, large whites, small whites, carioca, pinto, purples, tan, yellow, brown	5	52 entries x 5 agro-ecologic zones	Advanced breeding lines for preliminary evaluation for adaptability	Tadesse Mebrahtu c/o Asmeron Kidane, Ministry of Agriculture, Asmara (20 May 04)	Eritrea
Red mottled, red kidneys, small reds, large whites, small whites, carioca, pinto, purples, tan, yellow, brown	5	48 entries x 5 agro-ecologic zones	Commercially released cultivars in the region for preliminary evaluation for adaptability	Tadesse Mebrahtu c/o Asmeron Kidane, Ministry of Agriculture, Asmara (20 May 04)	Eritrea
Rwanda Collection (Red mottled, red kidneys, small reds, large whites, small whites, carioca, pinto, purples, tan, yellow, browns)	1	1036	Mineral analysis	Matthew Blair, CIAT (12 July 04)	Cali, Colombia
F ₅ Root rot lines	1	50	Line development	R. Otsyula	Kenya
Elite lines and germplasm	1	17	Pest tolerance/yield performance testing and evaluation	Farmers' groups	Kenya
Elite lines and germplasm	1	30	Pest tolerance/yield performance testing and evaluation	Farmers' groups	N. Tanzania

4.1.3 Exchange of germplasm in Southern Africa Bean Research Network (SABRN)

Various countries within SABRN grouping requested specific nurseries. The nurseries were organized either by market class, or constraint or growth habit of the bean plant. These nurseries serve as sources of germplasm with good attributes that might be useful to NARS partners. The ARS partners either use the selected germplasm in their breeding programs, or they can directly release them as varieties. During this reporting period several nurseries were distributed to various countries (Table 98).

Table 98. List of nurseries and trials that were distributed in the SABRN, 2004

Description	No of nurseries	No. of entries	Purpose	Recipient	Country
Sugar lines nursery	1	134	Yield and adaptation	ARI-Uyole	Tanzania
	1			AREX	Zimbabwe
	3			ARC	South Africa
Small reds nursery	1	91	Yield and adaptation	ARI-Uyole	Tanzania
	1			ARD	Swaziland
International ALS nursery	1	70	Resistance to ALS	ARI-Uyole	Tanzania
	1			AREX	Zimbabwe
	1			ARD	Swaziland
Small black lines	1	27	Yield and adaptation	ARI-Uyole	Tanzania
Drought nursery	1	153	Yield and adaptation	ARI-Uyole	Tanzania
Low N nursery	1	79	Screen for tolerance to low N		Tanzania
	1				Mozambique
	1				Zimbabwe
Low P nursery	1	85	Screen for low tolerance to low P		Tanzania
	1				Mozambique
	1				Zimbabwe
MCR lines nursery	1	62	Yield and adaptation		Tanzania,
	2				Zambia
	1				Mozambique
SARBYT	2	19	Yield and adaptation	ARI-Uyole	Tanzania
	2			DR&SS	Zambia
	3			INIA	Mozambique
	2			AREX	Zimbabwe
	2			ARD	Swaziland
	3			ARC	South Africa
	1			ARD	Lesotho
	2			DARS	Malawi
	3			INERA	DRC

Table 98. cont'd...

Description	No of nurseries	No. of entries	Purpose	Recipient	Country
SARBEN	1	99	Yield and adaptation	ARI-Uyole	Tanzania
	2			DR&SS	Zambia
	3			INIA	Mozambique
	2			AREX	Zimbabwe
	1			ARD	Swaziland
	1			ARD	Lesotho
	2			DARS	Malawi
	3			INERA	DRC
Mid- altitude climbers yield trial	2	20	Yield and adaptation	INIA	Mozambique
	1			DARS	Malawi
Red mottled lines	1	742	Yield and adaptation	INIA	Mozambique
	2			DARS	Malawi
Climbing bean nursery	2	27	Yield and adaptation	DR&SS	Zambia
	2			DARS	Malawi
Red kidneys lines	3	70	Yield and adaptation	ARC	South Africa
	1			AREX	Zimbabwe
Root rot nursery	1	78	Root rot screening	ARD	Swaziland
BSM nursery	1	36	Screening for BSM	ARD	Swaziland
Calima lines	3	68	Yield and adaptation	ARC	South Africa
Low pH nursery	1	108	Screen for tolerance to low pH	INIA	Mozambique
	1			AREX	Zimbabwe
Elite lines and germplasm	1	23	Pest tolerance/yield performance testing and evaluation	Farmers' groups	S. Tanzania
SUG 131	1	1	Pest tolerance/yield performance testing and evaluation	Farmers' groups	Malawi

4.1.4 Testing drought tolerant lines in Nicaragua

Rationale: The Pacific coast of Central America from Nicaragua to El Salvador is subject to repeated and severe droughts that not infrequently have resulted in complete crop losses for many farmers. CIAT and INTA participate in a BMZ-funded project to improve drought tolerance of common bean for this region.

Materials and Methods: F₆-derived families were selected in CIAT by INTA scientists in August, 2003 and shipped to Nicaragua for planting and evaluation under conditions of drought and BGYMV attack. Lines were selected based on seed quality and were increased in January, 2004 for planting in multi-locational yield trials with three repetitions, in Nandarola on the dry Pacific coast, in Matagalpa and in the coastal hills of Carazo in La Compañía Experiment Station, where drought is not normally a problem but which serves as a control treatment without drought.

Results and Discussion: Drought was excessive in Matagalpa and the trial was lost, but the Nandarola site received 120 mm during the growth cycle and experienced drought as the primary yield limitation. The Carazo site experienced no drought as expected. The difference in yield of the elite check variety, INTA Rojo, in the latter two sites was 1216 versus 2265 kg ha⁻¹, or a reduction of 46% due to drought (Table 99). Among the drought-selected lines, yields were superior to that of INTA Rojo by as much as 50% in Nandarola. This confirms that drought genes identified in CIAT-Palmira are effective and offer protection against drought in this Central American environment. Selected lines will be tested in validation trials, while other lines from crosses to fortify resistance to BGYMV are being tested.

Table 99. Yields of drought selected lines in two environments in Nicaragua.

Identification	Yield (kg/ha)	
	Nandarola (drought)	Carazo (non-drought)
MR 14148-54	1843	1663
MR 14143-28-2	1644	1660
MR 14143-28-4	1498	1714
MR 14258-7	1487	1793
MR 14143-28-1	1467	2014
MR 14143-28-7	1393	1780
MR 14148-80	1393	1926
MR 14292-63-1	1393	1729
MR 14143-28-6	1393	1622
MR 14143-28-5	1361	1960
MR 14292-63-3	1307	1882
MR 14000-2	1226	2550
MR 14143-28-3	1223	1915
INTA Rojo (Elite check)	1216	2265
MR 14202-10	1174	1964
MR 14292-63-2	1142	1864
MR 14152-14	1130	2065
MR 14215-9	964	1480
MR 14148-74	923	1778
MR 14273-4	807	2114
MR 14232-10-3	640	1399
MR 14232-10-2	470	1128
MR 14232-10-1	460	1014

Conclusion: Drought tolerance selected in Palmira can make a useful contribution to protecting the crop against drought in Central America.

Contributors: Aurelio Llano, Mauricio Guzmán, Rodolfo Valdivia, Sergio Blandón (INTA); S. Beebe (IP-1)

4.1.5 BCMV resistance in Peruvian dry beans

Rationale: Most of the local climbing and bush bean varieties grown in Peru have not been improved for BCMV resistance. We began a collaboration with Promenestras en Peru to develop segregating populations that would contain either the *I* or *bc3* resistance genes. The target seed classes have been alubias, bayos, canarios, caballero and ñuñas. Although these seed classes are for local consumption (except for Alubia) they have good potential for the export market, in which Peruvian producers are increasing the range of products they offer and the number of countries exported to.

Materials and Methods: Simple crosses were made to produce F₁ hybrids for multiple and triple or back crosses. Among the bush beans the parents included released white (INIA-Garza) and bayo (Bayo Mochica) varieties as well as a group of yellow-seeded Canario breeding lines (CIFAC series). Among the climbing beans, the parents included white beans (Caballeros, Fabes), yellows (Canario bola) and popping beans (ñuñas). The sources of BCMV resistance were a series of BRB lines with matching seed coat color. A few additional crosses were made between red-seeded bush (Catrachita x INIA-B, Montcalm, DRK57, Redcloud y RAA15) or climbing (rojo bolon) beans and BCMV resistance sources. Redcloud is known as Rojo Mollepatata in Peru and is a favored highland variety. Catrachita x INIA-B is an advanced line that will be released in the near future.

Results and Discussion: The list of F₂ and F₃ populations which were developed and multiplied in Darién for shipment to Peru are shown in Table 100a and 100b. In parallel to these breeding efforts, we inoculated Alubia and Fabes-type breeding lines developed by Promenestras confirming that many contained the *I* gene (Table 101). These genotypes were also evaluated with the SW13 SCAR marker and were found to contain the dominant band associated with *I* gene resistance. Further marker assisted selection will be possible with these genotypes, and Mr. K. Delgado from Promenestras was trained in marker techniques for this purpose. BCMV was confirmed to be the most serious Potyvirus in the samples from INIA-Cusco which were from the Yucay and Mollepatata experiment stations (Table 102).

Table 100. Populations generated with Peruvian commercial dry bean genotypes.

a. F₂ populations

No. Entry	Identity	Pedigree	Color Class
Bush Beans			
1	22434-(M) F2	Alubia Cerrillos X BRB197	Alubia
2	22436-(M) F2	Alubia Cerrillos X BRB232	Alubia
3	22439-(M) F2	CIFAC 90013 X BRB197	Canario
4	22440-(M) F2	CIFAC 90013 X BRB196	Canario
5	22441-(M) F2	CIFAC 90013 X BRB232	Canario
6	22442-(M) F2	CIFAC 91125 X BRB212	Canario
7	22443-(M) F2	CIFAC 91135 X BRB212	Canario
8	22444-(M) F2	Bayo Mochica X BRB130	Bayo
9	22445-(M) F2	Bayo Mochica X BRB212	Bayo
10	22446-(M) F2	Bayo Mochica X BRB232	Bayo

Climbing Beans

11	NV 22371-M (F2)Z	Perry Marrow x Q'osqo Poroto	White
12	NV 22372-M (F2)Z	G2333 x Q'osqo Poroto	Red, Yellow
13	NV 22373-M (F2)Z	Kaboon x Q'osqo Poroto	White, Yellow
14	NV 22374-M (F2)Z	BRC3 x Q'osqo Oroto	Red, Yellow
15	22375-M (F2)Z	BRC3 x Kori Inti	Red, Yellow
16	22376-M (F2)Z	Kori Inti x G2333	Red, Yellow
17	22447-M (F2)Z	Kori Inti x G2829	Yellow
18	22448-M (F2)Z	G2829 x Kori Inti	Yellow
19	22449-M (F2)Z	Kori Inti X BRB197	Yellow
20	22450-M (F2)Z	Kori Inti X Blanco Laran Mejorado	White, Yellow
21	22451-M (F2)Z	Blanco Salkantay X BRB156	White
22	22452-M (F2)Z	Blanco Salkantay X BRB196	White
23	22454-M (F2)Z	Blanco Salkantay X BRB130	White
24	22455-M (F2)Z	Blanco Salkantay X BRB191	White, Red Mt.
25	22456-M (F2)Z	Caballero X BRB 151	White
26	22457-M (F2)Z	Caballero X BRB 232	White, Yellow
27	22458-M (F2)Z	Caballero X Blanco Laran Mejorado	White
28	22459-M (F2)Z	Caballero X BRB 130	White
29	22460-M (F2)Z	Caballero X BRB 196	White
23	22461-M (F2)Z	Caballero X BRB 197	White
24	22462-M (F2)Z	Canario Bola X BRB 191	Yellow, Red Mt.
25	22463-M (F2)Z	Q'osqo Poroto X BRB 232	Yellow
26	22466-M (F2)Z	MAC56 X BRB 197	Yellow
27	22467-M (F2)Z	MAC56 X BRB 204	Yellow
28	22468-M (F2)Z	MAC57 X BRB 232	Yellow

b. F₃ populations

Bush	Climbers (cont'd)
ALUBIA CERRILLOS x BRB 130	BRB 212 x ALUBIA FABES
ALUBIA CERRILLOS x BRB 196	BRB 232 x ALUBIA FABES
ALUBIA CERRILLOS x BRB 212	BRB 232 x CAB 19
INIA GARZA x BRB 197	BRB 232 x WATA POROTO
CIFAC 90013 x BRB 130	CAB 19 x BRB 130
CIFAC 90013 x BRB 197	CAB 19 x BRB 196
Climbers	CAB 19 x BRB 197
BRB 130 x WATA POROTO	CAB 19 x BRB 212
BRB 130 x BLANCO SALKANTAY	CAB 19 x BRB 232
BRB 130 x ALUBIA FABES	BRC 12 x BL.SALKANTAY
BRB 196 x CAB 2	BRC 12 x ALUBIA FABES
BRB 196 x CAB 19	BRC 30 x ALUBIA FABES
BRB 196 x ALUBIA FABES	BRC 34 x WATA POROTO
BRB 196 x WATA POROTO	BRC 34 x BL.SALKANTAY
BRB 196 x Q'OSQO POROTO	WATA POROTO x BRB 130
BRB 197 x CAB 19	WATA POROTO x BRB 212
BRB 197 x WATA POROTO	MAC 56 x BRB 197
BRB 197 x BL.SALKANTAY	MAC 57 x BRB 130
BRB 197 x Q'OSQO POROTO	MAC 57 x BRB 196
BRB 212 x CAB 2	MAC 57 x BRB 197
BRB 212 x CAB 19	KORI INTI x BRB 130
BRB 212 x CABALLERO	KORI INTI x BRB 212

Table 101. Alubias and Fabes from PROMPEX-Peru, tested for BCMV resistance.

Entry no.	Advanced Line	N	M	Entry no.	Advanced Line	N	M
1	ALUBIA 3001	8	0	25	ALUBIA 3025	9	0
2	ALUBIA 3002	0	9	26	ALUBIA 3026	9	0
3	ALUBIA 3003	10	0	27	ALUBIA 3027	9	0
4	ALUBIA 3004	10	0	28	ALUBIA 3028	10	0
5	ALUBIA 3005	10	0	29	ALUBIA 3029	10	0
6	ALUBIA 3006	9	0	30	ALUBIA 3030	9	0
7	ALUBIA 3007	2	8	31	ALUBIA 3031	9	0
8	ALUBIA 3008	0	10	32	ALUBIA 3032	8	0
9	ALUBIA 3009	0	9	33	FABES 3001	10	0
10	ALUBIA 3010	10	0	34	FABES 3002	10	0
11	ALUBIA 3011	9	0	35	FABES 3003	10	0
12	ALUBIA 3012	9	0	36	FABES 3004	10	0
13	ALUBIA 3013	9	0	37	FABES 3005	10	0
14	ALUBIA 3014	10	0	38	FABES 3006	10	0
15	ALUBIA 3015	9	0	39	FABES 3007	10	0
16	ALUBIA 3016	9	0	40	FABES 3008	9	0
17	ALUBIA 3017	10	0	41	FABES 3009	9	0
18	ALUBIA 3018	10	0	42	FABES 3010	10	0
19	ALUBIA 3019	8	0	43	FABES 3011	10	0
20	ALUBIA 3020	10	0	44	FABES 3012	9	0
21	ALUBIA 3021	8	0	45	FABES 3013	9	0
22	ALUBIA 3022	8	0	46	FABES 3014	9	0
23	ALUBIA 3023	7	0	47	FABES 3015	8	0
24	ALUBIA 3024	9	0				

N = necrosis (resistance – *I* gene) ; M = mosaic (susceptibility)

Table 102. Potyvirus analysis of INIA-Cusco samples.

Entry No.	Sample	Laboratory results - ELISA			
		BCMV	BSMV	BMMV	Severe
1	Yucay I	+	+	-	-
2	Yucay II	-	+	-	-
3	Yucay III	-	-	-	-
4	Yucay IV	-	-	-	-
5	Yucay V	-	-	-	-
6	Yucay VI	-	-	-	-
7	Yucay VII	-	-	-	-
8	Mollepata I	-	-	-	-
9	Mollepata II	+	-	-	-
10	Mollepata III	+	-	-	-
11	Mollepata IV	+	-	-	-
12	Mollepata V	+	-	-	-
13	Mollepata VI	+	-	-	-
14	Mollepata VII	-	-	-	-
15	Mollepata VIII	+	-	-	-
16	Mollepata IX	+	-	-	-
17	Mollepata X	+	-	-	-
18	Mollepata XI	-	-	-	-
19	Mollepata XII	+	-	-	-

Future Plans: Remnant seed will be planted for pedigree and mass selection to develop locally adapted germplasm for Colombia and other areas of the mid-altitude tropics. Single plant selections will be made in the F₅ generation.

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4.1.6 New small red lines with high yield potential identified in regional evaluation in Eastern Africa

Rationale: Small red grain type is an important market class in bean producing countries of East and Central Africa. Small and medium size reds accounts for more than 20% of the area under bean production in Africa (Wortmann et al, 1998). Small reds are particularly important in Ethiopia, where they account for more than 50% of the production. They are also widely grown in Kenya, Rwanda, DR Congo, and Tanzania. Small and medium reds are becoming popular in Madagascar and some parts of western Africa. Productivity of small reds is constrained by diseases especially rust, root rots, common bacterial blight, angular leaf spot, drought and low soil fertility. Most of the regionally important commercial varieties such as Red Wolaita in Ethiopia, GLP 585 ('Wairimu') in Kenya, Maasai Red in Tanzania and Umubano in Rwanda, DR Congo and Uganda are susceptible and have low yield potential. Umubano is also susceptible to Fusarium wilt strains occurring in Rwanda. A regional program to develop and disseminate high yielding, marketable small red bean lines with resistance to biotic and abiotic stress factors and acceptable grain characteristics was started in 2001. This program involved the development of segregating populations from simple and complex crosses, screening existing advanced breeding lines from regional bean programs and the CIAT bean program in Colombia, followed by constraint evaluation and yield testing across agro ecological zones in Eastern Africa. We previously reported on the progress made in population development and constraint evaluation. This report highlights progress made in regional evaluation and identification of candidate lines.

Materials and Methods: Twenty five small red lines were evaluated in Ethiopia, Madagascar, Tanzania and Kenya in 2003/2004. The lines were identified from previous constraint evaluation in the regional program. The trials were laid out in a 5 x 5 lattice design with three or four replicates. Plots had four 5m rows. Spacing was 45-50 cm between rows and 10-15 cm within rows. Data was collected from the two inner rows. Normal cultural practices were followed. Regionally important commercial cultivars were included as checks. A variety selection meeting was conducted September 2004 to identify the most promising lines in each country and regionally.

Results and Discussion: In Ethiopia, yield of the 25 lines varied from 851 kg ha⁻¹ (ECAB 0420) to 2929 kg ha⁻¹ (ECAB 0426) with a trial mean of 1691 kg ha⁻¹. Sixteen lines had better grain yield compared to Red Wolaita, the most popular small red bean variety in Ethiopia (Table 103). Grain size of the new lines was comparable or slightly larger than that of Red Wolaita (22 g per 100 seeds). However, only six lines had better yield than Maasai Red. Sixteen lines had better grain yield compared to GLP 585 (Wairimu).

Table 103. Plant height, 100-seed mass and grain yield of 25 small red bean lines at Awassa in southern Ethiopia, 2003/04.

Line	Plant height (cm)	100-seed mass (g)	Grain yield (kg ha ⁻¹)
ECAB 0426	36	23.7	2929
ECAB 0427	45	24.0	2455
ECAB 0416	41	23.7	1934
ECAB 0429	43	20.7	1923
ECAB 0418	41	23.1	1966
ECAB 0419	40	24.3	1598
ECAB 0411	34	20.9	2564
ECAB 0402	40	24.5	2263
ECAB 0424	40	24.3	1935
ECAB 0421	37	25.8	1716
ECAB 0417	36	22.3	1553
ECAB 0415	33	24.3	2301
ECAB 0422	38	22.3	2229
ECAB 0410	44	21.5	1558
MCM 2001	39	22.8	1556
GLP 585	40	21.3	1346
Maasai Red	37	25.1	2032
Red Wolaita	35	22.0	1449
Trial mean	38	23.4	1691

In Madagascar, seven small red lines were selected. Grain yield of the selected lines varied from 771 to 1278 kg ha⁻¹. The selected lines were ECAB 0427 (771 kg ha⁻¹), ECAB 0418 (707 kg ha⁻¹), ECAB 0411 (1155 kg ha⁻¹), ECAB 0417 (1278 kg ha⁻¹), ECAB 0415 (1072 kg ha⁻¹), ECAB 0422 (824 kg ha⁻¹) and ECAB 0410 (780 kg ha⁻¹). This compared with 870 kg ha⁻¹ for GLP 585. The selected Flines flowered in 42 to 48 days in Madagascar. GLP 585, ECAB 0415 and ECAB 0410 flowered in 48 days. All other lines flowered in 42 to 43 days.

In Kenya, the best performing varieties included ECAB 0429 (1925 kg ha⁻¹), ECAB 0426 (1895 kg ha⁻¹), ECAB 0420 (1813 kg ha⁻¹), ECAB 0428 (1757 kg ha⁻¹), ECAB 0408 (1757 kg ha⁻¹), ECAB 0410 (1644 kg ha⁻¹) and ECAB 0402 (1617 kg ha⁻¹). Results also showed that, as in Ethiopia, Maasai Red was the best yielding check variety in Kenya.

Regionally, four new lines were selected in the three countries. These were ECAB 0418, ECAB 0411, ECAB 0417 and ECAB 0410. Eight lines were selected in two of the three countries. Three lines were selected in one country. Results from Tanzania are pending. These results indicate that the new small red lines may have both broad and country specific adaptation. No significant susceptibility to diseases was reported. However, further evaluation on-farm and on-station across agro ecological zones will confirm the best candidates for release and seed production.

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Collaborators: S. Beebe and T. Assefa

4.1.7 New red mottled bean lines identified in regional evaluation in Eastern Africa

Rationale. The large seeded red mottled bean is probably the most important market class in East and Central Africa and in major bean producing countries in southern Africa such as Malawi. Regionally, it has an estimated 20% market share, and probably higher in Kenya, Uganda and Malawi, the leading producers and consumers of red mottled bean. Red mottled bean is gaining popularity in the region. For example, red mottled is now a popular grain type in southern Ethiopia, five years since it was introduced in the area. In Awassa, the red mottled bean is selling at a higher price in local markets (20 to 30 Birr per kg, equivalent to US\$ 2 to 3) compared to the traditionally popular small red. However, most of the regionally important commercial cultivars such as GLP2, K20, K132 and Lymungu 85, are susceptible to diseases, pests and low soil fertility. This has contributed to decline in national production and low yields in farmers' fields, adversely affecting food security, nutrition and incomes of bean growers in the region. A regional program was started in 2001 to develop improved red mottled bean lines with resistance to diseases (especially angular leaf spot, anthracnose, common bacterial blight and root rots) and tolerance to abiotic stress factors especially low soil fertility and drought. Last year, we reported on development of breeding populations and identification of lines combining resistance to two or more biotic and abiotic stresses. In this report, we highlight the performance of the lines in regional trials and selection of candidate lines for release.

Materials and Methods: One hundred advanced red mottled lines were distributed to sites in Uganda, Ethiopia, DR Congo, Kenya, Burundi and Tanzania in 2003 for evaluation and identification of best performing lines in major agroecological zones. The study also sought to identify lines with broad and country specific adaptation both on-station and in farmers' fields. Regionally important red mottled commercial cultivars were included as checks. The trials were laid out in lattice design with three or four replicates. Each plot had four, 5 m rows. Agronomic data was collected from the inner two rows. Intra-row spacing was 10 cm and 45 between rows. Rating for biotic and abiotic stresses followed CIAT (1987) standard system. Collaborators added other promising red mottled lines to the standard set (25 entries) for comparison.

Results and Discussion: In Uganda, seven lines were selected. These were ECAB 0060, ECAB 0070, ECAB 0090, AFR 623, POA8, F7MG/1 and POA 4. Fifteen lines were selected in DR Congo from a regional multiple constraint nursery. These included CAL 143, AND 907, AND 897, AND 1060, AFR735, AFR 699, UBR93/4, AND 1005, POA 2, CAL 175, CAL 172, VAC 49, POA 8, AFR 623 and CAL 176. POA 2 is released in Uganda (as NABE 4). Selection was based on evaluation on-farm and on-station for two seasons. The nurseries were also distributed for further evaluation and selection in M'vuazi and Equator regions. Characteristics of the selected lines are shown in Table 104. In Ethiopia, 25 lines including a local check were evaluated at Awassa. Grain yield varied from 2018 kg ha⁻¹ for the local check to 3321 kg ha⁻¹ for ECAB 0027 with a trial mean of 2692 kg ha⁻¹ (Table 105). Growing conditions were favourable and no major disease incidence was recorded. The best yielding lines were ECAB 0027, ECAB 0008, ECAB 0081, ECAB 0063, ECAB 0042, ECAB 0043, ECAB 0098, ECAB 0019 and ECAB 0081. Test lines produced higher yields compared to K132, CAL 143, GLP 2 and Lyamungu 85.

Table 104. Days to flowering and maturity, reaction to angular leaf spot, anthracnose, ascochyta, rust and grain yield of bean lines selected from the regional multiple constraint nursery (MCN) in eastern DR Congo, 2003/2004.

Line	Days to 50% flowering	Days to maturity	Angular leaf spot	Anthracnose	Ascochyta	Rust	100-Seed mass	Grain yield (kg ha ⁻¹)
SCAM 80CM/2	41	92	4	1	1.6	1.6	35.8	2047
SEQ 1006	49	94	3.3	1	1	1.3	41	1874
CAL 143	47	94	4	1	1.6	1.6	37	1807
AND 907	47	94	3.3	1.3	1.3	1.3	38.5	1785
AND 897	47	94	3	1.3	1.3	1.3	39.2	1761
AFR 735	39	89	3.3	1	1.6	1	37	1675
AND 1060	47	92	3.3	1	1.6	1	43	1393
AFR 699	51	99	3	1	1.3	1.3	42	1196
UBR93-4	47	92	3.6	1	1	1	42	1436
AND 1005	51	99	3.3	1	2.0	1	45.2	1072
POA 2	47	92	3.3	1	1	1.3	36	1029
CAL 175	45	92	3.3	1.3	1.6	1	42	1160
CAL 172	45	89	3.3	1.3	1.6	1.3	37.2	1009
VAC 49	51	92	3.3	1	1.3	1	29	883
POA 8	45	92	4	1	1	1	53	950
AFR 623	47	92	3.3	1.3	1	1	43.5	1172
CAL 176	47	92	4.3	1.3	1.6	1.3	48.2	1280

Table 105. Plant height, 100-seed mass and grain yield of red mottled bean lines selected at Awassa, southern Ethiopia, 2003/4.

Line	Plant height (cm)	100-seed mass	Grain yield (kg ha ⁻¹)
ECAB 0056	39	41.5	2555
ECAB 0034	39	42.6	2581
ECAB 0042	34	45.5	2991
ECAB 0008	36	51.6	3261
ECAB 0063	43	46.7	3163
ECAB 0060	33	42.7	2389
ECAB 0068	40	43.0	2576
ECAB 0041	38	41.8	2789
ECAB 0043	34	50.8	3121
ECAB 0047	39	44.7	2706
ECAB 0020	39	43.2	2574
ECAB 0098	34	41.6	2990
ECAB 0019	35	41.5	2981
ECAB 0023	38	45.8	2956
ECAB 0081	35	47.9	3173
ECAB 0013	37	43.7	2329
ECAB 0050	36	45.1	2783
ECAB 0027	42	49.1	3331
ECAB 0097	48	47.0	2780
ECAB 0082	40	42.5	2039
K132	36	43.8	2156
CAL 143	35	38.2	2398
GLP 2	45	40.6	2455
Lyamungu 85	37	49.7	2217
Local check	38	50.2	2018
Mean	37.6	44.8	2692

In Tanzania, 23 lines were evaluated under irrigation at Madiira (Arusha) due to failure of rains during the season. Yields were generally high (over 2 t ha⁻¹). The best performing lines were: ECAB 0060, ECAB 0063, ECAB 0019, ECAB 0036, ECAB 0020, GLP 2, ECAB 0023, ECAB 0082, ECAB 0081, ECAB 0042, ECAB 0027, ECAB 0043, ECAB 0050 and ECAB 0013. In Madagascar, five lines were selected. Yields were lower in Madagascar compared to other sites. The best performing lines were ECAB 0034 (890 kg ha⁻¹), ECAB 0063 (866 kg ha⁻¹), CAL 143 (1022 kg ha⁻¹), K132 (727 kg ha⁻¹) and Lyamungu 90 (658 kg ha⁻¹). Based on performance at three locations over two seasons, the best performing lines in Kenya were: ECAB 0019, ECAB 0027, E8, ECAB 0063, ECAB 0041, ECAB 0060, ECAB 0023, ECAB 0081, ECAB 0098, ECAB 0013, ECAB 0097, ECAB 0056, ECAB 0043, ECAB 0008, ECAB 0020, ECAB 0047 and ECAB 0068.

These results indicate that most of the lines performed well in more than one country, indicating broad adaptation. Two outstanding lines that were selected at sites in four countries were: ECAB 0060 and ECAB 0063. Six lines showed good performance in three countries. These were ECAB 0020, ECAB 0019, ECAB 0023, ECAB 0081, ECAB 0013, and CAL 143. From the MCN nursery, POA 2, POA 8 and AFR 623 were selected in both DR Congo and Uganda. Twelve lines showed good adaptation in two countries. It appears that some regionally adapted lines, with better grain yield and resistance to the major diseases may be identified from these trials. Lines with broader adaptation are preferred by seed producers because they justify seed production for a larger market.

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4.1.8 New dark red kidney bean lines identified from regional evaluation in Eastern Africa

Rationale: Dark red kidney is one of the most important market classes of the common bean in East and Central Africa. It commands an estimated 10% market share in domestic and regional markets, and a much higher share in Kenyan and Tanzanian markets. Production is dominated by a single variety, Canadian Wonder which was introduced in the region more than 50 years ago. However the productivity of this variety has been on the decline because of susceptibility to diseases, especially angular leaf spot, anthracnose, common bacterial blight, root rots, drought and declining soil fertility. More recent releases such as Selian 97 have yet to meet consumer acceptability comparable to Canadian Wonder. Red kidney bean is predominantly produced by smallholder farmers, with limited options for inputs to reduce effects of biotic and abiotic stresses. Development of new varieties with natural host resistance to these stresses is probably the most effective strategy of improving productivity of red kidney bean. In 2001, the East and Central Africa Bean Research Network started a market led breeding strategy to develop high yielding, red mottled beans with tolerance or resistance to two or more biotic and abiotic stresses. This program started with development of segregating populations from simple and

multiple crosses, and introduction of red kidney grain type from CIAT, Colombia. During the first phase of this work, the segregating populations were selected for six to eight generations under natural and artificial disease epiphytotics, low soil fertility and drought stress. In second phase, red kidney lines with acceptable grain and resistance to major stresses were entered into regional evaluations to expose them to a wider range of pathogen diversity and production environments in East and Central Africa and to identify candidates for national and regional releases. This report highlights progress made in identification of promising red kidney lines from regional evaluation.

Materials and Methods: One hundred-twelve red kidney lines were evaluated in trials sites in Ethiopia, Madagascar, Tanzania, Rwanda and Kenya. The experiments were laid out in lattice design with three to four replicates. Spacing was 45-50 cm between rows and 10-20 cm within rows. A plot had four rows. Yield and other agronomic data were collected from the inner two rows. Rating for biotic and abiotic stresses followed CIAT (1987) standard system. Collaborators added other promising red kidneys lines to the standard set (112) for comparison. Normal cultural practices were followed. Breeders, pathologists, soil scientists and agronomists from participating countries made selections during 'candidate variety' selection meeting in Nairobi, September 2004. Canadian Wonder was included as the check variety.

Results and Discussion: In Tanzania, high yields were recorded because the trial was irrigated after rains failed. Grain yield varied from 3148 to 4897 kg ha⁻¹. There was a low incidence of rust on one line and anthracnose on two lines. Plant vigour varied from 1 to 3. Four lines which flowered in less than 41 days were grouped as early maturing. These were EACB 0243, ECAB 0294, ECAB 0287 and ECAB 0217. All other lines flowered within 44 days. Canadian Wonder had the lowest yield (3148 kg ha⁻¹). ECAB 0204 had the highest grain yield (4897 kg ha⁻¹) and was the only line that yielded better than Selian 97. In contrast, low yields were recorded in Madagascar. Yields of the best 12 lines varied from 710 to 1693 kg ha⁻¹. However, only five lines had better yields than Canadian Wonder (GLP 24) with a mean yield of 825 kg ha⁻¹. These were ECAB 0240 (889 kg ha⁻¹), ECAB 0247 (875 kg ha⁻¹), AND 931-B1 (982 kg ha⁻¹), TZ 201-439-3 (777 kg ha⁻¹), EMP 250-51 (1142 kg ha⁻¹), VTT 926/2-4 (1693 kg ha⁻¹) and UBR (91)45-1 (1266 kg ha⁻¹). ECAB 0240 and UBR (91)45-1 flowered in 40 days. TZ 201-439-3 was the last to reach 50% flowering (48 days).

Relatively high yields were recorded in Ethiopia. Grain yield varied from 2300 kg ha⁻¹ (ECAB 0281) to 3452 kg ha⁻¹ (ECAB 0270). Some characteristics of the 11 lines that produced more grain than the check Canadian Wonder are shown in Table 106. However, 21 lines (including Canadian Wonder) yielded better than Selian 97.

Table 106. Plant height, 100-seed mass and yield of the best yielding lines at Awassa, southern Ethiopia.

Line	Plant height (cm)	100-seed mass (g)	Grain yield (kg ha⁻¹)
ECAB 0241	39	39.2	3089
ECAB 0253	43	45.8	2964
ECAB 0233	42	44.2	2928
ECAB 0201	39	45.3	2975
ECAB 0243	39	45.8	2908
ECAB 0203	40	41.2	2973
ECAB 0267	36	42.1	2852
ECAB 0287	37	49.8	3089
ECAB 0217	35	43.8	3283
ECAB 0256	38	43.1	3150
ECAB 0270	37	38.5	3452
ECAB 0295	40	56.2	3333
<i>Checks</i>			
Canadian Wonder	37	44.1	2833
Selian 97	36	53.3	2562
Trial mean	38	44.9	2868

The best yielding lines at two locations in Kenya were (in decreasing order) ECAB 0296 , ECAB 0224 , ECAB 0240, ECAB 0234, ECAB 0219, ECAB 0246, ECAB 0228, ECAB 0290, ECAB 0262, ECAB 0288, ECAB 0251, ECAB 0231, ECAB 0232, ECAB 0248, ECAB 0282, and ECAB 0292. Mean yields at Kabete and Thika varied from 1908 kg ha⁻¹ for ECAB 0292, to 2218 kg ha⁻¹ for ECAB 0296. Mean yields were 1322 kg ha⁻¹ for Canadian Wonder and 1326 kg ha⁻¹ for Selian 97. Twenty-one lines selected at Awassa (Table 106) were also selected in previous trials in Kenya.

These results indicate most lines were adapted and therefore performed well in more than one country. Among the lines selected in four countries were: ECAB 0201, ECAB 0252, ECAB 0240, ECAB 0267 and ECAB 0247. Thirteen lines performed well and were selected in three countries. Only four lines were selected in two countries (ECAB 0295 and ECAB 0224).

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4.1.9 New lines identified in sugar beans, a market class gaining prominence in East and Central Africa

Rationale: Although sugar bean grain type has been a relatively small market class in eastern Africa, recently it has become more important because of growing demand in export destinations and among domestic consumers. In the Great lakes region, sugar bean is grown in eastern DR Congo for export to urban centers in the western part of the country. Sugars are important in southern Africa especially in South Africa, Zimbabwe, Zambia and Angola (Wortmann et al, 1998). South Africa imports sugar bean from China and Brazil to meet its domestic requirements. East and Central Africa bean growing countries are increasing production to meet the growing demand. For example, in 2003 Uganda secured orders to supply South African supermarkets. Recently, dealers from other countries in southern Africa have placed orders to supply 5,000 t of sugar bean. In Ethiopia, sugar bean are retailing at over \$350 per ton compared to \$200-250 per ton for other grain types (Asrat Asfaw, personal communication). Production of sugar bean is constrained by diseases, pests and lack of marketable varieties. Sugars are susceptible to rust, common bacterial blight, angular leaf spot, anthracnose, halo blight, drought, bruchids and excessive rain. Starting in 2001, DR Congo has been leading a regional effort to identify marketable sugar bean varieties with resistance to major diseases and pests. This report highlights progress made in this effort.

Materials and Methods: A regional germplasm collection was assembled and screened for sugar grain type. The collection comprised of segregating populations derived from 52 parents of diverse genetic backgrounds and known resistance to specific stress factors, especially angular leaf spot, common bacterial blight and halo blight. Included in this collection were six multiple constraint nurseries (MCN) constituted from advanced lines developed at CIAT, Colombia and from regional breeding programs in East and Central Africa. The materials were initially screened for adaptation and tolerance to biotic stress factors at Kabete Field Station, University of Nairobi and at INERA- Mulungu Research Station in DR Congo. Subsequently, 27 selected lines were evaluated in Uganda, DR Congo and Kenya in 2003 and 2004. Disease scoring followed the standard CIAT scale (CIAT, 1987).

Results and Discussion: Thirteen new sugar lines were identified at Mulungu Research Station in eastern DR Congo (Table 107). Lines with bush growth habit (Types I and II) flowered in 39 to 48 days, and matured in 82 to 94 days. As expected, climbing bean lines flowered and matured later. There was high disease pressure from angular leaf spot. All selected lines had intermediate reactions to angular leaf spot. Most of the lines had resistant scores to anthracnose, aschochcyta and rust. There was considerable variability in seed size. The 100-seed mass varied from 26.7 g in RWV 1134 to 47 g for MAC 70-2. Grain yield varied from 1009 kg ha⁻¹ for RWV 1128-2 to 2004 kg ha⁻¹ for KS 151-3F11-1 and 2024 kg ha⁻¹ for P94056. The climbing sugar bean lines did not show the expected superiority for grain yield compared to the bush lines.

Table 107. Days to flowering and maturity, reaction to angular leaf spot, anthracnose, aschochyta and rust, 100-seed mass and grain yield of 15 sugar bean lines selected at Mulungu, DR Congo from regional multiple constraint nurseries between 2001 and 2004

Lines	Days to 50% flower	Days to maturity	Angular leaf spot	Anthracnose	Ascochyta	Rust	100-seed mass (g)	Grain yield (kg ha ⁻¹)
a. Bush								
P 94056	48	92	4.6	1	2	2	27.5	2024
KS 65-2	48	92	3.6	1	1.3	1	34.8	1858
NM 12652/9A-1	41	85	3.6	1.3	1.3	1.6	-	1418
NM 12650/4A-1	39	85	4.3	1.3	1	1.3	36.0	1412
NM 12633/9A	39	82	4	1	1	1.6	44.2	1411
Montcalm 1	48	92	4.3	1.6	1.3	1.6	34.0	1403
VTTT 926/3-5	41	88	4.0	1.6	1.0	1.3	40.2	1327
NM 12656/14-1	39	82	3.3	1.3	1.6	1.6	42.5	1299
MX 875-3T	41	85	5.0	1.3	1.6	3.3	28.1	1107
NM 12647/A-1	39	85	4.6	1.0	1.3	2.0	35.2	1013
DOR 481	42	94	4.0	1.0	1.0	1.3	24.0	1288
KS 151-3F11-1	47	90	-	-	-	-	-	2004
b. Climbing beans								
MAC 70-2	49	98	3.3	2.0	1.0	1.3	47.0	1667
RWV 1134	47	105	4.6	1.3	1.3	2.6	26.7	1340
RWV 1128-2	45	110	4.0	1.3	1.0	1.6	41.0	1009

In Western Congo, two lines KS 65-2 and KS 47-1 that performed well in lowland conditions entered pre-release stages. In Uganda, MAC 31 was selected and released in 2003. This line is becoming very popular in local markets because of its large seeds and pods. It is being grown in eastern Uganda (Mbale district) for trial in export markets. Sugar 73 (MAC 73?) was released as NABE 5. Based on grain yield at two locations in Kenya, the best performing sugar bean lines were ECAB 0806 (1676 kg ha⁻¹), ECAB 0822 (1645 kg ha⁻¹), ECAB 0810 (1645 kg ha⁻¹), ECAB 0807 (1629 kg ha⁻¹), ECAB 0805 (1629 kg ha⁻¹), and ECAB 0823 (1565 kg ha⁻¹). These lines showed higher yields compared with Sugar 73 (1455 kg ha⁻¹).

These results indicate that improved sugar bean varieties were identified from the working collection. However, there is need to broaden the genetic base of existing populations to meet the growing demands. Colour retention in sugars remains a challenge. Most sugar varieties change from preferred wine red speckles on cream or white background to brown after storage, thus losing their consumer appeal. Only modest progress has been made for resistance to angular leaf spot and common bacterial blight. Recently identified sources of the diseases should be exploited to improve productivity in farmers' fields.

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Collaborators: Bean program teams at Kabete, Mulungu and Namulonge

4.1.10 Participatory selection of red mottled and red kidney bean lines tolerant to angular leaf spot and root rots in the Central and Eastern highlands of Kenya

Rationale: Involvement of farmers in variety development programs is advocated because it enhances farmer acceptance and adoption of new varieties. In addition it facilitates the inclusion of farmers criteria and development of varieties adapted to specific ecological niches (Ceccareli, 1994). Considerable experimentation with participatory approaches in bean improvement has been conducted in East and Central Africa (Sperling, 1993; CIAT, 2002; Kimani et al, 2004; Buruchara et al, 2004). Results indicate that not only does farmer involvement increase chances of adoption of a new variety but also may shorten time to new releases. Bean improvement programs have therefore incorporated elements of participatory breeding in the formal-led breeding schemes. Red mottled and dark red kidney beans are probably the most popular and widely marketed grain type in Kenya, Uganda, Tanzania and other countries in the region. However, limited participatory work has been conducted to improve these market classes. Most of the commercial varieties are susceptible to diseases and low soil fertility. These stresses cause significant yield reduction and are associated with declining yield in farmer's fields. Purpose of this study was to identify selection farmer's selection criteria for red mottled bean and select high yield lines adapted to this region. This report highlights progress in participatory selection of red mottled and red kidney bean varieties in Central and Eastern Highlands of Kenya.

Materials and Methods: One hundred red mottled, 115 red kidney and 53 root rot tolerant bean lines were evaluated by 60 farmers at Embu Research Station in Kenya between 2001 and 2004. The entries were initially selected from a diverse germplasm pool constituted from six multiple constraint nurseries (MCN 1-6). The MCN nurseries originated from regional breeding programs at Kawanda, Kabete, and CIAT bean program, Colombia. Preliminary selection for adaptation and tolerance to diseases especially angular leaf spot, anthracnose, root rot and drought were conducted at Kabete Field Station, University of Nairobi. Subsequently, 100 red mottled and 115 red kidney lines with tolerance to these stresses and local checks were sown at KARI-Embu research station to increase the seed and make preliminary observations during the short rain season, 2001. In the following long rain season (2002), three farmer groups from Meru, Embu and Kirinyaga were invited to evaluate and select the trial sown in larger plots at the station. The farmer groups came from semi-arid, bean growing areas with moderate to low rainfall.

Results and Discussion: Farmers used more than 20 criteria to identify preferred varieties. The criteria could be grouped into nine categories: yield related (high yield, pod load, germination percentage), seed characteristics (appealing colour, grain size), resistance to biotic and abiotic stresses (resistance to insect pests, diseases), maturity (early maturing lines were preferred for dry areas and late maturing for the wetter highlands), marketability (farmers selected grain types which they indicated were easy to sell and fetched high prices), harvesting and post harvest traits (resistance to shattering, good storability, colour and weight retention and resistance to storage pests), and cooking and organoleptic traits (short cooking time, good taste and low flatulence) and grain size. Small seeded types were preferred for making stews, medium size for traditional dish 'githeri' –a mixture of boiled maize and beans, and large seeds were preferred for mashed dishes. Appearance of cooked food, and ability to retain freshness when food is preserved for a few days were considered important.

Farmer evaluation and selection reduced the number of red mottled lines from 100 lines to 31, dark red kidney from 115 to 30, angular leaf spot and root rots resistant varieties to 23 (Table 108). The involvement of farmers in the evaluation and selection process ensured that only varieties acceptable to farmers were advanced to the next stage of experimentation and therefore more efficient use of resources (funds, land, inputs, time etc.) in the variety development program. In 2003, farmers evaluated the selected lines and started seed bulking in different agro-ecological zones in Embu, Meru Central and Kirinyaga districts. Number of criteria used to select these lines is probably much higher than could be accommodated in a conventional breeding program.

Table 108. Number of red mottled, red kidney and angular leaf spot and root rot tolerant lines selected by farmers in Meru, Embu and Kirinyaga districts in the Central Highlands of Kenya, 2003.

	Red mottled	Nursery Red kidney	Root rot and angular leaf spot tolerant lines
Total lines in trial	100	115	53
Number selected	31	30	24
Number of lines in seed bulking	20	20	24
Number of selector farmers	60	60	20

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4.1.11 Participatory selection of climbing beans in the central highlands of Kenya

Rationale and Background: Climbing beans offer new opportunities for increasing bean yields in farmer's fields. Typically, they have 3:1 yield advantage compared with bush beans. They are particularly suited to intensive bean production systems where land availability is declining because of rapid population growth. Climbing bean are well adapted to intensive production systems because of their upright growth habit when staked and therefore vertical exploitation of space, longer growing period, which result in high yields per unit area. Although climbing have been traditionally grown in some regions in East and Central Africa (Wortmann et al, 1998), production received new impetus with introduction of high yielding climbing beans in the Great Lakes Region in the late 1980's and early 1990's. Farmers quickly recognized their potential, experimented with them and started production. This contributed to increased bean production especially in Rwanda and DR Congo where adoption rates of more than 40% have been reported. Climbing bean technology is rapidly spreading to other countries in the highlands of eastern Africa where conditions (high population density, declining land sizes, and high per capita bean

consumption) are similar to those in Great Lakes region. In Kenya, the leading bean producer in Africa, climbing beans were first introduced in Western Kenya from Rwanda. Fifteen seeds each of six lines (Umubano, Vunikingi, Flora, Gisenyi, Puebla and Ngwinurare) were introduced in 1995 to the Central and Eastern Highlands from KARI-Kakamega. Seeds were increased, and the varieties evaluated with farmers. Farmers accepted the new varieties because of their yields and resistance to major bean diseases in the region (angular leaf spot, anthracnose and root rots). Between 1999 and 2002, the varieties were directly distributed to more than 6500 farmers (excluding farmer-to-farmer exchanges). Seeds of climbing beans were selling at between \$1.25 to 2.5 per kg. However, although farmers accepted the new climbing beans, they indicated that they were more difficult to sell because they lacked the preferred grain type. In this region, the preferred grain types are red mottled and red kidneys, and to a lesser extent pintos and small reds. None of the new varieties was red mottled or kidney. In 2001, ECABREN and KARI-Embu started a program to introduce climbing beans that were segregating for the preferred grain types. This report highlights progress in this program.

Materials and Methods: One hundred climbing bean genotypes were introduced to Embu Regional Research Centre during the 2001 short rain season (Oct-December). The genotypes comprised of F₄ segregating populations of medium altitude climbers (MAC) from CIAT, Colombia and advanced lines from the regional climbing bean nursery at Kabete. Preliminary evaluation for morphological traits (growth habit, pod clearance and plant height) and yield components was conducted at the station. During the short rain season of 2002, representative farmer groups from Meru, Embu and Kirinyaga districts were invited to evaluate and select single plants with preferred traits. Farmers agreed on the most important selection criteria. Progeny rows of selected lines were established at the station during the long rain season of 2003 to produce adequate seed for on-farm testing in 2004.

Results and Discussion: A total of 22 climbing bean lines were selected. Some characteristics of these lines are shown in Table 109. The F₄ populations were segregating for a wide range of grain types, which included red mottled, red kidney, small reds, pinto, sugars and yellows. The lines also showed considerable variation in duration to maturity, plant height, vigour, pod load and grain yield (Table 109).

Twelve of the selected climbers were planted at Kaguru Farmer's Training Centre (near Meru town) to increase seed for further evaluation and demonstration during a farmer's field day. Twenty farmers who either had experience or were interested in growing climbing beans were invited to evaluate the lines. Farmers used ribbons of different colours to indicate their selection. Selections with the highest number of ribbons were MAC 28-1 (20), MLV 216-97A (13), MAC 524B (11), MAC 64 (10), MAC 36-2 (9), MAC 59-97B2 (8) and MAC 36-1 (1). Plot yields of these lines at the farmer's centre varied from 7 t ha⁻¹ for MLV 216-97A to 3 t ha⁻¹ for MAC 26. MAC 28-1, the most popular line with farmers, had a yield of 4.4 t ha⁻¹ at Kaguru, Meru. Seed of the 20 climbing bean lines selected at Embu were distributed to Murang'a, Nyeri, Kirinyaga, Embu, Meru South, Meru Central, Kitui, Makueni and Machakos districts during the 2003 short rain season for evaluation by farmers and seed bulking.

Table 109. Days to flowering, maturity and grain yield of 22 climbing bean lines selected by farmers and researchers at KARI-Embu, Kenya, 2003.

Population/Line	Days to 50% flower	Days to maturity	Grain yield (kg ha ⁻¹)	Other attributes
MAC 64	40	88	3000	Red mottled
MAC 46	40	80	3000	Mwezi Moja type
MAC 36-2	40	80	1067	Mwezi Moja
MAC 17	43	88	1067	Large red kidney
MAC 50	44	81	1133	Medium pink (Mwezi Moja type)
MAC 13	48	99	800	Medium, red and round seeds
RD2-1	49	81	871	Small yellow
MAC 28-2	49	99	1200	Medium, dark red mottled
MAC 56	48	90	1600	Pinto, small seeded
MLV 216-97A	48	102	2467	Medium size, red kidney
MAC 20	48	90	2267	Purple kidney
MAC 36-1	49	96	3733	Red mottled, medium size
MLV 59-97A	49	104	3333	Cream
MAC 35	49	108	3800	True Mwezi Moja grain type; heavy podding and foliage yield
MAC 28-1	49	94	2948	Mwezi Moja type
UMUBANO	48	95	2933	Small, glossy red
RWV 524B	49	102	3000	Red kidney, large seeded, heavy podding
MAC 12-2	49	94	2933	Sugar /cranberry
RWV 1105	49	95	2000	Medium red mottled; attractive grain type
MAC 34	48	91	2267	Medium, red mottled
MAC 2 (26?)	48	91	2667	Pinto-segregating for pinto, Mwezi Moja, yellow pinto and red mottled (unstable grain type)
MLV 6-90B6	48	99	2333	

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4.1.12 Improved bean varieties for humid tropical lowlands identified

Rationale: Beans are traditionally cultivated in the medium and highland agroecological zones (>1000 masl) of East and Central Africa. Most of the varieties developed in the last 20 years are therefore adapted to the cooler altitudes. However, beans are widely consumed in the lowland areas in the region. But lowland production is limited because of lack of research effort for this zone. Most of the beans consumed in the lowlands are produced in the highlands and exported to markets in lowland zone. For example, bean consumed in western lowland zone in the DR Congo are imported from the highland production zones in eastern parts of the country, especially in North Kivu province. Because of the poor communication system, beans are either airlifted or transported by river for more than 1000 km. As a result, prices in Kinshasa and other markets are relatively high because of the high transportation costs, and are hardly affordable to the urban poor, contrary to the popular belief that bean is a ‘poor man’s meat’. For example, beans were retailing at more than US\$ 1.25 per kg in Kinshasa markets in July 2004. INERA (Institut National pour l’Etude et la Recherche Agronomiques) has identified bean as a priority crop for production in lowland zones of DR Congo. Interest for local bean production is growing in Congo (Brazzaville), Cameroon, Central African Republic, Cabinda (Angola) and other countries in the tropical humid lowlands of west and central Africa. Considerable potential exists to improve bean production in lowlands. A collaborative program between the regional bean program and INERA was initiated to identify bean genotypes adapted to the lowland humid tropical zones in western Congo and neighbouring countries. This reports highlights progress in this program.

Materials and Methods: Bean germplasm was introduced to INERA-M’vuazi from INERA research stations at Mulungu, Gandanjika, FOFIFA (Madagascar) and University of Nairobi (Kenya). The collection comprised of 80 sugar bean lines and 40 BILFA 5 nursery lines from Mulungu, 8 entries from FOFIFA bean program, more than 86 F₂ and F₃ segregating populations from the regional multiple constraint nurseries at University of Nairobi, PNL Gandanjika, and local collections. The collection was evaluated at M’vuazi, Kisantu and several on-farm sites in Bas Congo, Kinshasa and Bandu Provinces. M’vuazi, the main coordinating center for bean research is located at latitude 5°27’S, longitude 14° 54’E and 470 masl. It has mean annual temperature of 23.6°C and receives 1425 mm rainfall per year. All trial sites were below 1000 masl. The evaluations were conducted in collaboration with farmer groups, NGOs and community based organizations (CBOs).

Results and Discussion: Twelve bean varieties adapted to lowland conditions have been released and are being disseminated in association with NGO’s and farmers’ associations. The varieties are: Moore 88002, PVO 14 (local landrace), PVO 14/2, T-3, A445, Diniania, Ntendezi (local landrace), Manseki, Nguaku-Nguaku, Tuta (Congolesse landrace), G20854 and Lundamba. Ten varieties are in pre-release stages. These are Mbindi (from local germplasm), G22258, L4 (Congolesse germplasm), I7 (Congolesse landrace), G22501, Lyamungu 90, G16157, BF12 (Congolesse landrace), BF10 and G8047. BILFA lines performing well include ZAA 5/2, G22258, Mwamafutala and AFR 593. Two lines KS 65-2 (sugar) and KS 47-1 (medium yellow) selected from regional nurseries have been identified for release. KS 47-1 was in Kinshasa markets in July 2004.

Dissemination of the varieties is being conducted in collaboration with 14 NGOs and farmer's associations in areas near Mvuazi, and with INERA's Research and Development (extension) section and farmer associations and field schools in Kisantu, and with CADIM in Plateau de Bateke. Beans are grown over three seasons in the lowlands: Season A (November to February) is the main season. Season B (April to May) is used for seed production. In season C (June-October) beans are cultivated in valley bottoms on residual moisture. Cultivation in seasons A and B is on the 'uplands'. Major disease constraints to production in the lowlands include common bacterial blight, web blight, bean common mosaic virus, root rot, and rust. Major pests include bruchids, aphids and foliage/stem beetle (with symptoms similar to bean stem maggot). A visit to Kinshasa markets revealed that several released varieties were being traded. Yellows, whites and sugars dominated the markets in Kinshasa. Yellows were the most expensive (CFr 560per kg) and dark browns, the cheapest (CFr 200 per kg).

INERA M'Vuazi has been instrumental in disseminating bean germplasm to other countries in West and Central Africa. Some of the genotypes distributed to Liberia, Central African Republic and Congo-Brazzaville are presented in Table 110.

Table 110. Bean germplasm adapted to humid tropical lowlands distributed from INERA-M'vuazi, 2002-2003.

Destination	Type of Material	Number of Accessions
Liberia	Advanced lines and released varieties (2002)	15 (A445, T-3, G8047, G16157, G20854, G22501, Diniania, Ntendezi, L4, Tuta (GG), SEQ 1007 and PVO 14/2)
Central African Republic	MCR lines (2003)	15
	White bean (2003)	8
	Sugars (2003)	11
Congo-Brazzaville	Released varieties (2003)	12 (Moore 88002, T-3, A445, PVO14, Lundamba, L4, Fleetwood, SEQ 1007, Mbindi, G22258, G8047 and G23070)

These results suggest that bean may be more plastic than expected. Some of the varieties performing well in lowlands (as low as 470 masl) such as Lyamungu 90 were selected for highland zones. Additionally, climbing beans are traditionally grown at high altitudes. Several climbing bean varieties were performing well at Mvuazi (470 masl). It appears that there is considerable potential for expanding bush and climbing bean production to lowland agroecological zones.

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4.1.13 Evaluation bean germplasm for aluminium tolerance in low fertility acid soils in East and Central Africa

Rationale: Low soil fertility is a major constraint to bean production in east, central and southern Africa. The major stresses are low soil P, low soil N and soil acidity. More than 60-85% of the cultivated area has soils deficient in phosphorus (Wortmann et al, 1998). More than 60% of the soils in the cultivated areas are deficient in nitrogen. Bean production occurs in acid soils with a pH between 5 and 6. However, in the Great Lakes Region, where bean is an important crop, proportion of acid soil is higher and soil related constraints seem to be even more severe. Over 20% of bean production in southern Africa occurs in acid soils (Wortmann et al, 1998). Annual losses due to aluminum and manganese toxicity in Africa are estimated at 163,900 t. Over 16.7 % of bean in eastern Africa and 28% in southern Africa are produced in areas where the major soil type is orthic ferralsols. These soils are generally low in nutrients. Aluminum and manganese toxicities are of high or moderate importance (losses of 100-200 kg ha⁻¹) in eastern DR Congo, parts of Rwanda, Burundi, Madagascar, north-eastern Tanzania, central and western highlands of Kenya, western Angola, northern parts of Malawi and Zambia and eastern parts of South Africa.

Although soil acidity can be corrected by application of amendments such as lime, most of the resource-poor smallholder farmers cannot afford and rarely apply fertilizers to their bean crops. Application of organic manure is constrained by availability and cost of application. Consequently, organic manures are applied infrequently and normally below recommended quantities. The identification of genotypes adapted to soils with inadequate nutrient supply and low pH associated nutritional disorders is an indispensable component of an integrated soil management strategy, and is now considered as the most appropriate approach to improving bean productivity in this region. The materials of interest should be tolerant to Al/Mn toxicity prevalent in acid soils, with an effective uptake system, and efficient utilization of the low levels of available nitrogen and phosphorus. This report highlights progress in identification of bean lines tolerant to aluminium toxicity and soil acidity in East and Central Africa through the Bean Improvement for Low Fertility Adaptation (BILFA) nursery. Our objective was to screen segregating populations, advanced lines and accessions for tolerance to aluminium toxicity in low fertility acid soils.

Materials and Methods: Two nurseries were screened, BILFA 4 and BILFA 5. BILFA 4 had 300 entries, which comprised of F₃, F₄ populations, advanced lines and cultivars. The germplasm represented five market classes: red mottled, red kidney, navy (small white), pinto and small red. BILFA 5 nursery had three germplasm sets: 127 germplasm accessions and 41 aluminium tolerant lines from CIAT, Colombia and 26 F₃ red mottled families derived from crosses between low soil fertility susceptible and resistant lines from the regional program at Kabete. The germplasm was selected for three consecutive cycles (2001B, 2002B and 2002B) in field plots with toxic levels of aluminium in single row plots with two replicates, or without replication. Grain yield was the primary selection criterion. N, P, and K at 17 kg ha⁻¹ were applied to correct deficiencies. Diseases and pests were controlled following recommended practices. Lines selected in each cycle were re-evaluated in subsequent cycles. Lines selected after the third cycle were evaluated in 2003A at three sites: Nyamunyuye near Mulungu, in eastern DR Congo, Tonga and Gikongoro in Rwanda. At each site, the experimental design was randomized complete block with three replicates of 4-row plots. Susceptible and resistant check varieties

were included after every 10 test rows. In trial sites in DR Congo the resistant checks were MwaSole and Mwamafutala. Kirundo was the susceptible check variety. In Rwanda ACC714 was the resistant check. The trial site at Nyamunyunye (1730m) has very acid soils with more than 40% aluminium saturation and intermediate organic matter (5.5%). Soils at the trial site at Tonga (1400m) has low P (2.2ppm), pH 4.8, low organic matter (2.3% carbon) and more than 42% aluminium saturation. At Gikongoro, soils are very acid, low in P (4.2 ppm), organic matter (5%) and high aluminium saturation (>62%).

Results and Discussion: Of the initial 115 red kidney lines evaluated at Tonga and Gikongoro, only 28 were selected. Twenty-eight red mottled were selected from the 100 lines tested. Five navy, nine pinto and 10 small red were selected after three cycles from the initial 43, 19 and 32 lines screened, respectively. From BILFA 5, 74 lines were selected from a germplasm pool of 194 lines. Only 33 lines were selected at Nyamunyunye from 300 BILFA 4 lines. Table 111 shows the performance of these lines at Nyamunyunye. Only three lines had better yield than the tolerant line MwaSole under both stress and non-stress conditions. A few lines showed limited yield loss in stress and non-stress conditions. The aluminium tolerant lines showed up to three fold yield advantage compared to the susceptible line Kirundo.

Table 111. Grain yield bean lines under Al stressed and non-stress conditions in Nyamunyunye, DR Congo.

Line	Grain yield (kg ha ⁻¹)		Yield loss due to Al toxicity (%)	Yield advantage over check in stress (%)
	Stress	Non-stress		
VTTT 923-6-1	1494	1588	5.9	310.6
HM 21-7	1317	1455	9.5	273.8
AFR 593-1	1040	1801	42.2	216.2
MwaSole	999	1264	20.9	207.7
ARA 8-5-1	957	1394	31.3	199.2
AND 932-A-1	932	1206	22.7	193.8
BZ 12984-C-1	866	874	0.9	180.0
Mwa Mafutala	625	1510	58.6	129.9
Kirundo	481	988	51.3	100

The results showed that Al tolerant lines can reduce yield losses associated with acid soils. A desirable line is that which shows small losses under Al stress but responds to improved conditions. It should be stable across environments, with a high yield potential in its market class. Some of the lines tolerant to acid soils have been released. These include RAB 487 in Rwanda, ACC 714 and Mwamafutala in DR Congo, Mwasole in Congo and Burundi. MLB-49-89A is released in Congo and is widely adopted in western Kenya. Wider dissemination of these varieties has the potential to improve grain yield in areas with toxic levels of aluminium and soil acidity. The results also indicated that the Great lakes region is a potential source of germplasm with tolerance to low soil fertility acid soils.

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4.1.14 Developing drought tolerant bean varieties for smallholder farmers in Eastern Africa through a regional project

Rationale. Drought is one of the most important constraints to bean production in Africa. Each year more than 395,000 t of bean are lost due drought related stresses in Africa. Drought is an important constraint in Ethiopia, Kenya, Sudan, Tanzania, southeastern Rwanda, and parts of Burundi. Drought is a major contributor to the frequent food shortages in east, central and southern Africa. Although effects of drought stress can be reduced by irrigation and conservation of soil moisture, these are not practical options for resource-poor smallholder farmers with limited access to irrigation. Drought, which includes moisture and heat stresses, acts in conjunction with biotic stresses, especially diseases and pests (Amede et al, 2004). Soil fertility related stresses, the most important being low soil P and N, soil acidity and the associated aluminium and manganese toxicity, aggravate drought effects. Developing drought tolerant bean varieties is a critical component of an integrated strategy of reducing losses due to abiotic and biotic stresses in sub humid and semi-arid regions in eastern Africa. Several initiatives have been started to develop bean lines tolerant to drought including the formation of a regional working group known as 'Bean improvement for water deficit in Africa' (BIWADA). In this report we highlight progress in identification of drought tolerant lines in Eastern Africa.

Materials and Methods: Four trials were conducted at Katumani, Kiboko and Kabete (Kenya) and Amaro (Ethiopia) to screen new bean lines for tolerance to drought. Katumani (1400m) and Kiboko (1000 masl) are located in a semi-arid region in eastern Kenya with high frequency of droughts. Amaro (1200 m) is a drought prone area in the southern Rift Valley of Ethiopia. In the first trial, 30 bean lines from the BIWADA nursery were evaluated at Katumani. The trial was laid out in randomized block design with three replicates. Spacing was 10 cm within rows and 50 cm between rows. Kat B9 was the check. In the second trial, 36 entries from the International Drought Nursery were evaluated in single row plots at Katumani and Kiboko. The trial was laid out in a lattice design with three replicates. In third trial, 138 F₇ lines and three checks (DOR 390, Tio Canela and A774) received from CIAT, Colombia were advanced for two generations at Kabete and Thika. In the fourth trial, 164 F_{1.3} families developed through gamete selection in the regional program were evaluated under severe drought stress at Amaro. Grain yield was used as the primary selection criterion.

Results and Discussion: Results indicated significant genotypic differences ($P < 0.05$) for duration to flowering, maturity, 100-seed mass and grain yield at Katumani. Some characteristics of the best six lines from BIWADA nursery are shown in Table 112. The lines flowered in 33 to 42 days and matured within 81 days. Duration of rainfall rarely exceeds 60 days in the semi-arid areas of Kenya. MLB Y 91023 flowered and matured earliest. MUS 97 and DN 1004 had the highest grain yields under drought conditions. These results indicate that good yields can be obtained from the selected lines with normal rainfall regimes at Katumani. Final phases of grain filling can occur under residual moisture. Earliness can effectively contribute to drought escape.

Table 112. Duration to flowering and maturity, 100-seed mass and grain yield of six bean lines selected at Katumani, Kenya from BIWADA nursery, 2003/04.

Line	Days to 50% flowering (d)	Maturity (d)	100-Seed mass (g)	Seed yield (kg ha ⁻¹)
DN 1004	40.3	74.3	31.3	1388
DN 1009	40.3	76.7	27.8	1158
MLBY 91023	32.7	75.0	32.7	1167
BAT 85	37.3	77.7	21.0	1243
POMPADOUR	42.0	81.0	21.2	1209
MUS 97	38.7	77.7	26.4	1577
FB/GP/377-6-1	38.3	75.7	25.2	1386

Some characteristics of the seven best performing lines at Kiboko and Katumani are shown in Table 113. These lines flowered within 40 days and matured in 83 days or less. *P. acutifolius* accessions G40068 and G40159 had the highest yields. These results confirm our 2003 report that RAB 636, SEA 16 and RAB 618 were among the ten best performing lines under drought stress, in trials conducted at Thika and Kabete over three years. High yields of G40068 and G40159 at Katumani compared to Thika suggest possible genotype x environment interactions.

Table 113. Duration to flowering and maturity, 100-seed mass and grain yield of six bean lines from the International Drought Nursery, at Katumani and Kiboko, Kenya, 2003/04.

Line	Days to 50% flowering (d)	Maturity (d)	100-Seed mass (g)	Seed yield (kg ha ⁻¹)
RAB 619	39	78	25.7	1161
RAB 636	38	83	27.2	1161
RAB 618	39	80	29.1	1063
APETITO	37	81	24.4	1164
SEA 16	39	80	28.3	1056
G 40068	40	73	15.0	1651
G 40159	37	72	17.5	1554

At Kabete, most of the 137 F₇ drought lines succumbed to black root, suggesting the existence of necrotic strains of bean mosaic viruses at the location and I-gene in these lines. This necessitated within line selection based on resistance to black root, pod clearance and yield potential. The selected plants within a line were bulk harvested. Out of 138 F₇ lines, 97 F₈ were selected and sown at Thika and Kabete during the short rain season (November 2003 to February 2004). F₉ lines were sown at the same locations during the long rain season (May-August 2004).

Seventy-one families were selected from 164 F_{1,3} families based on grain yield, tolerance to low soil fertility, common bacterial blight, angular leaf spot and haloblight at three locations (at Kokat, 2150m, Awassa 170 and Amaro) in 2004A. The 71 families were sown at Amaro during

2004B (August-October). With only one shower, 9 F_{1.3} families dried up due to severe drought stress. However, 12 families with remarkable drought tolerance were selected. Yield of these lines varied from 1173 kg ha⁻¹ (CAW-02-04-7-7) to 1549 kg ha⁻¹ (CAW-02-04-7-7). At Selian (Arusha, Tanzania), six lines were selected from BIWADA nursery. These were CNF 5547, UBR (92) 17, UBR (92)9, MUS 97, RWR 109 and MMS 243. MUS 97 was also selected for drought tolerance at Katumani. The international drought nursery was distributed to Ethiopia, Kenya, Tanzania, Rwanda and Sudan in May, 2004 for further evaluation. These results indicate that some lines are ready for on-farm evaluation in drought prone areas.

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Collaborators: Bean program teams at Kabete, KARI-Katumani (Kenya) Awassa (Ethiopia), and Selian Agricultural Research Institute (SARI), Arusha (Tanzania)

4.1.15 Southern Africa Regional Bean Yield Trial (SARBYT)

Rationale: Many national programs in the SADC region do not have a bean breeding program. The network co-coordinates the regional germplasm nurseries and trials, which contain improved lines and released cultivars generated by various bean-breeding programs in the region, including CIAT and the private sector. The main objective of these activities is to share germplasm within the network so that each national program or private sector can benefit from the research that is carried out by others in the region. In particular, the beneficiaries are the weaker national programs that are not able to run a full-scale breeding program. Over time, several countries in the network have released varieties, which were accessed through such germplasm exchanges.

Material and Methods: There were 20 sets of SARBYT that were distributed to: D R Congo (3), Lesotho (1), Malawi (2), Mozambique (3), South Africa (3), Swaziland (2), Tanzania (2), Zambia (2) and Zimbabwe (2). Each set contained 19 entries, but each country had to add a local control to make 20 entries. The entries included promising cultivars or varieties that had been released in some countries. Each set had 4 replicates, which were planted at each site, using a standard protocol across sites. Data were collected on soil type, rainfall, weather, diseases and grain yield.

Results and Discussion: At the time of compiling this report, data were available from 5 sites in 4 countries. Several diseases were recorded angular leaf spot (ALS), common bacterial blight (CBB) bean common mosaic virus (BCMV), floury leafspot (FLS), halo blight (HB), and anthracnose (ANT) at various sites (Table 114). Most diseases were not severe, except ALS (Bembeke and Uyole), rust (Chitedze and Uyole) and FLS (Chitedze and Bembeke). A few cultivars were consistent in showing resistance to ALS at Bembeke and Uyole with scores ranging from 3-4. These were in both, small-seeded Mesoamerican genotypes (RJB-1 and ECA0638) and large-seeded Andean genotypes (GCI-CAL-28-AR, CIM 9314, CIM 9314-2 and CIM 9314-31). Among the large-seeded, all were red mottled and most of them were selections from CIM 9314. The two small-seeded cultivars and CIM 9314 were also good for FLS, with scores ranging from 3-4. This indicates that some lines might have resistance to more than one disease.

Table 114. Disease assessment of advanced cultivars in the SARBYT at different sites in the SADC region, 2003/2004

Variety	ALS				CBB				RUST			FLS		HB		BCMV		ANT	ASC	seed size	Color
	CTZ	HAR	BBK	UYL	CTZ	HAR	BBK	CTZ	BBK	UYL	CTZ	BBK	DEL	CTZ	CTZ	HAR	BBK	BBK	BBK		
AFR 708	2	1	3	5	2	2	1	5	1	5	4	4	3	1	2	1	1	2	3	30	Calima
UYOLE 96	1	1	5	4	3	1	3	4	1	2	4	7	3	1	2	2	1	2	3	43	Red
DC 12496-50	4	1	7	3	3	1	2	5	2	8	3	3	2	1	1	1	1	1	2	32	Pinto
CAL 143	1	1	3	5	3	2	1	4	1	4	4	5	3	1	1	2	1	1	3	38	Calima
SUG 135	1	1	5	4	3	1	2	4	1	2	4	4	5	1	2	2	1	2	3	47	Sugar
DC 95-170	5	1	7	6	2	1	1	5	1	3	4	4	5	1	1	1	1	1	2	40	Pinto
MCR 2301	3	1	8	3	3	1	1	3	1	2	3	5	3	1	1	2	1	2	2	28	Calima
CIM 9314-31	2	1	4	4	3	1	2	4	1	3	5	4	1	1	1	1	1	2	4	47	Calima
CIM 9314-2	2	1	4	3	2	2	2	5	1	4	5	5	1	1	1	1	1	2	4	37	Calima
PC 512-B4	2	1	7	5	3	2	2	6	1	4	4	5	3	1	2	1	1	1	6	32	Sugar
CIM 9314	2	1	4	3	2	2	2	4	1	4	4	4	1	1	2	2	1	2	3	38	Calima
DC 96-95	2	1	7	5	3	1	2	5	1	4	5	4	3	1	1	1	1	1	3	33	Sugar
RJB -1	2	1	3	2	3	1	2	4	1	1	3	4	1	1	2	1	1	1	2	26	Red
ECAB 0638	2	2	2	2	3	1	2	4	2	4	4	3	3	1	1	1	1	1	3	19	Navy
CIM 9302-1	2	1	5	3	3	1	1	4	1	3	3	5	3	1	1	1	2	2	4	42	Calima
GCI-CAL-28-AR	2	1	3	4	2	2	2	5	1	3	4	5	3	1	1	1	1	1	4	39	Calima
F6 BC3 Davis old (19)	2	1	7	5	3	1	2	5	1	4	4	6	3	3	1	2	1	1	3	35	Sugar
BOA 4-3/4	2	2	6	9	3	2	2	4	1	5	3	7	6	1	1	1	1	2	4	34	Sugar
BOA 1-5/20	2	1	4	2	3	1	2	3	1	5	3	5	3	1	1	1	1	1	3	32	Red
LOCAL	2	1	7	2	3	1	2	4	1	1	3	6	1	1	1	1	1	7	2		

Diseases: ALS= Angular Leaf Spot; CBB= Common Bacterial Blight; BCMV= Bean Common Mosaic Virus; HB= Halo Blight; ANT=Anthracnose; FLS= Floury Leaf Spot ASC = Ascochyta Blight

Sites: CTZ= Chitedze (Malawi); BBK = Bembeke (Malawi); DEL= Delmas (South Africa); HAR= Harare (Zimbabwe); UYL= Uyole (Southern Highlands of Tanzania)

Yield data were analyzed by site, then across sites. The differences among cultivars were statistically very highly significant ($p < 0.01$) at all sites except Swaziland (Table 115). The sites mean yields were high, over 2,000 kg ha⁻¹ at Delmas (South Africa, Harare (Zimbabwe) and Uyole (Tanzania). The across sites analyses showed that the genotype x environment intercropping were statistically, highly significant ($p < 0.01$), as were the differences among the cultivars. The top 5 yielding cultivars across sites were GCI-CAL-28-AR with 20% yield advantage above CAL 143, followed by AFR 708, CIM 9314, CIM9314-2 and SUG 135. All of them are large seeded, in calima (red mottled) grain market class, except SUG 135, which is cream mottled. It was interesting to note that among the top 5, three of the cultivars GCI-CAL-28-AR, CIM 9314 and CIM 9314-2 were also on the list of cultivars with resistance to ALS. One of them CIM9314 was also on the list of lines with resistance to FLS. Thus some cultivars combine acceptable market class, good yield potential and multiple disease resistance.

Table 115. Grain yield performance of advanced cultivars in the SARBYT at different sites in the SADC region, 2003/2004

Rank	Variety	Seed yield in kg ha ⁻¹							Seed	
		CTZ	BBK	DEL	HAR	SWZ	UYL	Mean	Size (g)	Color
1	GCI-CAL-28-AR	1108	1852	4193	4094	1209	2428	2481	39	Calima
2	AFR 708	1444	1141	4164	4156	1060	2249	2369	30	Calima
3	CIM 9314	1474	1469	3758	3917	1177	2151	2324	38	Calima
4	CIM 9314-2	1292	1333	4185	3458	963	1974	2201	37	Calima
5	SUG 135	1042	1432	2378	4833	923	2407	2169	47	Sugar
6	CIM 9302-1	1247	1190	4336	2990	845	1973	2097	42	Calima
7	CAL 143	1235	1305	3448	3281	1194	2111	2096	38	Calima
8	ECAB 0638	608	1000	4435	3542	1114	1632	2055	19	Navy
9	BOA 1-5/20	1318	1172	3609	2563	1188	1950	1967	32	Red
10	CIM 9314-31	1422	1266	3536	2531	1036	1624	1903	47	Calima
11	F6 BC3 Davis old (19)	2117	612	2794	1938	1041	2365	1811	35	Sugar
12	RJB -1	453	1677	2378	2135	1456	2242	1724	26	Red
13	DC 12496-50	316	813	3221	2104	1307	2017	1630	32	Pinto
14	MCR 2301	1229	760	2432	2250	983	2072	1621	28	Calima
15	UYOLE 96	731	924	1555	2979	1218	2262	1612	43	Red
16	DC 95-170	1549	883	1281	2344	1045	2004	1518	40	Pinto
17	PC 512-B4	1457	599	1633	2333	912	2070	1501	32	Sugar
18	DC 96-95	1189	555	2854	1177	1120	2027	1487	33	Sugar
19	BOA 4-3/4	599	964	2221	2115	1190	1746	1473	34	Sugar
20	LOCAL	1258	286	2997	3552	1210	2076	1897		
	Means	1154	1062	3070	2915	1110	2069	1897		
	CV (%)	29	31	29	28	23	12	20		
	SE +- Loc									
	Var.	170	164	448	411	130	127	226		
	LxV									
	Signif. Loc							**		
	Var	***	***	***	***	ns	***	**		
	LxV							**		

Sites: CTZ= Chitedze (Malawi); BBK = Bembeke (Malawi); DEL= Delmas (South Africa)
HAR= Harare (Zimbabwe); UYL=Uyole (Southern Highlands of Tanzania)

Conclusion: Various nurseries and yield trials were again distributed to NARI's partners. These are particularly helpful to the NARIs that did not have breeding programs. Results from SARBYT indicated that some cultivars, which were distributed, combine multiple attributes like, grain market class, high yield potential, and resistance to one or more diseases. Such lines will be potential candidates for future releases. During this reporting period, Tanzania had released one cultivar, DRK 124, as *Uyole 03*, which was introduced to Tanzania from CIAT through network germplasm exchange.

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4.1.16 Implementation of IPM with African farmers through participatory methods

Rationale: The promotion of bean IPM strategies among bean farming communities in eastern and southern Africa had in the past three seasons focused mainly on the management of bean insect pests using both traditional and improved technologies. During the reporting period however, the dimension of the promotional activities was expanded through additional funding support to include the promotion and dissemination of products/outputs from other bean research projects. These include disease tolerant germplasm, improved high yielding pest tolerant varieties and soil fertility management technologies that have been generated from activities supported by different NARS programmes, ECABREN, CIAT, NGOs and other active partners.

Methodology: The participatory approach continued to be adopted with the involvement of innovative farmers, farmer groups and locally active partners from the local government administration (policy makers, extension personnel, etc.), NGOs, community based organizations-CBOs (civil and religious), local schools and the private sector (market traders and input suppliers). Participating farmers, collaborators and partners at activity sites continued to play the major role in planning, implementation and evaluation of project activities with backstopping from the other stakeholders. Traditional and improved pest management technologies were promoted in pilot and satellite sites. Farmers were reached through the standard farmer field school (FFS) approach in the case of south western Uganda and parts of western Kenya, and the modified farmer field school approach (MFFS), i.e. farmer research group (FRG) approach as were the cases in parts of Kisii district in western Kenya, northern and southern Tanzania and central Malawi. Linkages with existing partners were maintained and strengthened. New farmers, farmer groups and partners joined in to support and participate in project activities. The MEDIEA Company Ltd produced a radio programme (Pilika Pilika) on agricultural production, i.e. crops (with focus on beans) and livestock in Kiswahili. The programme has been aired in 4 national radio stations (3 private, 1 public) in Tanzania from March 2004. Pilot studies to document community behaviour in IPDM uptake have been initiated with a Masters degree student in Hai district site in northern Tanzania. More and new promotional materials were prepared and distributed to target village information centres and partners.

Findings/Observations: Project activities and IPDM awareness creation have spread to wider and new areas during the reporting period and more farmers have received the message (Table 116). The participatory farmer research group approach, farmer meetings, field demonstrations combined with field days and exchange visits), promotional materials including farmer activity reports, village information centres, small seed packets, local farmer seed displays and exchanges, visits to farmer groups (by local administrators and policy makers, donor representatives, CIAT DG and other staff), radio, etc. are proving to be very effective tools in getting the message to the bean farming communities. Observations show that these tools work differently at different sites depending on the community culture and behaviour. No one tool seems to be self propelling at any of the active sites. Participating and non-participating farmers are happy with the approach of involvement in management of their own resources. Partners are willing to contribute to costs involved in farmer exchange visits when such activities are linked to areas of priority for their development goals in those particular communities.

The government policy makers in each of the participating countries (Malawi, Tanzania, Kenya and Uganda) have declared a “YES” to the community group approach. Tanzania has gone ahead to declare the community group approach for its new national planning policy with a district focus in rural development and community empowerment for food security, poverty eradication and in addressing the HIV/AIDS pandemic. In the uptake studies, 39 farmer groups (out of 77) in 27 villages (out of 54) in Hai district, northern Tanzania have been surveyed. Data processing is in progress. Project promotional materials have been on high demand by participating and non-participating partners. Postage on the CIAT website has led to demands from outside the continent, e.g. a recent request for the leaflet on “Cultivation of climbing beans” from Chile.

Table 116. Spread of Bean IPDM project message in eastern, central and southern Africa as per June 2004

Pilot site	Satellite sites	Number of farmers reached with at least 1 technology	Estimated number of farmers aware of bean IPDM message
Malawi (Dedza)	Kasungu	500	> 1000
Tanzania - Southern (Mbeya and Mbozi)	Mbeya, Mbozi, Iringa, Njombe, Chunya,	7000	>10000
Tanzania - Northern (Hai, Lushoto, Arumeru)	Babati, Rombo, Moshi,	8800	>31000
Kenya (Kisii, Kabondo)	Homabay, Gucha, Marani, Rachuonyo, Vihiga, Hamisi, Kakamega	2500	>3000
Uganda	Kabale, Bushenyi, Kisoro, Iganga		
DR Congo	Katana, Kavumu, Mudaka		
Rwanda	Runyinya		

Discussion:

The FFS and FRG members and participating partners were instrumental in training new farmers and helping in the formation of groups. For example, in south western Uganda, the Kabamare FFS members trained 4 new groups including a polytechnic school community. The FFS group leader has trained several neighboring farmers, helped in setting up demonstrations for the five groups at his site and trained groups collaborating with other partners including NGOs. The whole concept is to use trained farmer groups to be trainers of community members at their locations. These innovators were also the key players in spreading the word by mouth to neighbouring farmers and relatives and to the various visitors. Farmers were very happy learning together, sharing information, experiences and resources (e.g. seed, etc.). For example, Rombo district farmers invited by Shari village IPDM groups in Hai (~ 150 km away) for a field day with a bean seed sharing event in March 2004, brought local bean seed for 6 different cultivars and in exchange they selected both improved (from bean programme) and local bean cultivar seed from Hai to experiment with in Rombo. In the same field day, visiting Babati farmers collaborating with and sponsored by Farm Africa, also selected some of the bean seed for experimentation in their fields.

The tools used in disseminating bean and other crop and livestock production products among bean farming communities have helped the project reach farmers beyond expectation. The radio programme in Tanzania, has played a key role in sending the message across communities in the past six months because every bean growing community that we have interacted with have farmers asking questions pertaining to the programme captions. Some of the farmers have participated in the radio question time and won prizes that were contributed by the national bean research programme (improved bean seed packs) and the IPDM project (leaflets).

More farmers in Malawi, Tanzania, Kenya and Uganda have accessed the improved high yielding and pest tolerant bean variety seeds (from the national programmes) and high yielding pest tolerant germplasm (from NARS, ECABREN and CIAT). Dissemination of improved pest tolerant bean varieties particularly focused on products generated in previous bean research projects in the southern highlands of Tanzania, Malawi and Uganda. Despite the unreliable weather conditions that prevailed in most areas in the region during the past bean production period, a number of farmers received the seed and some were able to harvest the grain.

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4.1.17 Varietal releases in Latin America and Africa during 2003-2004:

Latin America:

Country	Name	Year of release
ARGENTINA	A 281	2003
ECUADOR	CANARIO "SIETE COLOINAS" (INIAP 426) TIB 3042 x G11732	2004
HONDURAS	MACUZALITO*	2004

* participatory breeding with CIAL's farmers from Yoro region (ASOCIAL-FIPAH-EAP)

Africa:

Country	Varietal Name	Year of release	Country	Varietal Name	Year of release
BURUNDI	Mwasole (INERA)		D.R. CONGO	LSA 144	2003
				M50/98	2003
				ACC 714 (INERA)	2003
ETHIOPIA	DICTA 105	2003		GR 13P	2003
	DOR 554	2003		CNF 5520	2003
	MAM 48	2003		G1810	2003
				NAMULENGA	2003
				G11460	2003
				Moore 88002	
TANZANIA	WANJA (A 197)	2003		PVO 14 (local landrace)	
	Uyole 03 (DRK 124)	2003		PVO 14/2	
	Urafiki	2003		T-3	
	(Kabanima x Canadian Wonder)			A445 (CIAT line)	
				Diniania	
				Ntendezi (local landrace)	
UGANDA	NABE 4 (POA 2)	2003		Manseki	
	(MAC 31)	2003		Nguaku-Nguaku	
	NABE 5 (Sugar 73)	2003		Tuta (local landrace)	
				G 20854	
				Lundamba (INERA)	
				Mwamafutula (INERA)	
				Mwasole (INERA)	
				MLB-49-89A (INERA)	

Progress towards achieving output milestones:

- More fixed lines and cultivars combining acceptable market type, high yield potential and resistance to diseases will be made available to NARIs partners for further evaluation in various countries within SABRN in the next crop season.
- Improved IPDM practices are estimated to have reached more than 31,000 bean farmers in Tanzania where the effort to diffuse practices initiated, and an additional 14,000 users in other countries.
- The community group approach employed for the diffusion of IDPM practices is receiving wide attention in official circles, boding well for its deployment and future efforts for diffusion.

Activity 4.2 Development of sustainable seed systems to support wide dissemination

Highlights:

- There was a significant increase in number and diversity of partners for bean research and development in the PABRA region, particularly in support of decentralized seed systems. Formalization of working relationships among partners was done through memoranda of understanding.
- Partners facilitated awareness creation, knowledge and skills enhancement about new or existing technologies through development and dissemination of diversified tools and approaches including promotional and training materials, field days, radio talks, agricultural shows, etc.
- Through enhanced partnerships, a total of about 12,000 M tonnes of assorted bean varieties were produced and made accessible to about 2.5 million farmers in PABRA region.
- Eight case studies on seed relief to assist disaster-affected and chronically stressed communities were completed are being compiled for publication.

4.2.1 Partnership development: a key to wider utilization and enhanced accessibility of improved bean based technologies to farmers

Rationale: The increasing contribution of beans to farmers' income and household food security, national and regional economies in East Central and Southern Africa (ECS- Africa) coupled with highly appreciated and newly developed varieties and with increasingly differentiated consumer demands have encouraged differentiated bean seed demand in relation to specific varieties and seed channels. However, many farmers still have inadequate access to new varieties of their choice to respond to emerging agro-ecological situations and market demands. The growing involvement of commercial seed sector in the bean seed marketing is still inadequate with regard to quantity of seed supplied (their annual bean seed supply is estimated at about 1% across the region). Furthermore, the sector focuses only on already popular varieties thereby narrowing farmers' choices and exposure to new improved bean varieties. In the ECS- Africa region, the majority of farmers mainly obtain their bean seeds and information about varieties from local seed systems (farmer saved seeds, seed from other farmers and local seed traders), thus strengthening local seed systems greatly improves the access to quality seeds of improved bean varieties to farmers, enhances decentralized support service delivery and ultimately improves farmers' living conditions.

However, this initiative requires partnership with a range of service providers offering complimentary services e.g. National Agricultural Research Institutes (NARIs), government seed regulatory bodies, development agencies (government and non government), seed traders, farmer/community based organisations, local farmer seed producers. Preliminary results of this

initiative across the ECS Africa are encouraging and similar efforts across crops are being initiated

Process: Across the 19 member countries of the Pan –Africa Bean Research Alliance (PABRA), various rural service providers (NGOs/ CBOs, GOs and individual farmers) are involved and interested to support farmers to access quality seeds of improved bean varieties and related support services as a deliberate effort to alleviate poverty or/and increase food and nutritional security of vulnerable households. However, the majority of these service providers are neither adequately aware nor linked to bean research products and services. Early efforts by NARIs alone to support local seed systems did not create much change due inadequate involvement of partners who could offer complementary services to existing capacities of NARIs and local seed systems. The following steps are being encouraged to develop sustainable partnerships in facilitating accessibility of quality seeds of improved bean varieties and other non-variety technologies:

1. To identify target areas based on intervention objectives
2. To identify interested and involved potential partners such as Non Government Organisations (NGOs), Government Organizations (GOs), and Community Based Organisations (CBOs), Farmers’ Organizations (FOs), commercial seed actors, individual farmers, policy makers in the target areas or at the national level in each of 19 PABRA member countries.
3. To understand and analyse existing seed systems e.g. roles, motivation and interests of each partners, participatory analysis of existing seed systems (strengths, weaknesses, opportunities, threats and potential conflicts)
4. Draw and implement a joint action plan to respond to partners’ interests and with focus on partnership building and development. Generally the following points emerge as part of the action plans:
 - Carry out community dialogue on seed issues, understand local seed systems and how to strengthen them (using them as a springboard)
 - Understand farmers’ bean variety preferences through their knowledge/ information on existing bean varieties and exposure to new promising ones
 - Build partners capacity in both technical and organisational development (pre and post bean harvest aspects, seed/agro-business development, train farmer seed producers and suppliers in pre-and post-harvest skills and seed business management to ensure social and financially sustainable of in the scheme
 - Promote awareness of new varieties through field days, posters, leaflets, seed fairs and any other public awareness opportunity.
 - Ensure two-way linkages between partners and bean research programs for a continued flow of promising varieties, expanding this most often to include other crops
 - Build a strong research and development partnership through focus on the comparative advantage of each institution
 - Enhance a co-learning process from participatory monitoring and evaluation (PM&E) schemes based on regular reviews, interactions and exchange of information and experiences among partners.
 - Assess informally and formally the efficiency of the system

Results and Discussion:

Strategic alliances: With support from CIAT and bean regional research network staff, NARIs in each of the PABRA countries have established, consolidated and are still establishing strategic alliances with major partners based on their comparative advantages. Table 117 illustrates the status of partnership including categories of partners, the number and status across the regions. Table 118 illustrates the partners' profiles and responsibilities in building their partnership for research and development.

There is a growing trend at national level to build a common vision and agree on the partnership development processes. More often the partners formalize the working relationships through memoranda of understanding (MoU) for an agreed period of time (generally between three and five years) with clearly stipulated objectives and responsibilities

Technology Dissemination and Support Services: As result of partnership development, actors are also involved in others support services to bolster technology dissemination, especially focusing on building the capacity of decentralised seed producers and suppliers and also the farming communities. Table 119 illustrates some of support services provided through partnership in ECS Africa. The awareness raising and the partnership development have stimulated the demand of bean varieties and Table 120 illustrates the amount of seed produced and supplied to partners in the year 2004. There have been contributions and synergistic roles of both informal and informal seed producers.

Table 117. Status of partnership development for bean research and development in 14 PABRA member countries in year 2004

	Types and number of partners			
	GOs	UN/International NGOs	Commercial seed companies	Local NGOs/CBOs
Total	58	87	15	112
Status of partnership	Government through Institutional linkages	54 formalized through Memoranda of understanding (MoUs)	3 formalized through MoUs	20 formalized through MoUs

Table 118. Partners' profiles and responsibilities in the PABRA member countries.

Partners' category	Profile	Major Responsibility	What do partners expect from NARIs/Bean Network/CIAT
Government Organisations	Government owned or bilateral rural development programmes and local (district) based extension service delivery unit	-Enhance Extension service delivery (skills and knowledge building) -Facilitate the accessibility of agricultural inputs (seeds) -Design and production of information and training manuals	-Information on new improved and promising varieties -Skills/knowledge (agronomy and organisation development) building for staff
UN-International NGOs	FAO food/seed security programmes and emergency project programmes International NGOs which are predominantly International NGOs with offices in each PABRA country: WVI, CRS, CARE	-Enhance Extension service delivery (skills and knowledge building) -Facilitate the accessibility of agricultural inputs (seeds) -Design and production of information and training manuals - Support to grassroots organisations and sometimes assets transfers	-Information on new improved and promising varieties -Skills/knowledge (agronomy and organisation development) building for staff -Engage them and farmers in testing promising options
Seed companies	National medium-size seed companies marketing between 100-500 metric tones per year each.	Contracting farmers to produce certified seeds, supplied to NGOs, UN-Agencies, GOs, traders and farmers	-Information on new improved and promising varieties -Skills/knowledge (agronomy and organisation development) -Accessibility to foundations/basic seeds on cash and carry basis
CBOs (community based organisations)	Umbrella of farmers' organisations with legal status	-Members' resource mobilisation -Sometimes enhanced extension service delivery -Operations aiming at large economy of scale -Production of local seeds (farmers' seeds and quality declared seeds) done at individual or groups	-Information on new improved and promising varieties -Skills/knowledge (agronomy and organisation development) building for staff -Engage them and farmers in testing promising options
Individual farmer seed producers (limited)	Large scale farmers producing bean seeds/grains to market as seeds/grains	-Production and supply of local farmers and quality declared seeds -Provide information, knowledge and skills to local farmers -Testing and popularising improved varieties	-Information on new improved and promising varieties -Skills/knowledge (agronomy and organisation development) building for staff -Engage them in testing promising options -Provision of seed market information
National Agricultural Research Institutes /organisations (NARIs)	Government funded research bodies (parastatals, government research department and universities)	-Varietal development -Development of information and training manuals for improved concepts and technologies -Production of prototypes -Provision of national leadership in R &D -Facilitate relevant national fora -Supply of breeder/basic seeds	-Provision of wider range germplasm -Support and exposure in the new concept formulation -Play a catalytic role in bringing actors together -Skills, knowledge and practice building (institutional support)

Table 119. Types of support services offered by the partners in PABRA countries .

Category of support services	Types and their number	Developer/actors	Audiences targeted	Estimated number of material produced	Estimated audience reached
Promotional materials developed (varieties)	Posters for 15 new varieties	NARIs and UN-NGOs/CBOs	Extension staff and farmers	31,800	100, 000
Promotional materials for non variety technologies	Posters of 3 new soil fertility management options	NARIs and UN-NGOs/CBOs	Extension staff and farmers	3,800	12,100
Bean seed production training manual translation into local languages	Translation in Swahili Chewa Luganda, Runyakore and Amharic	NGOs and NARIs	Farmers and extension	1,000	5,000
Field days and demonstrations		NARIs, UN-NGOs and CBOs	Farmers, extension staff, local leadership	50	2,050
Radio talks on bean and agric. shows		NARIs, UN-NGOs and CBOs	Farmers, extension staff, policy makers and traders	Done in 6 countries on regular basis	Listeners
Training on pre-post harvest management aspects of bean seed enterprise, business skills at national level	Training of trainers (about 10 held)	CIAT, Bean Research networks, NARIs, GOs, NGOs, CBOs, FOs	Extension service providers		

Table120. Amount (metric tones) of bean seeds produced by partners in 14 PABRA countries and estimated number farmers reached in Yr 2004

Category of Seed suppliers	Estimated amount of basic seed (tones)	Estimated amount of seeds produced (tones)	Estimated number farmers reached
NARIs	106.5		
Seed companies		4,050	810,000
Farmers supported by NGOs, CBOs & GOs.		8,010.3	1,602,000
Total	106.5	12,063.3	2, 412, 000

The amount of seed produced by farmers with partner support is much higher than what is being recorded by partners. The seeds are more often exchanged among farmers, or sold as grains in the local market to traders who later sell them as seed (at planting time). Despite tangible results achieved, the unavailability of basic seeds on cash and carry at NARIs level or lack of private sector involvement in the supply of basic seeds limits the production of seed by formal and informal producers. The possibility of stimulating the private investment in basic seed production especially for popular bean varieties will be explored in the course of next year.

Contributors: J.C. Rubyogo, R. Muthoni and R. Buruchara

Collaborators: NARIs and their partners (GOs, NGOs, UN-bodies, CBOs, Commercial Seed Companies, Farmers' organizations, bean traders, farmer seed producers)

4.2.2 Strategies developed for supporting seed systems in both acute and chronic stress

Seed Systems Under Stress Program: overview

Within the last 20 years, disaster situations—drought, civil strife, floods, crop plagues, or combinations of these—coupled with systemic poverty, have become the norm for most countries of eastern, central, and southern Africa. Humanitarian relief practitioners, although skilled in quickly delivering short-term food aid, usually do not understand the technical complexities of the agricultural context. Even though seed aid began in the early 1990s, the long-term effectiveness of such activities remains disappointing. Both food and seed aid are still being delivered to many countries year after year.

Because they base their diagnoses on food assessments, relief practitioners are typically ignorant of or misunderstand stress situations as they apply to agriculture. For example, they commonly assume farmer seed systems to have collapsed or to have been inadequate in the first place. Yet field results show that seed systems are resilient. For example, in Rwanda, even after its genocidal war, local seed markets continued functioning, and crop diversity profiles remained stable.

Even research institutions tend to view disasters as opportunities to expose farmers to “improved” varieties of current crops or to alternative crops. But evidence shows that system resilience, not only productivity, is also key to recovery and sustaining household food security after disasters.

CIAT, in partnership with relief and developmental agencies, facilitates the Seed Systems Under Stress Program, which concentrates on:

- Helping to shape emergency relief, particularly in terms of seed and germplasm
- Analyzing the effects of different types of disaster (war, drought, flood, or crop plague) on the functioning of a seed system (including its crop and variety diversity)
- Evaluating emergency operations to further refine practices of seed system maintenance and strengthening
- Working with policy makers to institutionalize “best practices”
- Developing robust assessment tools for use during and after disasters to diagnose the strengths and weaknesses of surviving systems, and thus target response

This Program's success depends on its links with many collaborators. These include the Eastern and Southern African bean networks, SADC Seed Security Network and Germplasm Resource Center, NGOs (e.g., Catholic Relief Services, World Vision International, Save the Child and Action Aid), IARC collaborators, and international relief practitioners (particularly FAO and the U.S. Office for Foreign Disaster Assistance).

Seed Systems Under Stress Program: Projects and updates

The Program currently executes two main projects:

Project 1: Assisting disaster-affected and chronically stressed communities in eastern and central Africa: small-farmer seed systems

This project is USAID-funded and is implemented jointly by CIAT, CRS, and CARE/Norway. Goals are to develop diagnostic tools (SSSA= Seed System Security Assessments) to determine the effects of a stress, either natural or man-made, on agricultural and seed systems (including on crop and variety diversity) and to analyze the effectiveness of various support strategies in reducing constraints. Action-oriented fieldwork evaluates on-the-ground implementation in Ethiopia, Zimbabwe, Burundi, Kenya, Uganda, Malawi, and Mozambique. Case studies and Project Briefs determine interventions appropriate to acute versus chronic seed-stress situations. They also address the various challenges to achieving seed security in terms of availability, access, and use.

Milestone: All eight case studies were completed in 2004. They are now being prepared for (first an USAID Project Volume- then elaborated into a formal book)

- **Burundi**: Drought, civil strife, and seed vouchers and fairs: the role of the trader in the local seed system
- **Kenya (west)**: The use of informal seed producer groups for moving root-rot resistant varieties during periods of acute stress
- **Kenya (East)**: Comparison of Seed Voucher and Fairs (SV&F) and Direct Seed Distribution (DSD): Lessons Learned in Eastern Kenya and Critical Next Steps
- **Mozambique**: Crisis management when the staple crop is destroyed by disease: The case of Cassava Brown Streak Disease in coastal areas of northern Mozambique
- **Uganda**: Seed vouchers & fair and agro-biodiversity in western Uganda
- **Zimbabwe**: Relief seed assistance in Zimbabwe
- **Ethiopia**: Relief seed assistance in Ethiopia
- **Malawi**: A review of seed security strategies in Malawi

Milestone:: Annotated Bibliography of Seed Systems and Seed Relief Completed. This bibliography is geared for use particularly by Seed Aid Program Managers and Humanitarian Relief Practitioners. It was particularly challenging to compile as the large majority of works are in the (very) gray literature. The compilation of 55 references sought particularly to identify web-based reference resources—quickly downloadable and hence widely available.

Collaborators: Catholic Relief Services (CRS); Care/Norway (CN); International Plant Genetic Resource Institute (IPGRI)

Project 2: Seed aid and germplasm restoration in disaster situations: synthesizing lessons learned and promoting more effective practices

This IDRC-funded project analyzes trends in seed aid and germplasm restoration practice, and their possible interconnections, particularly in Africa. It reviews c.25 classic cases—developed through documentation, interviews, and selected field visits—to analyze current situations and provide a basis for improving practices over the next decade. More than 15 organizations are involved in synthesizing current practices, and raising global awareness of options for making progress. The list below highlights the germplasm restoration cases being analyzed, for several reasons. One of the rationales for CGIAR genebanks (including the Global Trust) is to allow for ‘restoration’, if necessary. The list below, however, suggests that there seem to be relatively few purported cases of CG restoration (that is, to farming communities and fields), and under closer scrutiny, most of these have not been as extensive as surrounding CG publicity would suggest (for instance, restoration of local germplasm *per se*, was not required after the Rwandan genocide/war). The restoration analyses, conducted by a range of IARCs are also posing questions of: what the goals of restoration might be (returning the system to ‘what was’? strengthening the system against future stress?) and what the subject of restoration should be (germplasm/seed? skills to maintain germplasm? local knowledge—or that which adds additional value?)

Key cases : (possible) restoration of germplasm

Intervention	CG Center/Other leading effort
1. Somalia –early 1990s (drought/war)	IPGRI
2. Rwanda (genocide/war)	Seeds of Hope (CIAT lead)
3. Philippines, Cagayan Valley (floods/drought, MVs, storage..)	IRRI/PhilRice
Liberia, Sierra Leone, Côte d’Ivoire, Guinea, Guinea Bissau (civil strife)	WARDA
4. Native tubers in the Andes (disease/virus build up)	CIP
5. Eritrea millet (war)	ICRISAT
6. India finger millet (intensification)	ICRISAT
7. Afghanistan (war/drought)	ICARDA?
8. Mozambique (flood)	(studied by Noragric/ICRISAT)
9. Ethiopia (drought)	IPGRI/ Biodiversity Institute

Major Contributors: Louise Sperling; other IARCs: International Plant Genetic Resource Institute (IPGRI); International Center for Research in the Semi-Arid Tropics (ICRISAT); West Africa Rice Development Association (WARDA); NGOs: Catholic Relief Services (CRS); World Vision International (WVI); Save the Children (SC); Action Aid; VECO (Zimbabwe); African Regional Networks/Institutes; SADC Seed Security Network; SADC Germplasm Resource Center

Progress towards achieving output milestones:

- Two hundred and sixty-two new and existing partners improved their linkages with research institutions and are currently involved in knowledge and skill enhancement and dissemination of varietal and non-varietal technologies.
- About 2.5 million farmers were reached by seed of new and existing improved varieties.
- Fifty-eight governmental agencies, 87 international NGOs and/or UN agencies, 15 commercial seed companies and 112 local NGOs or CBOs are involved in alliances for the diffusion of improved seed and agronomic practices.

Activity 4.3 Socio-economic activities

Highlights:

- Demand for beans on the market is influenced by grain color, and prior knowledge about cooking time and taste of the variety.
- Market studies of bean sub-sector in Uganda and Kenya show rising production and consumption trends of fresh and dry beans in Uganda but a stable consumption level in Kenya. Insufficient production in Kenya and demand in other countries offers opportunities for regional exports of dry beans from Uganda, while significant growth market opportunities for Kenya exist for green beans on international markets.
- The bean market price at the time of harvest in Malawi was primarily influenced by the supply and demand.
- Researchers and extension agents that work with farmers in both NARIs and NGOs in the Andean region should be aware of the profitability of bean production. For this reason we have started an analysis of the cost-benefit ratio of climbing versus bush beans in the production systems in practice in the region.

4.3.1 Development of participatory monitoring and evaluation (PM&E) in PABRA

Rationale: The PABRA conceptual framework for the period 2003-2007 is established on three outcome level deliverables, namely (a) Increasing utilization of Bean Based Technologies (b) Enhancing capacities of communities to plan and manage initiatives to meet their needs and (c) Strengthening Institutional and organizational capacities of PABRA, constituent sub-regional organizations and partners. The framework is based on Result Based Management (RBM) as a major tool for Participatory Monitoring and Evaluation (PM&E). The RBM is a management philosophy and approach that emphasizes development results in planning, implementation, continuous learning, and reporting. As a mechanism for PM&E, the RBM framework facilitates the management of project effectiveness; involvement of partners; incorporation of lessons learned; and reporting on the project impact.

Methods and Materials: The approach for developing PM&E in PABRA assumed three broad steps:

- a) Determining baseline data as sets of conditions existing at the onset of the five year PABRA work plan.
- b) Strengthening and consolidating the PABRA performance framework and
- c) Establishment of Participatory Monitoring and Evaluation (PM&E) in ECABREN and SABRN and member countries

Results and Discussion:

Baseline data: In the absence of baseline data as the starting point from which change could be measured, the first step in the performance measurement process was to seek baseline data from both ECABREN and SABRN countries. The process was guided by indicators along the three outcome levels in the PABRA work plan and against indicators. Baselines were obtained largely from existing databases on bean based technologies, from secondary sources (especially from

network publications, research studies, program documents and trip reports). 75% of baseline data for outcomes and outputs relating to increased bean based technologies; enhancing capacities of communities and for strengthening institutional and organizational capacities have been collected and entered in a database. Results will be measured against the acquired and incoming data.

Strengthening and consolidating the PABRA performance framework:

During 2004, the PABRA performance framework was consolidated to include logically interconnected steps for measuring results in a result chain. These steps were analyzed and presented in two categories of information namely (a) identifying what to monitor and (b) determining the methodologies for monitoring. Key results were discussed and entered in the PABRA RBM framework under the following headings (a) performance indicators for qualitative and quantitative development activities and resources (b) baseline data (c) data sources (d) methods of data collection (e) frequency of data collection (f) and roles and responsibilities of partners in delivering results in the framework.

Participation is an important aspect of RBM, ensuring that activities for Research for Development reflect the needs, priorities and vision of stakeholders is critical to managing results. In February and March 2004, two workshops and five working sessions were conducted with regional and national scientists, breeders, pathologists, Participatory Monitoring and Evaluation specialists, and social economists from CIAT and NARS to review outcomes, outputs, and impacts in the PABRA conceptual framework. In total, five regional scientists from CIAT and four national scientists were part of this process.

The workshop participants reviewed consolidated PABRA performance frameworks with a view to prioritize indicators for key results. This process of engaging partners from various disciplines led to the development of methodologies for data collection and for reporting that is adapted to various technologies being developed in PABRA. The result was a set of tools developed for analyzing information from various technologies. (Tables 121 and 122)

Establishment of Participatory Monitoring and Evaluation activities in ECABREN and SABRN and member countries:

Establishment of Participatory Monitoring and Evaluation (PM&E) in ECABREN and SABRN is based on the following: identification and analysis of existing M&E systems in member countries; building capacity for Participatory M&E (PM&E); institutionalizing mechanisms for PM&E; and developing systems for collecting, analyzing and recording data, for use in decision making, reflection and for learning.

The first step undertaken was the launching of PM&E in Uganda, Tanzania, Ethiopia, Madagascar, Rwanda, Burundi, DR Congo, Kenya, and Sudan in an ECABREN steering committee. During the ECABREN steering committee meeting in April 2004, principles and guidelines for undertaking PM&E were introduced to representatives of member countries and their partners. The results of the meeting were: (a) launching PM&E, (b) soliciting partners interest in monitoring and evaluation by means of the RBM framework for managing programs

and projects; and (c) encouraging better reporting to ECABREN network. A similar meeting is planned for SABRN national partners and regional scientists during the upcoming SABRN steering committee scheduled for the end of October 2004.

The second step in establishing PM&E is a research process whereby PM&E principles and guidelines are tested in the Bean Based Technology transfer project under the Ugandan National bean program. A component of this project is capacity building of national project scientists and technicians in mechanisms that include data collection, analysis, recording and dissemination. A result of this activity has been the use of multiple methods and tools for data collection. On this account, project reports now carry impact related information that is of greater interest to partners. Future work in this endeavour is to link PM&E at the national project framework level to the broader regional PABRA conceptual framework.

Contributors: R. Muthoni, R. Buruchara, P. Mukishi, R. Chirwa.

Collaborators: S. Kaaria (ERI), J. C. Rubyogo, national partners.

4.3.2 Social and economic impact of beans in Africa

Rationale: The objective of these efforts are to evaluate and document the impact of improved bean varieties in all seven key bean producing countries in PABRA (i.e Uganda, Malawi, Tanzania, Rwanda, Ethiopia, Congo, and Kenya).

Methodology: A team of three PABRA social scientists is assisting scientists in member countries to implement country proposals developed by the countries to conduct impact assessment studies. The studies use household level formal surveys, participatory rural appraisal, and analysis of secondary data to construct a data set for estimating impact. Descriptive statistics, social and economic analysis tools are used to evaluate the impact of improved bean varieties released during the past 17 years.

Summary Progress: Two impact studies have been completed in Uganda: a) An ex-post Impact study, and b) A longitudinal impact monitoring study. The results were presented at a PABRA steering committee meeting held in Mozambique in April 2004.

Five studies are being implemented in Tanzania, Rwanda, Malawi, Ethiopia, and DR Congo. The studies are being led by social scientists from these member countries with close technical support and collaboration by PABRA resource persons. The resource persons have helped train staff and initiate the studies in five countries. They continue to make regular monitoring visits and participated in data collection, cleaning, and analysis. Rwanda and Tanzania are expected to have completed the studies by December 2004.

Contributors: R. Kalyebara R. (NARO), Andima D. (KARI), Mugisha K.S. (CIAT/PABRA).

Collaborators: NARS Programs in Uganda, Malawi, Ethiopia, Rwanda, and DRC Congo, Tanzania.

Table 121. Information Analysis for PM&E system in the PABRA Performance Framework

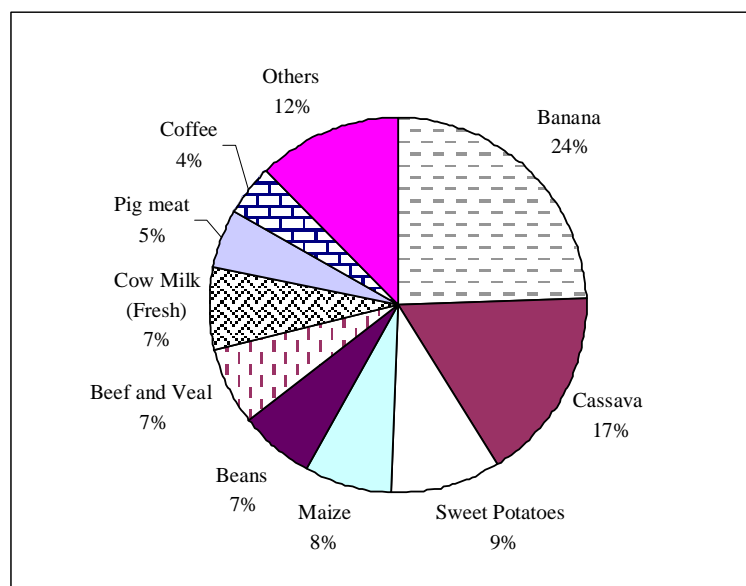
Determining what to monitor				
Result Expectations	Performance Indicators	Baseline Requirements for period 2003	Activity analysis	Milestones
(As in Log frame) Outcome #2 Enhanced capacity of 25 villages / communities in the projects 3 pilot areas to plan and manage initiatives to meet their needs Outputs#2. (Outputs that combine together to generate Outcome #1) Increased skills of men and women to achieve gender equity at the community and household levels	(As in Log frame) Indicator PI #1 x x x Indicator PI #2 Perceptions of who has access and control over agricultural resources (Land, income, labour, inputs, information) within the household	The PME system seeks to obtain the “before” situation for the purpose of adding value to the “after” situation Baseline situation obtained to be assembled	(Determining what needs to be done to achieve the objectives i.e. defining key activities; to include content and process related activities that occur simultaneously in the project: ➤ Election of men and women committees for enterprise development, experimentation, and monitoring and evaluation ➤ Ensure representation of men and women in all community project meetings is equal ➤ Facilitate experiential learning that enables women to empower themselves and speak in an organized manner ➤ Increase gender awareness campaigns ➤ Capacity building in community based participatory M&E ➤ Facilitation in leadership, group development skills, conflict management, and gender awareness training ➤ Establish community monitoring groups ➤ Train community monitoring groups in monitoring and documentation of events ➤ Train community development facilitators in designing and establishing PM&E systems	(What shows that you are successfully progressing from one stage to the next in the right direction?) ➤ Involvement of women in formulating and implementing community by laws ➤ Men and women consulting on major investment and expenditure decisions ➤ Change in gender roles ➤ Women and men demanding rights ➤ Economic independence of men and women ➤ Household conflicts

Table 122. Information analysis for PM&E system in the PABRA Performance Framework

Determining how to monitor							
Result Expectations	Performance Indicators	Milestones (Key results of your activity sets at various project stages) as given in worksheet # 1	Developing performance questions (What question do you need to ask to get a status report of on each of your milestones & how often will you ask the question?)	Determining the source of your information	Developing quantitative and qualitative tools for CARD (Collecting, Analyzing, Reporting and Disseminating) information	Sharing roles and responsibilities for CARD amongst NARS, Partners and Networks	
Result Expectations	Performance Indicators	Performance question i.e. seasonally, quarterly, annually	Frequency i.e. start of season, mid term, end of season	Determining the source of your information	Developing quantitative and qualitative tools for CARD (Collecting, Analyzing, Reporting and Disseminating) information	Sharing roles and responsibilities for CARD amongst NARS, Partners and Networks	
(As in Log frame)	(As in Log frame)	Involvement of women in formulating and implementing community bylaws	What is the extent of involvement of women in formulating community bylaws?	Annually	Farmer research Committees	Farmer research Committees	
Outcome #1 Enhanced capacity of 25 villages / communities in the projects 3 pilot areas to plan and manage initiatives to meet their needs	Indicator PI #2 Perceptions of who has access and control over agricultural resources (Land, income, labor, inputs, information) within the household	Men and women consulting on major investment and expenditure decisions	What is the extent of consultations on major household investments? What is the nature of family resources controlled by men and women? Are men/women involved in activities previously predominantly done by women/men?	Ditto	PM&E committees Community development facilitators	PM&E committees Community development facilitators	
Outputs#1.1 (Outputs that combine together to generate Outcome #1) Increased skills of men and women to achieve gender equity at the community and household levels		Change in gender roles Women and men demanding rights Economic independence of men and women Household conflicts	What are the perceptions of men and women on their economic independence? What are the perceptions of men and women on household conflicts?	Ditto Ditto Ditto	NGO's CBO's	NGO's CBO's	

4.3.2.1 Social and economic impacts of improved bean varieties in Uganda

Background: Beans are a major food and cash crop for the majority of Ugandan farmers and consumers. In terms of gross contribution to the country's GDP, beans account for 7% of the total national agricultural GDP, ranking 5th behind bananas, cassava, sweet potatoes, and maize (Figure 73). The estimated economic value of total bean output when valued at market prices in 2001 was higher than total earnings from coffee which has been Uganda's chief export commodity. Though not a very accurate measure of value, this illustrates one important point: any changes in output resulting from investment R&D will have major implications on the welfare of Ugandans.

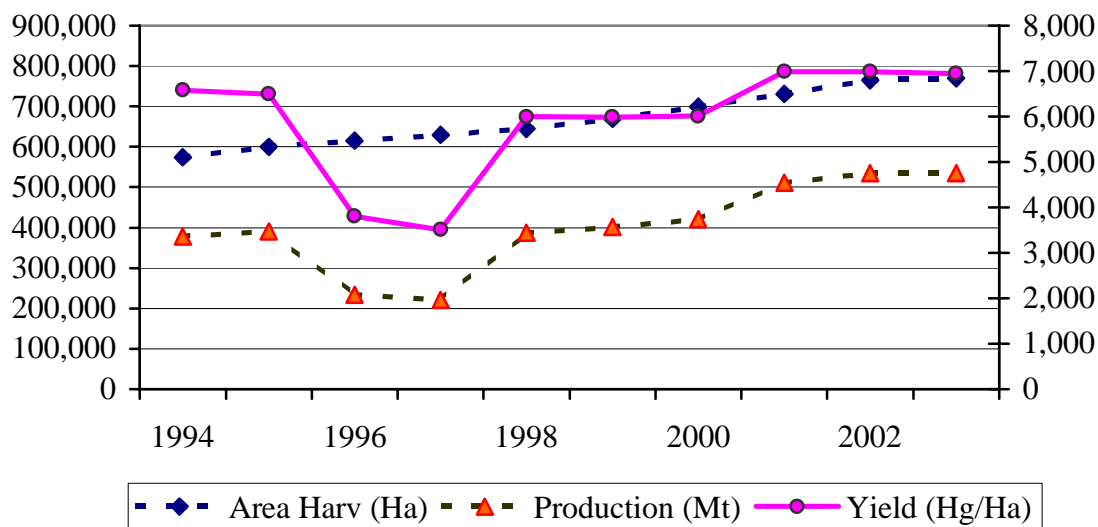


Data source: FAOSTAT database, 2002.

Figure 73. Share of Beans in Total Agricultural GDP (2001)

Production is entirely by small-scale farmers and is concentrated mainly in the Central, Eastern, and Western regions. The average plot size ranges from 0.25 to 1.0 acre per household (David and Hoogendijk, 1997). Most of the country grows bush beans, whereas climbers have traditionally been limited to highland areas constituting about 20% of total bean acreage. Typically, bush beans are grown in intercroops with various crops, the most popular intercroops being maize, cassava, cotton, bananas, and groundnuts. Climbers are mostly intercropped with maize or grown in pure stand. The majority of beans are produced under low input labour intensive agriculture, with no purchased inputs apart from seed purchases to supplement own stocks.

In the last 10 years bean output has more than doubled (Figure 74). Production has increased due on account of area expansion, but also a significant improvement in yields coinciding with the introduction of improved varieties that were more disease resistant.



Source: FAOSTAT database, 2003

Figure 74. Uganda's Bean Production 1994 - 2003

Rationale: Considering the major role that beans play in alleviating poverty and food insecurity, significant resources have been invested in Research and Development to develop and disseminate improved technologies to farmers. Nine bush and five climbing bean varieties have been released over the last 10 years by the National Agricultural Research Organization (NARO) in collaboration with and CIAT and other partners. Various stakeholders have expressed interest in establishing the extent and level of impact generated across different target groups, and returns to investment in R&D. There is some evidence from case studies that past Research and Development (R&D) on bean varieties has generated significant impact particularly through improvement in household incomes and food security (David and Sperling, 1999; David et al., 2000), however no detailed evidence is available on wider and long term contributions of new bean-based technologies. This study examined the impact of eight improved bush bean varieties and complementary management practices released between 1994 and 1999. The study was conducted by NARO with collaboration from CIAT and PABRA between July 2003 and February 2004. The objectives of this study were to:

- (a) Estimate the social and economic impact of improved bean varieties in Uganda.
- (b) Estimate the return to past investments in bean R&D.

Methodology

Data sources

The data was obtained through a formal survey of 529 bean farmers for two seasons in 2003 in six districts, representing six major agro-ecological zones: south-western highlands, eastern highlands, eastern mixed farming zone, Lake Victoria crescent, western mixed farming zone, and mid-northern mixed farming zone. Additional information was obtained from key informant discussions, participatory rural appraisal (PRA), experimental data, and secondary data from the Uganda Bureau of Statistics (UBOS) and FAO. The main focus of household surveys was to collect quantitative data on household socio-economic characteristics, bean adoption, acreage, yields, output, utilization, marketing; and social and economic impact parameters.

Social Impact Assessment

The analysis involves use of social analysis tools to investigate social impacts; and economic analysis which is mainly concerned with estimating the financial value of benefits and costs. Social impact assessment on the other hand specifically seeks to document the effects of technological change on the wellbeing of communities and changes in social organization and social relations. Social equity, poverty reduction, and food security are central concerns in social analysis.

Estimation of Economic Returns from Bean Research & Development (R&D)

Benefits from adoption of improved varieties are examined from the point of view of increasing incomes to households and society from investment in bean R&D. The efficiency of technologies and R&D systems in generating surpluses (profits) is investigated. Aggregate benefits to society are calculated using the economic surplus method. Benefits are computed from farm level data provided by the household survey, and aggregate bean production statistics. Research and development costs are calculated using historical data obtained from NARO, FAO, the Ministry of Agriculture, and the Uganda Bureau of Statistics (UBOS) for the period 1986 to 2003.

Longitudinal Impact Monitoring

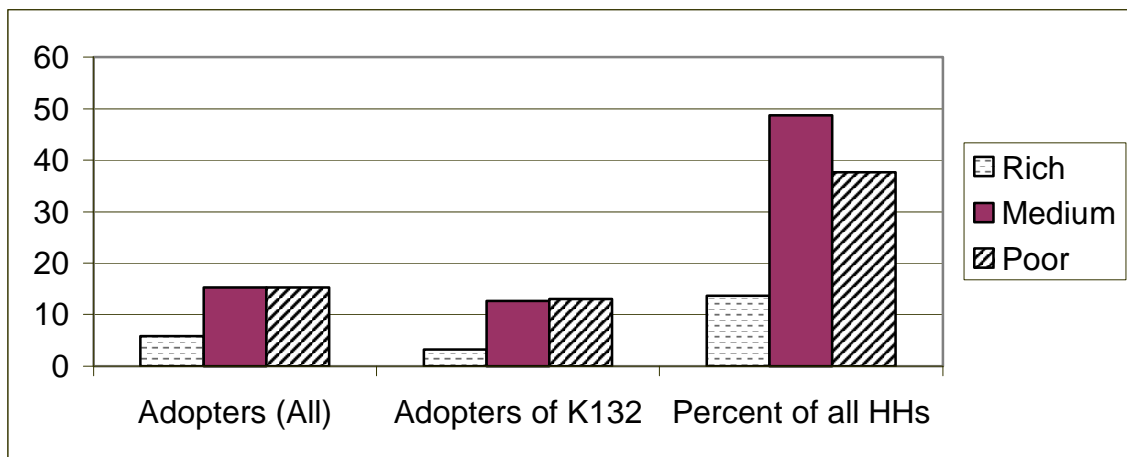
Uganda has been a site for a longitudinal study of bean impacts that has been going on for the last 10 years. This involves a series of Impact assessment studies repeated after an interval of 4 years in order to monitor and evaluate changes in social and economic impact over time. This is the second in a series of such studies. The impact study monitors the impact of new bean varieties that were initially disseminated to women groups in three neighbouring villages in Eastern Uganda in 1994. The focus is on in-depth social and economic impact assessment; however unlike the earlier studies, this second study also evaluates the impact of bean varieties on the nutritional status of children in 1 case study village.

Results and Discussion: Results from a formal household survey of six districts, indicate that new varieties particularly K132 (CAL 96), K131 (MCM 5001), and NABE 2 have an average yield advantage of 37% (20-196%) over farmers' varieties under farmer conditions. The

observed average yield of 855 kg ha⁻¹ for new varieties under farmer conditions is a significant improvement over the observed average yield of 625 kg ha⁻¹ for farmers' varieties; however it is still far below the potential yield of 1.5 – 2.0 tonnes per hectare under optimal farmer management as reported by the national bean programme of NARO.

K132 released in 1994 is still the most widely adopted variety mainly due to its high yield potential and high market demand. However its acreage is declining due to its susceptibility to bean root rot. About half (53%) of the sample households had adopted at least one new variety, while 40% had adopted K132. When extrapolated to national estimates, the observed adoption of new varieties is equivalent to approximately one million households adopting new varieties, which is a very promising result in anticipation of achieving the PABRA goal of reaching 10 million households in the whole PABRA region by the year 2008.

The majority of adopters are in the 'poor' and medium wealth categories (Figure 75). This is indicative of the major role played by beans in poverty alleviation, and also confirms that poor households are accessing improved varieties. However benefits to the poor are limited by access to complementary resources such as land: the average bean plot for poor households is just over one third of the average plot size for rich households.



* HH stands for 'household'.

Figure 75. Proportion of adopters by wealth category (national survey), N = 529.

Regional distribution of impact

The number of adopting households is lower (20 - 50%) in the southwest, northwest, and western regions; and relatively high in the eastern highlands and central regions (40 – 80%). The distribution of new varieties corresponds closely with access to major markets, and extent of formal seed dissemination efforts by government institutions and NGOs. There is concern that new varieties are not yet easily accessible in some areas due to limited seed dissemination and low market access.

Contribution of new varieties to bean output

Survey results showed that new varieties have contributed 41% of total bean output in the sample with K132 alone contributing 36% of total bean output. The increase in total bean output due to improved varieties is attributed to partial replacement of old varieties by new ones which have a 37% yield advantage.

Marketing and utilization

There is a clear differentiation by farmers between varieties grown for sale and those for home consumption (Table 123). The data confirms the previously observed trend that new varieties are mainly grown for marketing than home consumption. An important finding is that the share of output sold by the poor is close to that for the rich. In the case of Uganda this has a major implication for poverty reduction: incomes of the poor can be enhanced through improved access to new varieties.

Table 123. Share of bean output sold per household by wealth category (national survey), N = 529.

Variety	Rich	Medium	Poor
K 132	71	77	60
Kanyebwa	54	62	54
Ocuc	44	49	45
Masindi Yellow	31	33	41

Impact of new varieties on household bean consumption and income

Average annual household bean income has more than doubled since introduction of new varieties, while annual household bean consumption has increased by just 37%! New varieties account for 67% (97,657 Ushs yr⁻¹) of annual household bean income; and 45% of household bean consumption. Whether this implies that new varieties have had a greater impact on household incomes than food consumption is a question that is answered by a nutrition study.

Poor households earn about 40,000 Shs (\$23) from beans annually compared to 60,000-70,000 Shs per year (\$34 - 40) earned by wealthy households (Table 124), indicating that beans are contributing relatively more to poverty reduction given that the rich have bigger bean plots, and other sources of income. The poor eat more beans per capita than the rich! Not very surprising but a good indicator of the contribution of beans to food security for the poor. Per capita bean consumption varied according to the level of adoption of new varieties. For example in Mbale (Eastern Uganda) where adoption (of K 132) was high, adopters consumed more beans (50% - see Annual Report 2003) than non-adopters. However, there was no difference in per capita bean consumption between adopters and non-adopters at a national level (Table 124). This is partly explained by the fact that adoption levels varied widely across the country, with areas that had low access to improved varieties (and therefore low adoption) consuming more traditional varieties per capita. The other reason was that a larger proportion of the main new variety adopted (e.g. K 132) was sold because of its high market demand.

Table 124. Impact on household income (in Uganda Shillings) and bean consumption (kg) by wealth category (national survey), N = 529.

	Rich	Medium	Poor
Annual bean income today (UShs)	54,250	104,583	42,667
Income from K132 (Ushs)	69,188	99,300	40,390
Per Capita Daily Bean Consumption (Adopters) kg	0.15	0.12	0.20
Per Capita Daily Bean Consumption (Non-adopters) kg	-	0.14	0.20
Amount of Beans Sold per Year (kg)	167	180	105

Reaching disadvantaged groups

Reaching and empowering disadvantaged target groups is a key pillar of CIAT's efforts to eradicate poverty. In this study, we investigated access to benefits of improved varieties by the poor, women, and children. Results are encouraging. There is more participation of women in decisions regarding adoption of new bean varieties: In 41% of surveyed households, women were responsible for decisions to continue growing new varieties (Table 125). This may be surprising to some, given that the Ugandan society is male dominated; but it confirms the notion that because beans play a major role in household food security, a lot of decisions related to beans lie in the hands of women. The total area sown to beans is much larger for women as compared to men. The longitudinal survey revealed that between 1998 and 2002, the women from three pilot villages in Eastern Uganda increased the area under beans four fold while during the same period, men increased their acreage by about 0.2 times. The area sown to women's plots accounted for 19 ha while that sown to men's plots was a mere 5 ha. This result confirms that women still maintained significant control of bean output as its level of commercialisation increased, and suggests that women have considerable control of bean income since in this society men and women own separate plots.

Table 125. Changes in household welfare due to K132 perceived by farmers, Sironko district, Eastern Uganda (N= 80)

Change	Percent of respondents	
	Positive Changes (%)	Negative Changes (%)
Total household income	100	0
Availability of beans during times of shortage	100	0
Family health	96	4
Work done by women	8	92
Prices offered by traders	19	81
Amount of wood fuel used	73	27

Growing new bean varieties was perceived by farmers as having had significant positive welfare effects through household income, availability of food during periods of food scarcity, family health, and amount of fuel wood required for cooking; and negative impact by increasing the amount of work done by women, and reduction in bean prices. Generally the poor and medium wealth households perceived much higher positive impacts due to new bean varieties compared to the rich.

A preliminary investigation in one case study village in eastern Uganda indicated that beans have a significant correlation with the growth status of children: the height of children aged 1-5 years was found to be positively correlated with availability of beans for household consumption. The results indicate that children living in households that produce enough beans for home consumption are less likely to suffer from malnutrition. This proposition will hold depending on the amount of beans consumed by the child. Further studies are needed to confirm the contribution of beans to child nutrition relative to other factors. However, it is evident from this study that the effect of beans is more pronounced among the poor as the data indicates that the poor eat more beans per capita than the rich (Table 124).

Returns to investments in Bean R&D

The Net Present Value (NPV at 2003) of benefits to Uganda, from public investments in bean R&D by Uganda alone for the period 1986 to 2010 (25 years), is approximately 476 million dollars with an average return of 16 million dollars per year (Table 126). The internal rate of return from the investment at a nominal market interest rate of 15% is 41%. This is relatively higher than the IRR found by Laker-Ojok (1994) for competing crops (maize 27%, groundnuts 23%, and sesame 27%). Wessler et al. (1999) observed a very similar IRR of 45% for improved bean varieties in Uganda. This confirms that investment in bean R&D is beneficial to society. This is based on the assumption that research costs of international centres are sunk costs. It is not known how profitable bean research would be if developing countries were to fund their own breeding programs and pay royalties for imported germplasm.

Table 126. Benefits and returns to investments in bean research and development

NPV of Bean R&D Benefits (US\$)	471,591,817
Average NPV per Year (US \$)	15,719,727
Total Investment in R&D by Uganda (nominal 2003 US\$)	14,021,598
Internal Rate of Return (nominal)	41%

References:

- David Soniia, Roger Kikby and Sarah Kasozi, 2000. Assessing the Impact of bush bean varieties on poverty reduction in Sub-Saharan Africa: Evidence from Uganda. Network on Bean Research in Africa, Occasional Publication Series, No. 31, CIAT, Kampala, Uganda.
- David Soniia, L. Mukandala and J. Mafuru, 2002. Seed availability, an ignored factor in crop varietal adoption studies: a case study of beans in Tanzania. CIAT, Kampala (Unpublished).
- David Soniia and Louise Sperling, 1999. Improving technology delivery mechanisms: Lessons from bean seed systems research in eastern and central Africa". Agriculture and Human Values. 16: 381-388.
- David Soniia, 1997. Dissemination and adoption of new technology: A review of experiences in bean research in Eastern and Central Africa, 1992-1996, Network on Bean Research in Africa, Occasional Publication Series, No. 21, CIAT, Kampala, Uganda.
- Wessler G.H., P.K. Ngategize, L. Aliguma, M. Mutetikka, Y. Baguma, R. Sabiiti, b. Tayebwa, and P. Karuhanga, 1999. Economic Assessment of Agricultural Research in Uganda. National Agricultural Research Organisation, Socio-Economics Working Paper No. 1, Entebbe Uganda.

Contributors: R. Kalyebara Robert, (NARO), Andima D. (KARI), Mugisha K.S. (CIAT/PABRA), Nasirumbi L. (NARO).

Collaborators: NARO Bean Program

4.3.3 Bean sub-sector market studies for Uganda and Kenya

Rationale: Systematic market studies for bean sector were planned to be carried out in Uganda, Kenya Tanzania, Ethiopia and Democratic Republic of Congo in collaboration with FOODNET. The purpose of these studies was to provide a review of the current status and research and development investment options, in the bean sub-sector for the main bean producing countries of the ECABREN/ASARECA region. The aim was also to analyze the potential for developing more robust levels of environmentally sustainable economic growth through improved systems of bean production, processing and marketing.

Methodology: The studies were based on a rapid market appraisal technique developed by Holzman (1995). Due to the rapid nature of this process the review is illustrative as opposed to rigorous and serves to prioritise options and constraints. It uses both secondary and primary data to determine market prospects. Primary data was obtained through interviews using a structured informal questionnaire with producers, traders, retailers and exporters. Secondary data was acquired through literature review and the collection of available statistics. The study reviewed demand for and trade in major market sectors including fresh and dry beans and processed bean products. An important element of the work was to examine the comparative and competitive advantages of specific bean types and their related production zones. The analysis considered bean types and the impact of new varieties in terms of their current market share and market potential. Coverage includes local, regional and international markets.

Results and Discussion: Studies have been completed in Uganda and Kenya and reports developed. Studies are underway in Tanzania and Ethiopia. Results from Uganda show rising production and consumption trends of fresh and dry beans, and rising price trends over the previous three years. Major factors influencing market prices are relief purchases by World Food Program (WFP) and the Kenyan market. Uganda is currently uncompetitive in international markets for dry and green beans implying that bean research and development efforts could focus on regional and national markets. Regional market opportunities exist in: Kenya, for a 'pure' colored dry bean (e.g. K 132 is notably dominant and successful in Kenyan export market) and South Africa for small white canning beans and speckled sugar beans.

The Kenyan market for dry beans is relatively stable with approximately 450,000 metric tones of beans consumed annually. Due to insufficient production, Kenya is a major regional dry bean importer (approximately 100,000 metric tones) mainly from Uganda and Tanzania with the majority of it going through informal trade due to border tariffs. Kenyan dry bean production is becoming increasingly extensive due to declining terms of trade as the price of purchased inputs rises in comparison to that of the dry beans produced. Significant growth market opportunities for Kenya exist for green beans on international markets. Opportunities exist to increase levels of value addition in Kenya through products such as pre-packed, topped and tailed beans and frozen beans. A major challenge to green bean exports is the European Union Hazard Analysis and Critical Control Point (HACCP) legislation. Areas of moderate growth in the next five years are in ready-mixed bean based foods, e.g. githeri (bean and maize), a quick to prepare protein providing meal favored by low income urban consumers, and processed tinned beans sold to higher income groups in domestic and regional markets.

Recommendations include the balancing of research and development investment towards market opportunities for both regional and export markets, support to post-harvest activities and actors through business related services such as information provision, networking and producer group facilitation while research supports initiatives addressing technology issues.

Contributors: S. Ferris, J. Jagwe, and P. Mukishi

Collaborators: FOODNET, ECABREN, NARO, KARI, R. Buruchara, R. Kirkby.

4.3.4 Bean market price study in Malawi

Rationale:

Despite the fact that a wide range of bean varieties are currently grown and put on the market in Malawi, very little is known about consumer choice factors for beans. Various bean varieties have different characteristics that could in one way or another determine their attractiveness to consumer. Such characteristics as grain size, color, shininess, damage level, cooking time, taste, etc. have not been adequately investigated. A study was therefore undertaken to assess factors that determine choice of beans on the markets, soon after harvest in the Central and Southern regions of Malawi. The majority of the traders indicated that most consumers preferred dark red kidney market class (Phalombe), followed by Sugar (Nanyati) and red mottled (Napilira) (Table 127).

Table 127. Bean varieties mostly preferred on the market

Type	Count	Percentage (%)
Phalombe (Dark Red Kidney)	47	63.5
Nanyati (Cream Mottled)	25	33.8
Napilira (Red Mottled)	15	20.3
Saperekedwa (Red)	8	10.8
Kamtauzgeni (Brown)	7	9.5
Kaulesi (Purple)	5	6.8
Kalima (Dark Red Mottled)	5	6.8
Nyauzembe (Dark Green)	4	5.4
Mixed	4	5.4
Total	120**	162.6**

** Total count and percentage exceed 74 and 100% respectively due to multiple responses. The percentages are out of 74

Napilira, which is red mottled in color, is a relatively new market type in Malawi, dating back to mid 90s when CAL 143, a CIAT line was released in Malawi. Availability of beans, coat color, and cooking time were among the factors that influenced demand and price on the market (Table 128). More than half (56.8%) of the sampled traders indicated that bean prices vary according to availability, indicating that price depended on supply. In general, the price was low soon after harvest (March to June) but it is expected to go up, sometimes even more than double, during the lean season, towards time to plant the subsequent crop between October- January, all the way until the next harvest In March-April.

Table 128. Factors determining bean price

Factor	Count	Percentage (%)
Availability	42	56.8
Cooking time	16	21.6
Coat color	16	21.6
Taste	8	10.8
Grain size	4	5.4
Damage level	1	1.4
Others	22	29.7
Total	109**	147.3**

**Total count and percentage exceeding 74 and 100% respectively due to multiple responses. The percentages are out of 74

On average, Napilira (red mottled) and Nanyati (cream mottled) market classes had the largest sales volume; about 8800 kg (Napilira) and 8000 kg (Nanyati) were handled by wholesalers in a month at the time of the study (Figure 76). The traders attributed this mainly to the Napilira's high yielding ability, owing to its tolerance to low soil fertility and resistance to diseases. This made it to be readily available on the market. On the other hand Nanyati was abundant because many farmers in Malawi have been growing this market class for a long time, and it occupies a larger share of the land that is put to beans. At the wholesale market, Napilira was the cheapest, selling at about MK36 kg⁻¹ on average, where the range across various market types was MK30-80 kg⁻¹. (Table 129).

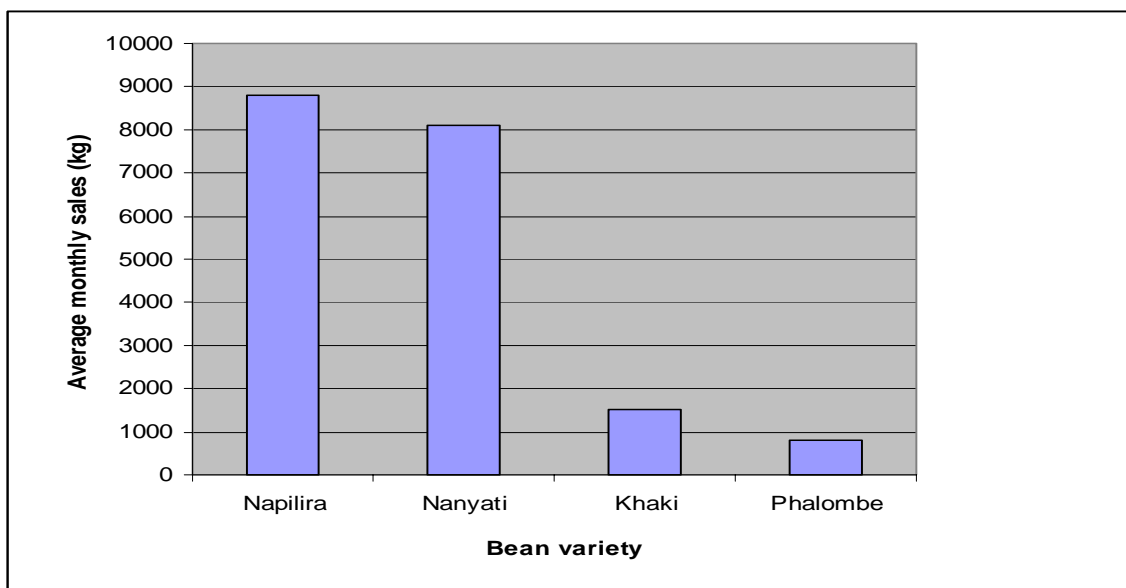


Figure 76. Wholesalers average bean sales

Table 129. Bean wholesale prices (MK per kg) by type in March/April 2004

Variety	Minimum Price	Maximum Price	Average Price
Phalombe (Dark Red Kidney)	35.00	80.00	46.43
Nanyati (Cream Mottled)	30.00	70.00	39.38
Napilira (Red Mottled)	35.00	40.00	35.71

Conclusion:

The bean market share in the central and southern Malawi is dominated by the dark red kidney, followed by cream mottled (sugar) and red mottled. Supply, bean market type and cooking time are some of the factors that influence the price on the market. The combination of large volumes of Napilira on the market due to its high productivity, and low market price, offers affordable protein to many rural and urban poor households.

Contributors: M.A.R. Phiri and R. Chirwa

4.3.5 Economic analysis of climbing bean production cost-benefit ratio in Colombia

Rationale: We have begun a project to analyze the economic returns achievable with trellised climbing bean monocultures. The goal of this project is to perform a market and cost-benefit analysis of climbing beans, identifying the technology and agricultural practices (trellising, seed inputs, disease control, land management) found in various departments of Colombia, and analyzing profitability on a per unit land basis. This study will allow us to get a better idea of costs of production and profitability of climbing beans in different regions of the country and whether the bean supply is affected regionally or nationally by the new systems of production that have been implemented for climbing bean production. Our ultimate goal is to develop new varieties of beans that fit into the most accepted and profitable production systems.

Methodology: Surveys were prepared for both producers and consumers as two separate groups of interview subjects so as to ascertain the status of both supply and demand of common beans as a commodity in the regions of Colombia that were targeted. Special attention was given to the producer survey so as to obtain useful information for the cost-benefit analysis. The consumer survey was targeted to two subgroups: final consumers and intermediaries whether wholesalers or retailers. Information on planted area, harvested area, per hectare yield and regional supply were obtained from diverse sources including the Ministry of Agriculture and municipal extension offices (UMATAs) (Table 130 – Figure 77).

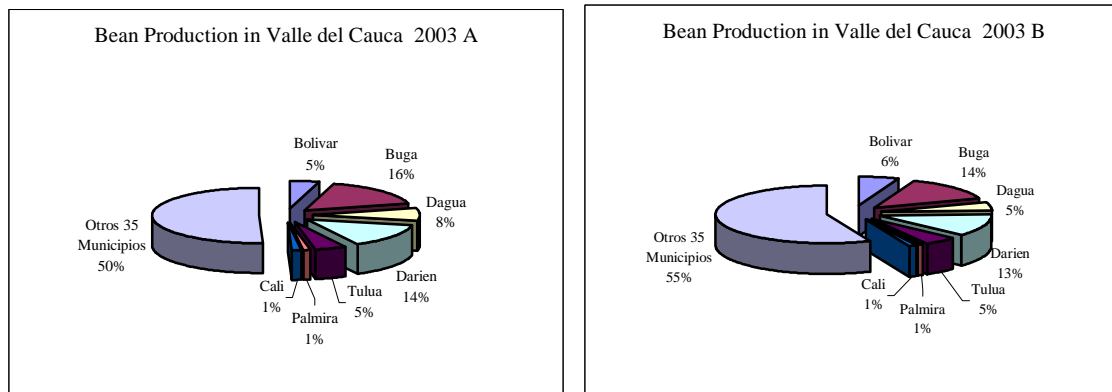
Table 130. Production of dry beans (in hectares) in municipalities of the department of Valle, Colombia in 2003.

	Semester A				Semester B			
	Planted Area (ha)	Harvested Area (ha)	Yield*	Total Production (MT)	Planted Area (ha)	Harvested Area (ha)	Yield*	Total Production (MT)
Buga	113.8	113.8	1.1	125.18	127.0	122.3	1.0	122.3
Darién	107.6	107.6	1.0	107.6	120.0	115.5	0.95	109.73
Dagua	72.2	72.2	0.8	57.76	55.0	53.0	0.76	40.02
Bolívar	43.9	43.9	0.8	35.12	63.0	65.5	0.76	49.45
Tulúa	44.8	44.8	0.8	35.04	55.0	53.0	0.78	41.34

* yields are in tons/ha

Results: Surveys have been tested with producers and consumers in the department of Valle de Cauca during the dry season between the 2004A and 2004B seasons and although data analysis is pending, initial results suggest that the cost-benefit analysis will be difficult because climbing beans are part of complex rotation system for which individual input records for each crop are not kept. It is notable that almost no climbing bean – maize intercropping is practiced within the department of Valle de Cauca except in home gardens and that trellised climbing beans are the predominant production system.

Future Work: Additional surveys will be conducted in the departments of Nariño, Caldas, Quindío, Risaralda and possibly Antioquia y Cundinamarca. A cost-benefit manual will be written to help with future studies by officers of extension or local agricultural services departments.



Source: Unidad Regional de Planificación Agropecuaria – URPA, Ministerio de Agricultura y Desarrollo Rural del Valle del Cauca.

Figure 77. Percentage production of common bean among the municipalities of Valle de Cauca in 2003A.

Contributors: MW Blair (SB-2, CIAT)

Collaborators: D.X. Marín, A.L. Herrán (Univ. Javeriana), N. Johnson, J. García (Impact Assessment, CIAT), Y. Viera (IP-1, CIAT), J. Restrepo, P. Ojeda (FIDAR)

Progress towards achieving milestones:

- A completed impact study in Uganda shows that average annual household bean income has more than doubled since introduction of new varieties.
- Systematic market studies for the bean sub-sector have been completed in Uganda and Kenya and reports developed. Similar studies are underway in Tanzania and Ethiopia.
- Napilira (CAL 143), which is a red mottled bean type, is a relatively new market class, which has been in Malawi since the mid 1990s. While a formal impact study is pending, it is coming up strongly on the market, commanding largest volumes of sales per month, at harvest time. It also sold at a lower price compared to other types, offering many rural and urban poor households to access more beans, and therefore improving their protein consumption.

Output 5: Strengthened institutional, organizational and collaborative capacity of NARS and sub-regional networks in Africa and Latin America

Activity 5.1 Strengthened capacity of NARS: increasing the knowledge and skills of scientists and staff from NARIs, NGOs and Rural Service Providers

Highlights:

- In Latin America, two PhD candidates and one MSc candidates received their degrees, while in Africa two PhD and three MSc degrees to scientists working the bean project.
- In Africa a total of 408 persons attended courses or workshops, for a total of 1497 person-days of training.
- Participatory plant breeding was strengthened regionally with a course in Kenya attended by 22 scientists from the region, including four from SABRN
- Former IPM farmer groups in central Malawi have now taken up seed production as a business.
- Interaction between breeders in Africa and headquarters increased this year, with training in headquarters in marker assisted selection and with seed shipments renewed from Africa to Colombia, leading to closer integration of the breeding programs in Latin America and Africa.
- The ECABREN program assistant acquired skills in participatory monitoring and evaluation systems to support national bean programs
- 28 Biophysical scientists, NGOs partners, and technicians from Northern Tanzania were exposed to Participatory M&E organized by PABRA/ECABREN
- ECABREN partners in Tanzania and Uganda acquired knowledge in seed systems and distribution channels
- Two researchers from ISABU and Centre Technique Horticole d'Antananarivo, Madagascar developed knowledge and skills during training in production of promotional materials carried out at ATDT/ISAR project.
- Farmers and researchers in northern Tanzania select and name nine new marketable bean lines with tolerance to bean stem maggot and angular leaf spot after four years of participatory selection. Seed bulking by farmer groups and broader evaluation of new bean lines initiated.
- A compilation on participatory breeding experiences across crops, countries and regions of Africa was completed.

5.1.1 Degree and non-degree training in Latin America

PhD candidates:

- Andrea Frei, ETH, Switzerland, completed her thesis on resistance to *Thrips palmi* in beans (C. Cardona, M. Blair, S. Dorn, H. Gu).
- Oscar Vizgarra, an Argentine PhD candidate continues writing his thesis, involving a statistical analysis of multi-locational trials carried out over a 15 year period in the north-west of Argentina (S. Beebe).
- Oscar Checa, Universidad Nacional, Palmira, Colombia, completed his studies on the inheritance of climbing ability in common bean and the importance of genotype x environment interaction in this trait (M. Blair).
- Ivan Ochoa, Pennsylvania State University, USA is finishing his thesis on genetic mapping to understand the inheritance and mechanisms of low phosphorous tolerance in common bean and the role of adventitious rooting in adaptation to low phosphorous stress (collaboration M. Blair with J. Lynch).
- Enrique Bravo from the Universidad del Valle continues his research on the molecular characterization of the NL4 strain of bean common mosaic virus (F. Morales).

MSc candidates:

- Juan Miguel Bueno, Universidad del Valle, completed his thesis on sampling methods for whiteflies on beans and snap beans (C. Cardona).
- Orlando Chaveco, a Cuban MSc student continues to carry out a physiological analysis of lines derived from the cross of DOR 364 x BAT 477, the latter of which has expressed resistance to multiple abiotic stresses. The study will reveal the physiological relationship between resistances to low P, nitrogen and drought stress (S. Beebe).
- Maria Antonia Henríquez, Universidad Nacional de Colombia, Palmira, continues her MSc thesis on “Use of Expressed Sequence Tags (ESTs) to understand the interaction of bean genotypes and *Phaeoisariopsis griseola*” (G. Mahuku).
- Juan Manuel Díaz, Universidad Nacional de Colombia, Palmira is working on evaluation of genetic diversity in Andean accessions of the common bean core collection using microsatellites (M. Blair).
- Lucy Díaz, Universidad Nacional de Colombia, Palmira is working on evaluation of genetic diversity in Mesoamerican accessions of the common bean core collection using microsatellites (M. Blair).
- Wilfredo Pantoja, Universidad Nacional de Colombia, Palmira, is working on evaluation of genetic diversity in Tepary bean accessions (M. Blair).
- León Darío Vélez, Universidad Nacional de Bogota, Colombia is studying the inheritance of intercropping ability between common bean and maize (M. Blair).

Pregraduate students:

- Gina Viviana Caldas, Universidad del Valle completed her studies on tannin QTL mapping (M. Blair).
- Maria Fernanda Montenegro, Universidad Nacional completed her thesis on the effect of insecticides on natural enemies of whiteflies (C. Cardona).
- Sergio Prieto, Universidad Nacional, completed his thesis on molecular markers for arcelin (M. Blair and C. Cardona).

- Mónica Navia, Universidad del Valle completed her work on “Elucidation of the infection process of common bean by *Phaeoisariopsis griseola*, the causal agent of angular leaf spot disease” (G. Mahuku).
- Henry Lozano, Universidad Nacional, completed his studies on “Inheritance of mineral content in advanced backcross population of common bean using the Wild QTL approach” (M. Blair).
- Sandra Jimena Valencia, Universidad Nacional, initiated studies on “Sub-lethal effects of antibiosis on the demography of *Zabrotes subfasciatus* and *Acanthoscelides obtectus*, storage pests of beans” (C. Cardona).
- Lorena Cortés, Universidad del Valle, is working on “Effect of different sources of green manure to manage root rot pathogens of common bean (*P. vulgaris*)” (G. Mahuku).
- Yenni Lorena López Galvis, Universidad Nacional, is working on “Evaluation of common bean genotypes *Phaseolus vulgaris* L. for drought tolerance under greenhouse conditions” (I. Rao).
- Lina María Rodríguez, Microbiol. Univ. de los Andes, Colombia, initiated studies on “Geminivirus resistance markers” (M. Blair).

Visiting Researchers:

- Gloria Santana, CORPOICA, Rionegro, Antioquia, Colombia (Sept 2003). Training in molecular marker techniques and indirect selection for BCMV resistance, at CIAT.
- Andrea Frei, ETH, Switzerland, (February 2004). Preparation of a publication on quantitative trait loci involved in resistance to the leaf-feeding insect, *Thrips palmi* in common bean.
- Carlos César Caula, Cuban Institute of Biotechnology, (to March 2004). Training in microsatellite mapping, marker assisted selection and gene tagging.
- Hernan Campos, Univ. San Simon, Cochabamba, Bolivia (to April 2004). Training in population evaluation and crop physiology.
- Kattia Delgado, Instituto Peruano de Leguminosas / PROMENESTRAS / PROMPEX, Chiclayo, Peru (April - May 2004). Training in Andean bean breeding and marker assisted selection.
- Dennis Flores, Instituto Peruano de Leguminosas / PROMENESTRAS / PROMPEX, Chiclayo, Peru (July – Sept 2004). Training in Andean bean breeding.
- Andrea Dávila, Centro Fitoecogénético Pairumani, (August-December 2004). Univ. San Simón, Cochabamba, Bolivia. Training on evaluation of genetic diversity in Bolivian accessions of common bean.
- Luz Nayibe Garzón, Universidad Nacional de Bogotá, Colombia, (Sept – Dec 2004). Training on development of molecular markers for anthracnose resistance in common bean.
- Paul Kimani, CIAT-Kenya/ University of Nairobi (August 2004). Specialization in marker assisted selection.
- Rowland Chirwa, CIAT-Malawi (August 2004). Specialization in marker assisted selection.
- Tereza Cristina Olivieras Borba, EMBRAPA-CNPAP, Univ. Federal Goias (Sept – Nov 2004). Development of fluorescent microsatellites for common bean.
- Orlando Chaveco, Cuban Ministry of Agriculture (October 2004). Training in Andean bean breeding and physiology.

- Carmenza Muñoz, University of Lyon (October – November 2004). Preparation of a publication on genetic diversity of tepary bean.
- Gloria Iriarte, CENICAFE (short visits). Preparation of a publication on advanced backcross method in common bean.

Courses:

Date	Title	Duration (days)	Total No. participants	No. Women participants	No. of CIAT/Network instructors	No. of NARS instructors
Oct. 17, 2003	The B biotype in the Cauca Valley	1	25	3	3	-
Nov 20-22, 2003		3	27	2	3	6
Dec 16, 2003	The B biotype in the Cauca Valley	1	25	nd	3	-
Jan 29, 2004	The B biotype in the Cauca Valley	1	110	nd	1	-
Apr 10, 2004	The B biotype in the Cauca Valley	1	35?	nd	1	-
May 5, 2004	Whiteflies and their control (field day)	1	76	~15	3	-
Jun 4, 2004	Pests of beans and their control	1	60	nd	1	-
Jul 27, 2004	Sampling methods for whiteflies	3	275	nd	2	-
Aug 5, 2004	The B biotype B in the Cauca Valley	1	197	nd	1	-

Workshop at CIAT Headquarters on “Common Bean and *Brachiaria* Improvement for Acids Soils”

This workshop was held at CIAT headquarters, Cali, Colombia during 25 to 26 February, 2004 to review and discuss research progress made by different partners participating in the special project funded by BNZ-GTZ, entitled “An integrated approach for genetic improvement of aluminum resistance of crops on low-fertility soils”.

Workshop at CIAT Headquarters to review results of Rhizobium-bean symbiosis project

A second Workshop with the attention of nine participants from Cuba, México, Belgium and Colombia was held at CIAT Headquarters, Cali Colombia during November 14-17, 2003 to review the results of the project “Integration of biofertilisation in bean cultivation by optimizing the use of the *Rhizobium*-bean symbiosis”. In this workshop a review was made to the research advances in the relation plant-Rhizobium not only for field trials but also for lab trials.

5.1.2 Degree and non-degree training in Africa

Rationale: New knowledge and tools can facilitate and improve efficiency and effectiveness of our partners. For example, molecular tools can facilitate more precise and rapid identification of genotypes carrying certain desirable genes and the characterization of pathogens and their variation. The use of the PPB approach has been credited for its consideration of the user perspective and orientation and the reduction of the period it takes to breed a variety by almost half in some cases. A start has been made in training within the networks, but many national program partners have yet to acquire such skills and apply these new tools and approaches. Some of the PABRA countries hardly have functional multi-disciplinary teams in place. For example many of the SABRN countries have only one scientist working on all aspects of beans and sometimes, including other legumes. Many of those available are young scientists with only a BSc. degree. Thus there is need for higher-level training in the region, as well as to groom others to take up more responsibilities of network activities from CIAT.

The SABRN network through its Pan African Bean Research Alliance (PABRA) continued to provide support for students who are training at Ms. degree level. CIAT-SABRN is also supervising thesis research for students sponsored by Rockefeller Foundation, and sponsored by Bean-Cowpea CRSP

PhD candidates:

- Geoffrey Tusiime PhD, Makerere University, has completed a degree and thesis titled “Variation and detection of *fusarium solani* f. Sp. *phaseoli* and quantification of soil inoculum in common bean fields”.
- Julius Mukalazi, PhD, Makerere University, has completed a degree and thesis titled “Pathogen variation and quantification of *Pythium* species in bean fields in Uganda”.
- Virginia Gichuru, PhD, Makerere University, continues study on “Characterization and pathogenicity of *Pythium* isolates on crops, which are intercrops of beans in South Western Uganda”
- Otsyula Reuben PhD, Makerere continues study on “Study of inheritance and development of root rot (*Pythium*) resistant varieties using marker assisted selection in common beans”.
- Claire Mukankuzi PhD, University of Kwa Zulu-Natal continues study on “Breeding beans (*Phaseolus vulgaris*) for resistance to Fusarium root rot (*Fusarium solani* f.sp *phaseoli*) and large seed size in Uganda”.
- Geoffrey Kananji, PhD, University of Natal, South Africa continues study on “Improvement of dry bean resistance to bruchid in Malawi”.

MSc candidates:

- Kennedy Muimui, MSc, University of Nairobi, Kenya, has completed a degree and thesis titled Inheritance of resistance to common bacteria blight and selection for multiple resistance to rust and angular leaf spot in yellow and navy bean genotypes.

- Annet Namayanja, MSc, Makerere University, has completed a degree and thesis titled “Inheritance and marker assisted selection for angular leaf spot (*Phaeoisariopsis griseola*) resistance in common bean”.
- Lianda Mauyo, MSc, Moi University, has completed a degree and thesis titled “Cross-border bean marketing patterns in the border districts of Kenya and Uganda”.
- Walter Ocimati MSc, Makerere University continues study on “Effects of management options for Pythium root rots on selected crops grown in association with beans in southwest Uganda”.
- Simon Bereng, MSc, University of Free State, South Africa continues study on “Screening bean germplasm for low P tolerance under acidic soils with and without lime application in Lesotho”.
- Barthlomew Y. E. Chatayika, MSc, University of Malawi (Bunda College of Agriculture) continues study on “Mode of inheritance for angular leafspot and common bacterial blight resistance in common bean”.
- Mathias Zulu, MSc, University of Zambia continues study on “Pathogenicity identification, severity and distribution of anthracnose (*Colletotrichum lindemuthianum*) of common bean (*Phaseolus vulgaris*) in northern, luapula and northwestern provinces of Zambia”.
- Augustine Musoni, MSc, University of Nairobi continues study on “Inheritance of fusarium wilt (*F. oxysporum f.sp. phaseoli*) and selection for multiple disease resistant and marketable climbing bean varieties”.
- David R. Macharia, MSc, University of Nairobi continues study on “Transfer of angular leaf spot, anthracnose and tolerance to low soil fertility in red mottled and red kidney beans”.
- Lunjalu, J.O., MSc, University of Nairobi continues study on “Effects of cooking on nutritional value of high iron and zinc beans”.
- Mark Korir, MSc, Moi University continues study on “Bean marketing along the Tanzania-Kenya border”.
- Kibyego, Michael, MSc, Moi University continues study on “Bean marketing in Nairobi and its environs”.
- Ngongo Mulangwa from INERA started his degree training program for the ‘Diplôme d’Etudes Approfondies’ or MSc at the Institut des Sciences Agronomiques, Yangambi, DR Congo.
- Sophia Komba, MSc, continues study on “Socio-economic benefits and impact of IPDM technologies to farming communities in Hai district, northern Tanzania”.
- Frida Bengtsson and Jennifer Joy West, MSc, Agricultural University of Norway, continue study on “Seed Relief, HIV/AIDs and Agro-Biodiversity; a case study from MBere District, Kenya”.

Courses and workshops:

Date	Title	Duration (days)	Total No. participants	No. Women participants	No. of CIAT/ECABREN instructors	No. of NARS instructors
Oct 25, 2003	Training on Partnerships in the aspect of seed production for researchers, Arusha, Tanzania	1	9	3	1	0
Dec 8-12, 2003	Meeting with stakeholders at Mpigi, Wakiso, Masindi and Apac (Uganda)	4	70	18	1	2
Mar 2-3, 2004	Bridging the gap between relief and development: Best practices in seed stress situations	2	40		1	
Mar 8-12, 2004	Seed Aid and Germplasm Restoration in Disaster Situations: Synthesis of Lessons: launch meeting	2	11	1	1	
Mar 18-19, 2004	Workshop on decentralized seed systems in East Zambia	2	30	5	2	2
Apr 13-17, 2004	Regional planning and steering committee meetings, Nairobi, Kenya	6	38	10	1	2
Apr 18-24, 2004	Participatory Plant Breeding: Country-specific Workplan Formulation and Basic Skill-building	5	22	3	3	
Apr 26-30, 2004	Community based seed production of improved open pollinated varieties in Arusha Tanzania in collaboration with ICRISAT, CIMMYT, IITA and SADC Seed Security Network	4	30	-	2	5
May 6-7, 2004	Participatory Monitoring & Evaluation skills, Arusha, Tanzania	2	28	9	2	0
May 13-14, 2004	Climbing bean project Stakeholders meeting in NZ, Moshi, Tanzania	2	37	14	1	3
May 26-27, 2004	Training/Demonstration for stakeholders on bean recipes, Tengeru, Tanzania	2	21	11	0	3
May 28-30, 2004	National workshop for Kenya Bean Research Team	3	20	5	2	7
Jun 1-2, 2004	Seed production, distribution & marketing to SARI bean Programme and its stakeholders, Arusha, TZ	2	19	6	0	4
Jun 9 – 10, 2004	Bean Seed Dissemination Workshop	2	28	0		
Jun 9-10, 2004	Ethiopian workshop for Stakeholders in Bean Research Development	2	30	0	1	4

Courses and workshops:

Date	Title	Duration (days)	Total No. participants	No. Women participants	No. of CIAT/ECABREN instructors	No. of NARS instructors
Jun 15-16, 2004	Workshop on decentralized seed systems for CARITAS Rwanda projects	2	26	6	1	3
Jun 21-26, 2004	Proposal writing retreat, Arusha, Tanzania	6	10	2	0	0
Jun 27-Jul 2, 2004	Seed Aid and Germplasm Restoration in Disaster Situations: Synthesis of Lessons: case analysis	5	18	2	1	
Aug 16-17, 2004	Review workshop on decentralized seed systems in northern Tanzania	2	28	5	1	2
Sep 10, 2004	Climbing bean project- Stakeholders meeting in western zone, Bukoba, Tanzania	1	32	6	0	2
Sep 27-29, 2004	Community based seed production of improved open pollinated varieties in Maputo –Mozambique in collaboration with ICRISAT, CIMMYT, IITA and SADC Seed security network	3	25	6	2	5
Sep 27-30, 2004	ECABREN Regional variety selection & proposal development meeting in Nairobi	3	11	2	0	0
Oct 5, 2004	Workshop on decentralized seed systems for Swaziland sector seed stakeholders	1	24	5	2	2
Oct 7, 2004	Workshop on decentralized seed systems for Lesotho seed sector stakeholders	1	8	3	2	2

5.1.3 Trips and attendance of Headquarters staff at meetings

The Bean Project Manager made the following trips:

- September-October, 2003, Nairobi. Biofortification Organizational Workshop.
- September-October, 2003, Berne, Switzerland and UK. Visit to donors.
- April, 2004, El Salvador. Annual meeting of PCCMCA.

The Mesoamerican bean breeder visited the following countries:

- October, 2003, USA. BIC Biennial meeting in California
- November, 2003, Nicaragua. Attend workshop on participatory breeding for drought tolerance.
- January, 2004, Nicaragua. Revise harvest of drought trials and plan follow up.

- March, 2004, South Africa, Zimbabwe, Malawi, Mozambique. Plant breeder's conference in South Africa and field tour of SABRN.
- May, 2004, Rome. Planning workshop for End User project of HarvestPlus.
- May, 2004, Kenya. Discussions on planning of bean bioefficacy trial.
- August, 2004, Nicaragua. Field visit to review progress on drought project and consultation on INTA-CIAT collaboration.
- October, 2004, UK and Denmark. Workshop on *in vitro* methods for estimating bioavailability of minerals in humans.

The Andean breeder/germplasm specialist visited the following countries:

- January 8-15, 2004, San Diego, California, USA. Plant & Animal Genome Conference – co-organized Generation Challenge Program markers meeting.
- January 29-31, Medellin, Colombia. Visit to field experiments and plan for collaborative activities with CORPOICA.
- March 14-18, 2004, Durban, South Africa. South African Plant Breeding Association Meeting –presented a poster on marker assisted selection and met with colleagues from Eastern and Southern Africa regions.
- March 19-31, Malawi, Mozambique, South Africa, Zimbabwe. Coordination on breeding objectives in the region and evaluation of nurseries.
- April 24-29, 2004, Universidad Autónoma de México, Cuernavaca, Mexico. Seminar presentation and coordination with UNAM team on generation of EST sequences for common bean.
- June 8-10, 2004, Sacramento and University of California – Davis, California, USA. USAID-Linkage program conference and coordination with bean research colleagues at UC-Davis.
- June 12-18, 2004, University of Geneva, Geneva, Switzerland. Presented paper at the Phaseomics III conference and met with colleagues to discuss progress on TILLING / mutagenesis.
- June 20-25, 2004, Instituto Agronomico del Mediterraneo, Zaragoza, Spain. Attend the Genotyping Workshop of the Generation Challenge Program.
- July 1-5, 2004, Bolivia. Attend “Congreso Nacional de Productores de Frejol,” coordinate with PRONALAG and present Biofortification activities to Bolivian bean producers organization.
- September 12-17, 2004, EMBRAPA–Centro Nacional de Pesquisa Arroz e Feijão, Brazil. Coordination with plant breeding and genetics units, presenting two seminars on the Generation and Harvest Plus challenge programs.
- September 21-24, 2004, University of Queensland Brisbane, Australia. Attend Generation Challenge Program annual meeting.

The bean entomologist:

- November, 2003, Texcoco, Mexico. Evaluate Apion nurseries.
- March, 2004, Chota, Ecuador. Visit whitefly management trials.
- May, 2004, Beijing, China. Attend International Plant Protection Congress.

The bean virologist:

- February 2004, El Salvador and Yucatan, Mexico. Tropical Whitefly Project.

The plant nutritionist:

- January 5-9, 2004, Okayama University, Kurashiki, Japan. International Symposium on Frontier Research to Improve Crop productivity on Acid Soils
- January 9-17, 2004, JIRCAS, Tsukuba, Japan. To review the on-going collaborative research on nitrification inhibition in *Brachiaria humidicola*.
- February 1-4, 2004, University of Hannover, Hannover, Germany. To review progress in aluminum resistance research supported by BMZ-GTZ.
- March 16-18, 2004, CATIE, Turrialba, Costa Rica. International Workshop on “Adaptation to Climate Change, Sustainable Livelihoods and Biological Diversity”
- April 18-21, 2004, San Salvador, El Salvador. PCCMCA (Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos y Animales).
- 31 July-5 August, 2004, Sendai, Japan. International Symposium on Plant-Soil Interactions at Low pH (PSILPH).
- August 6-8, 2004, Okayama University, Kurashiki, Japan. International Symposium on Al Stress Research in Plants: Present Status and New Directions for Future.
- July 5-9, 2004, Agropolis, Montpellier, France. Generation Challenge Program Workshop on Phenotyping and Water Deficit.

The bean pathologist:

- July 11-16, 2004, Kampala, Uganda. Discussion on the workplan to implement molecular techniques for detection of *Pythium* species that cause bean root rots.

Meetings and Workshops:

The bean project manager:

- Annual meeting of PCCMCA. El Salvador
- Biofortification Workshop in Nairobi
- Planning workshop for End User project of HarvestPlus in Rome
- Workshop on *in vitro* methods for estimating bioavailability on minerals in humans in UK and Denmark

The Mesoamerican bean breeder visited the following countries:

- BIC Biennial meeting in California, USA
- Workshop on participatory breeding for drought tolerance in Nicaragua
- Plant breeder’s conference in South Africa
- Discussions on planning of bean bioefficacy trial in Kenya

The bean entomologist:

- International Plant Protection Congress. Beijing, China.

The plant nutritionist:

- International Symposium on Frontier Research to Improve Crop productivity on Acid Soils held at Research Institute for Bioresources, Okayama University, Kurashiki, Japan.
- 6th International Symposium on *Plant-Soil Interactions at Low pH* (PSILPH) held from 31 July to 5 August, 2004 by the Japanese Society of Soil Science and Plant Nutrition, Sendai, Japan.
- International Symposium on “Al Stress Research in Plants: Present Status and New Directions for Future”. Satellite Symposium of the 6th PSILPH in Sendai. Research Institute for Bioresources, Okayama University, Kurashiki, Okayama, Japan. 7 August, 2004.
- Generation Challenge Program Workshop on Phenotyping and Water Deficit held at Agropolis, Montpellier, France (5-9 July, 2004).
- International Workshop on Adaptation to Climate Change, Sustainable Livelihoods and Biological Diversity” held at Turrialba, Costa Rica. March 16-18, 2004.

The Pathologist Research Assistant:

- Workshop to train technicians (65) on the agronomic management of snap and dry beans and integrated disease management, held in Ibagué, Tolima, Colombia. June 4, 2004.
- Workshop to train technicians (110) on the agronomic management of snap and dry beans and integrated disease management, held in Bogotá, Colombia. June 24-25, 2004.
- Workshop to train technicians (110) on the agronomic management of snap and dry beans and integrated disease management, held in Pitalito, Huila, Colombia. July 30, 2004.

Awards

- The "Hernan Alcaraz Viecco 2004" award was given to Isaura Rodríguez, Héctor Morales, Juan M. Bueno and César Cardona, for the best paper presented during the XXXI Congress of the Entomological Society of Colombia, SOCOLEN in Bogota, CO., entitled “El biotipo B de *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) adquiere mayor importancia en el Valle del Cauca”
- S. Beebe received the Meritorious Service Award from the Bean Improvement Cooperative at its annual meeting in Sacramento, California, October 2003.

5.1.4 Trips and attendance of African staff at meetings

The Plant Pathologist/PABRA Coordinator made the following trips:

- October 17 – 21, 2003, Ethiopia. Join the SDC-PABRA representative in visiting PABRA partners, and visit bean program activities.
- October 25- 29, 2003, Malawi. Attend SABRN steering committee.
- October 30 –Nov 2, 2003, Zambia. Visit thesis research of Mathias Zulu in Lusaka
- November 8-12, 2003, Rwanda. ISAR planning meeting to develop research projects to support IPM and biotechnology activities.
- January 14-17, 2004, Rwanda. Planning meeting with ISAR.
- January 26–30, 2004, Nairobi, Kenya. Attend a stakeholders meeting on Bioscience facility.

- February 23-25, 2004, Embu, Kenya. Attend Annual Meeting on Conservation and sustainable management of below ground biodiversity.
- April 13-17, 2004, Nairobi, Kenya. Attend ECABREN Steering Committee.
- April 20 – 24, 2004, Kakamega, Kenya. Attend a PPB a skill building training workshop.
- May 4 – 7, 2004, Rome, Italy. Attend end-user meeting of Harvest plus.
- May 10 – 13, 2004, Pretoria, S. Africa. Participate development of a proposal under the challenge program on agriculture and health led by SIMA-IWMI.
- May 19 – 21, 2004, Bilene, Mozambique. Attend PABRA Steering Committee.
- May 31- June 2, 2004, Jinja, Uganda. Participate in CIAT Africa staff meeting.
- June 2-4, 2004, Nairobi, Kenya. Support national partners in developing a proposal for support under ASARECA Competitive Grant System on biotechnology.
- July 5 – 9, 2004, Addis, Ethiopia. To participate in a workshop to build capacity in biotechnology.
- September 21, 2004, Nairobi, Kenya. Join the DG of CIAT in a meeting with the Rockefeller Foundation.
- September 24, 2004, Nairobi, Kenya. Join the DG of CIAT in a meeting with the University of Nairobi.
- September 26 – 29, 2004, Nairobi, Kenya. Support and participate in the development of three CNs by ECABREN members for the ASARECA Competitive Grant System.
- October 10 – 13, 2004, Rwanda. Technical backstop visit to ISAR Bean program.
- October 14-15, 2004, Nairobi, Kenya. Participate with CIAT-TSBF to develop a full proposal for submission to Belgium.

The East African breeder maintained the following travel schedule:

- January 12-15, 2004, Kampala, Uganda. Visit NAARI bean program and develop work plans.
- January 15-17, 2004, Rubona, Rwanda. Developing work plans for ISAR and INERA bean programs and visit HarvestPlus material and meeting with ATDT manager.
- February 12-15, 2004, Kakamega, Kenya. Planning meeting with KARI-Kakamega.
- February 22-28, 2004, Cali, Colombia. To attend acid soils Workshop.
- March 15-21, 2004, South Africa. Present a paper at breeders meeting in Durban and visit ARC bean program.
- March 21-25 October 14-15, 2004, Nairobi, Kenya. Participate with CIAT-TSBF to develop a full proposal for submission to Belgium., 2004, Harare, Zimbabwe. Visit bean program in Zimbabwe.
- March 25-30, 2004, Lilongwe, Malawi. Visit bean program in Malawi and Mozambique.
- April 12-17, 2004, Nairobi, Kenya. Regional Steering Committee meeting for ECABREN.
- April 17-25, 2004, Kakamega, Kenya. PABRA PPB training workshop.
- May 10-13, 2004, Kakamega, Kenya. Adoption study seminar and visit trial sites.
- May 26-30, 2004, Nakuru, Kenya. National bean meeting.
- June 22-27, 2004, Arusha, Tanzania. Visti SARI bean program and ECABREN proposal writing.
- July 14-21, 2004, Kinshasa, Mvuazi, DR Congo. Visit INERA bean program in Western DR Congo.

- July 27-28, 2004, Arusha, Tanzania. Developing ECABREN work plans.
- July 29 -August 1, 2004, ISAR, Rwanda. Student supervision and meeting with ATDT/ISAR manager.
- August 12 -September 19, 2004, Cali, Colombia. Marker assisted breeding training.
- September 26 -October 2, 2004, Nairobi, Kenya. Regional Variety selection and development of concept notes.
- October 14-15, 2004, ILRI, Nairobi, Kenya. TSBF proposal writing.
- October 17-25, 2004, Melkassa, Awassa and Alemaya, Ethiopia. Visit Ethiopian bean programs.

The SABRN coordinator/Breeder made the following trips:

- February 16-21, 2004, Lesotho, South Africa. Supervise Ms. Student thesis research.
- February 22-29, 2004, Maputo, Mozambique. Participate in Harmonizing seed Regulations.
- March 8-11, 2004, Nairobi, Kenya. Participate in the Relief Seed Strategy meeting.
- March 14-21, 2004, Durban, South Africa. Participate in the Southern Africa Plant Breeders Association.
- March 21-25, 2004, Harare, Zimbabwe. Provide breeding support to Zimbabwe national program.
- April 25-29, 2004, Arusha, Tanzania. Attend CIAT, CIMMYT, ICRISAT, IITA and SSSN joint workshop on seed multiplication of OPV and self-pollinated crops.
- May 18-21, 2004, Bilene, Mozambique to attend PABRA Steering Committee Meeting.
- June 21-26, 2004, Maputo, Mozambique to provide support to Mozambique NARS together with the ERI team.
- July 6-9, 2004, Maseru, Lesotho. Follow up on progress for MSc. Student research.
- July 11-17, 2004, Chokwe, Mozambique to conduct a participatory variety selection with farmers.
- July 20-24, 2004, Northern Mozambique. Explore potential bean production environments in the northern part of the country with Mozambican scientists, and establish contacts with possible partners and collaborators in participatory research and seed production.
- August 16-18, 2004, Dedza, Malawi. Organize bean IPM farmers to start bean seed multiplication.
- August 15-September 15, 2004, Cali, Colombia. Visit CIAT headquarters to sharpen skills in use of molecular tools in plant breeding.
- September 26-29, 2004, Maputo, Mozambique. Attend CIAT, CIMMYT, ICRISAT, IITA and SSSN joint workshop on seed multiplication of OPV and self-pollinated crops.

The ECABREN coordinator made the following trips:

- November 3, 2003, HAI district, Tanzani. Visit R4D activities with CIAT DG.
- November 14, 2003, Katumani, Kenya. Meeting with KARI staff on strengthening coordination of national bean program.
- February 11-14, 2004, Bukavu, DR Congo. Discuss wider impact strategy with INERA scientists and development partners

- February 16-18, 2004, Kampala, Uganda. Visit CIAT Africa and attend NARI Planning meeting for Participatory M&E of Bean Research & Development in Uganda.
- February 22-24, 2004, Rwanda. Discuss bean research for development activities with ISAR scientists.
- February 24-27, 2004, Bujumbura, Burundi. Meet and discuss bean research and development activities with ISABU partners.
- March 23, 2004, Hai district, Tanzania. Visit IDPM Project sites with DFID Crop Protection Programme (CPP) Managers.
- March 24-April 4, 2004, Embu, Kenya. Attend P M&E training course.
- August 9-13, 2004, Lushoto/Hai/Arumeru districts of Northern Tanzania. Monitoring & Evaluation of Farm Africa/ECABREN - Climbing bean project.
- August 25-30, 2004, Ethiopia. Monitoring and orientation of ECABREN projects & activities at Melkasa and Awasa Research centers.

The Monitoring and Evaluation expert made the following trips:

- February 16, 2004, Namulonge, National Agricultural Research Center-Kampala, Uganda. Launching Participatory Monitoring & Evaluation in National Research and Development Institutions.
- March 15-16, 2004, Namulonge, National Agricultural Research Center-Kampala, Uganda. Working sessions with project officers on PM&E.
- March 24, 2004, Embu, Kenya. Workshop on Strengthening Participatory Monitoring and Evaluation in R&D Institutions.
- April 12, 2004, Nairobi, Kenya. Launching PM&E in ECABREN, ECABREN Steering Committee
- April 6, 2004, Namulonge, National Agricultural Research Center-Kampala, Uganda. Strategic meeting for PM&E in bean research projects.
- May 6, 2004, Arusha, Tanzania. Launching PM&E for R&D in Selian Agricultural Research Institute.
- September 21, 2004, Namulonge, National Agricultural Research Center-Kampala, Uganda. Meeting with National Bean Program Coordinator to develop work plan for PM&E in bean Program.

The Africa & Agrobiodiversity Program Senior Scientist made the following trips:

- March 1-3, 2004, Oslo, Norway. Noragric-USAID/Care Norway-funded Seed Security/Seed Aid project: presentation of project results and awareness raising among Nordic donors
- March 9-12, 2004, Nairobi, Kenya (Catholic Relief Service Offices). IDRC-funded Seed Aid and Germplasm Restoration Project: Launch meeting.
- April 18-24, 2004, Kakamega, Kenya (Kenya Agricultural Research Institute). Participatory Plant Breeding Training Course: East, Central and Southern Africa Regions
- May 31-June 2, 2004, Kampala Uganda. CIAT/Africa Staff Meeting.
- June 27-July 2, 2004, Nairobi, Kenya. IDRC-funded Seed Aid and Germplasm Restoration Project: Restoration: 25 case analysis.
- July 25-28, 2004, Ottawa, Canada, Commission on Biological Diversity. Consultation with CBD on Seed Aid and Seed Security- for vulnerable farmers.

- September 13-17, 2004, Kampala, Uganda. HarvestPlus: Reaching Enduser Coordinator Interviews.

Meetings and Workshops:

The SABRN coordinator/Breeder:

- March 8-11, 2004, Nairobi, Kenya. The Relief Seed Strategy meeting
- April 25-29, 2004, Arusha, Tanzania. CIAT, CIMMYT, ICRISAT, IITA and SSSN joint workshop on seed multiplication of OPV and self-pollinated crops.
- May 18-21, 2004, Bilene, Mozambique. PABRA Steering Committee Meeting.
- September 26-29, 2004, Maputo, Mozambique. CIAT, CIMMYT, ICRISAT, IITA and SSSN joint workshop on seed multiplication of OPV and self-pollinated crops.

The ECABREN coordinator:

- October 6-15, 2003, Nairobi, Kenya. Course on Project planning and EDF procedures organized by MDF in cooperation with ASARECA
- October 16-18, 2003, Nairobi, Kenya. 27th ASARECA Committee of Directors' meeting
- April 13-17, 2004, Nairobi, Kenya. ECABREN Regional Planning & Steering Committee meetings
- April 21 -22, 2004, Entebbe, Uganda. ASARECA/REDSO Financial Management Training workshop
- May 6-7, 2004, Arusha, Tanzania. Training workshop on Participatory M&E systems
- May 19-22, 2004, Bilene, Mozambique. PABRA Annual Steering Committee Meeting
- May 24-27, 2004, Nairobi, Kenya. ASARECA-Competitive Grant System Pre-Inception Planning Workshop
- May 31-June 2, 2004, Njinja, Uganda. CIAT Africa Staff Retreat
- June 21-26, 2004, Arusha, Tanzania. ECABREN Proposals Development Retreat
- July 5-9, 2004, Nairobi, Kenya. ASARECA-CGS Inception Call Planning and Writing Workshop
- September 7-10, 2004, Entebbe, Uganda. REDSO-CGS Meeting and Call Writing
- September 25-26, 2004, Nairobi, Kenya. ERI-PRIAM meeting for CN development
- September 27 – 30, 2004, Nairobi, Kenya. ECABREN Variety Selection and Planning Meeting

The Africa & Agrobiodiversity Program Senior Scientist:

- March 2-3, 2004. Bridging the gap between relief and development: Best practices in seed stress situations.
- March 8-12, 2004. Seed aid and germplasm restoration in disaster situations: Synthesis of lessons: launch meeting.
- April 18-24, 2004. Participatory Plant Breeding: Country-specific workplan formulation and basic skill-building.
- June 27-July 2, 2004. Seed aid and germplasm Restoration in disaster situations: Synthesis of lessons: case analysis.
- May 5-7, 2004. Reaching EndUsers in HarvestPlus: Coordination and workplan meeting.

Conclusions: Many of the national program partners, especially in SABRN, are young scientists with only BSc. Degree, and the network is trying hard to provide them with higher-level training. All of them have made good progress on their thesis research, and one has submitted it for review. Further progress has been made in collaboration on seed issues with other networks run by other future harvest centers (CIMMYT, ICRISAT, and IITA) in the SADC region to sensitize stakeholders in Mozambique and Tanzania. In addition the future harvest centers in the SADC region together with the SSSN have finalized the seed regulations in the region to facilitate regional movement of seed.

5.1.5 Participatory Plant Breeding in Africa

Participatory Plant Breeding (PPB) continues to be an effective vehicle for developing and screening new varieties with farmers. NARSs in the southern and east/central African networks, have institutionalized the approach within their regional logframes and two sites in particular, Southern Ethiopia and Rwanda, use PPB as their routine approach to variety development. One particular milestone this year bears mention, the first Africa-wide compilation of PPB and Participatory Plant Genetic Resource Enhancement (PPGRE) experiences.

These proceedings emerged from an Africa-wide symposium on Participatory Plant Breeding (PPB) and Participatory Plant Genetic Resource Enhancement (PPGRE) held in Ivory Coast, May 2001. It brought together work from 19 countries, covering 13 crops, (Table 131), and, despite the relative newness of the work, embraced an impressive range of different experimental approaches.

Table 131. Africa-Wide PPB/PPGRE Proceedings

Geographic focus	Crop focus
Benin	Pearl millet
Democratic Republic of Congo	Barley
Eritrea	Bean (<i>Phaseolus vulgaris</i>)
Ethiopia	Maize
The Gambia	Rice (upland and irrigated)
Ghana	Sweet potato
Ivory Coast	Banana
Kenya	Sorghum
Malawi	Cowpea
Mali	Cassava
Morocco	Yam
Mozambique	Indigenous vegetables
Niger	Cotton
Senegal	
Sierra Leone	
Tanzania	
Tunisia	
Uganda	
Zimbabwe	
Total 19	13 crops

The proceedings were published bilingually during 2004 (English/French) and represent a close collaboration between CIAT/PRGA and CIRAD (Montpellier).. They have several unique features

- **Linking of PPB and PGR themes**

PPB work in Africa has mainly focused on the goal of moving new varieties and at improving production gains. However, particularly in African subsistence context, encouraging a greater diversity of intra-species variety use could potentially render increased stability in the heterogeneous and marginal production systems.

On-farm plant genetic resource work in Africa, for its part, continues to be filtered through a “conservation” or, at best, a “conservation and use” lens. Relatively few initiatives to date emphasize dynamic varietal diversity enhancement (adding value to local materials or broadening the scope of local material use) or specifically program support for dynamic farmer-based processes—such as support for farmer plant breeding or evolutionary seed management practices.

The proceedings include a small but growing number of programs that suggest how the PGR and PPB goals can be practically united—on the ground.

- **Bringing farmer breeders and farmer collaborators directly into the debate**

The proceedings include reports directly from farmers and farmer-breeders. One set of reports, drawn from those who normally collaborate in PPB projects, give farmer assessments of “what it means to work together with research institutes in plant breeding work”. The other type of farmer report, from a Benin yam farmer, describes the technical nuances and processes of his own yam domestication. This process has been little documented although such domestication is critical for advancing yam evolution in West African region.

- **Broadening theme discussion beyond breeding *per se*—to ancillary services concerns**

To be effective, and to achieve institutionalization, PPB has to draw beyond insights and methods of breeding *per se* and address key “ancillary concerns”. Two of these more prominent concerns, Intellectual Property Rights (IPRs) and Seed Production for PPB are reported within this synthetic volume.

The IPR issues as well as more general access and benefit sharing are becoming increasingly important in PPB work in the African region (and have been integrated as elements in CIAT’s PPB training work). Ethiopia is just about to release several PPB-generated varieties— with the variety release committee officially recognizing that “the varieties were uniquely developed through participatory approaches.”

5.1.6 Tanzanian farmers' perspectives on participatory breeding: selecting new bean varieties tolerant to bean stem maggot and angular leaf spot

Rationale: Most case studies in participatory plant breeding have reported on involvement of farmers in selection from fixed or nearly fixed lines (Weltzien, et al, 2003). This is also true of beans (Mbikayi and Bakunzi, 2004; Kapapa, 2004; Dauro et al, 2004). This approach has been referred to as participatory variety selection (PVS). Ceccareli et al (2000) suggested participatory plant breeding *per se* should refer to involvement of farmers when the amount of genetic variation is at its maximum, normally at F₂ generation. Consequently, little is known about the ability of farmers to recognize and select within a variable population. Dauro et al (2004) noted that although farmers were keen to participate in evaluation and selection, they had difficulty rejecting inferior lines and tended to select a larger number of lines than they could possibly evaluate in their home plots. In Alemaya, Ethiopia, after participating in a breeding trial for three years, farmers decided the number of lines they could accommodate in future participatory bean breeding trials for effective selection was 6 to 8 lines for women farmers with small plots, and 10-15 lines for resource rich farmers with larger plots and resources to hire additional labor (CIAT, 2002). The regional bean program has been integrating participatory selection in its formal-led breeding activities to facilitate both formal release of new varieties and rapid access of new varieties through informal seed production. In this report, we highlight selection of new bean varieties tolerant to bean stem maggot and angular leaf spot from segregating populations in northern Tanzania.

Materials and Methods: This study was conducted to determine the ability of farmers to recognize and select within a variable population at Selian Agricultural Research Institute (SARI), near Arusha, Tanzania (Ngulu et al, 2004; CIAT 2002). Farmers selected from six populations segregating for resistance to bean stem maggot (BSM) and nine segregating for angular leaf spot (ALS). The BSM populations were generated from crosses among seven contrasting parental lines (G3844, ZPV 292, EMP 81, G2005, Lyamungu 85, Canadian Wonder and Dore de Kirundo). The ALS populations originated from crosses among seven parents (UBR (92)25, LB2878, ZAA84044, LB 842-1, LB2465, 2702/2 and A409). Hybridization and advancement of the segregating populations to F₄ was conducted at the station, mainly to increase seed. Both BSM and ALS populations were also segregating for seed color and size, growth habit and other agronomic characters. Farmers and breeders made single plant selections and used them to establish progeny rows in their plots. Farmers finally selected and named bean lines that performed well in their fields. The 15 participating farmers were divided into user groups based on their preferences (Table 132)

Table 132. Socio-economic characteristics and variety preferences of user groups participating in bean selection at Selian, Arusha, Tanzania.

User group	Varietal preferences	Socio-economic characteristics
I. Subsistence small – scale bean farmers	Early maturing, fast cooking, low flatulence, tasty grain, keeps well over night, high yielding, small seeded, cream and red colored	Main farmer is a woman above 18 years of age, cultivates beans mainly for home consumption on < 1 acre of land, land preparation by oxen or hand hoe, belongs to the low middle and poor wealth categories
II. Semi-subsistence small – scale bean farmers	Tolerance to poor soils, resistance to storage pest, early maturity, possible to intercrop, brown and red color, resistance to shattering	Farmer may be a man or a woman above 18 years of age producing beans on household and/or personal plots for both subsistence and sale, cultivates beans on < 3 acre, land preparation by oxen or hand hoe, belongs to low middle and poor wealth categories
III. Market oriented farmers	High yielding, tasty grain, red and brown color, large seed types	Farmer is typically a man, rarely a woman who produces beans mainly for sale on 3-15 acres on average, land preparation by oxen or tractor, may use chemicals to control field pests, belongs to middle to high wealth categories

Results and Discussion: Results showed that market oriented farmers were disenchanted with the small quantities of seed of the segregating populations. They declined to plant and manage the populations in their fields. Only a few participated during selection. Yield, seed color and taste were important to all groups. Overall, yield and seed color accounted for 28% and 27% of the criteria used by farmer-selectors and farmer evaluators. Pod load, disease resistance, drought and seed size each accounted for 5% to 9%; the other 10 criteria accounted for less than 4% each. Cream seed was by far the most popular color (30% of selections) followed by pink, red kidney and brown-maroon. Small and medium seeded materials accounted for 82% of the selections. Marketability was important to the market oriented and semi-subsistence groups in the final evaluations. Thirty-two lines were selected from the BSM population and 13 from ALS population in 2001, after four years selection (Ngulu et al, 2002). Seed of these lines was increased and final evaluations conducted in 2002 and 2003 by all farmer groups including traders and urban consumers. Six BSM and three ALS lines were finally selected. The selections were mainly based on seed color and seed size. There was a tendency to select lines with characteristics similar to commercial/local varieties. Market oriented farmers tended to select fewer lines compared to subsistence/semi subsistence farmers. The farmer evaluators were very proud of their selections. They named the lines after the name of their village (Makiba) and used acronyms derived from farmer selectors' and researchers' names. The names of the nine lines were: Neema, Makiba, Heriipo, Siliwima, Hujuti, Ushindi, Kiimarisho, Tulizana and Hamadi. Characteristics of these lines are shown in Table 133. The nine lines were also entered into advanced yield testing to determine other potential areas to which they may be adapted and to generate additional data required for formal release. At the same time, farmers started multiplication and informal seed dissemination for the nine new varieties.

Table 133. Names and characteristics of nine bean lines selected by farmers from segregating populations in Selian, Arusha, Tanzania.

Line name	Source population	Reasons why it was selected by farmers
Heriipo	ZPV292 x Lyamungu 85	High yielding, early maturing, resistant to bean stem maggot, good taste, large seeds and red mottled grain
Kiilarisho	ZPV292 x Lyamungu 85	Early maturing, high yielding, large purple seeds, good taste and resistant to bean stem maggot.
Siliwima	ZPV 292 x Lyamungu 85	High yielding, early maturity, resistant to bean stem maggot, good taste, large purple seeds.
Tulizana	ZPV292 x Lyamungu 85	Early maturing, high yields, resistant to bean stem maggot, large purple seeds and good taste.
Hamad	ZPV202 x Lyamungu 85	Early maturing, high yields, resistant to bean stem maggot and red mottled (calima) grain type.
Makiba	UBR(92)25 x LB2465	High yielding, resistant to angular leaf spot, small seed size, climbing growth habit and cream-speckled (mulatinho).
Hujuti	ZPV 292 x Canadian Wonder	Early maturing, high yielding, resistant to bean stem maggot, large khaki seeds.
Ushindi	UBR{92}25 x LB2465	High yielding, resistant to angular leaf spot, small brown-maroon seeds, semi-climbing growth habit.
Neema	LB842 -1 x LB2878	Good yield, resistant to angular leaf spot, small red seeds and climbing growth habit.

Contributors: Paul Kimani, Festo Ngulu, S.O. Kweka and J. Musaki

Collaborators: SARI bean program

Progress towards achieving output milestones:

- Progress is underway with students training at Ms. Degree level.
- Further progress has been made in collaboration on seed issues with other networks run by other Future Harvest centers (CIMMYT, ICRISAT, and IITA) in the SADC region.
- Farmers participating in promotion of bean IPM activities, have greatly been empowered to demand other services from different stakeholders. Now they are adventuring into bean seed production as a business.
- Proceedings of a workshop to review participatory plant breeding across Africa was compiled: Participatory Plant Breeding and Participatory Plant Genetic Resource Enhancement: An Africa-wide Exchange of Experiences.

Activity 5.2 Collaborative projects developed and executed with NARS and regional networks

Highlights:

- The Swiss government extended its commitment to support the PABRA research network until 2007
- A system of competitive grants under the auspices of ASARECA is operational and CIAT is participating in project development
- A long term (6 year) project was approved by the Canadian government to improve Latin American crops for nutritional value, under CIAT's leadership
- The CIAT bean team is participating in two CGIAR Challenge Programs

5.2.1 Special projects developed in Africa

Title	Donor	Comments	Funding period	Total amount
Assisting disaster-affected and chronically-stressed communities in East and Central Africa: Focus on small farmer seed systems.	USAID		2002-2004	US\$ 305,000
Supporting improved nutrition, food security and community empowerment for poverty alleviation	CIDA	To support PABRA	2003-2008	US \$ 4,458,513
Seed aid and germplasm restoration in disaster situations: Synthesis of lessons learned and promotion of more effective practices	IDRC		2003-2005	US \$ 126,000
Climbing bean & agroforestry interventions	FARM-AFRICA MATF	Bilateral project	2004-2006	UK£59,997
East and Central Africa Bean Research Network	USAID/REDSO	Coordination , capacity building & backstopping funds	2004-2006	\$490,000

Special projects developed in Africa cont'd ...

Title	Donor	Comments	Funding period	Total amount
Supporting improved nutrition, food security and community empowerment for poverty alleviation	SDC	To support PABRA. Proposal approved and funds available as of October	2004-2007	US \$2,000,000
Application of marker assisted selection (MAS) for the improvement of bean common mosaic necrotic virus resistance in common bean (<i>Phaseolus vulgaris</i>)	USAID/ through ASARECA Competitive Grant System	For support of NARS in Kenya, Uganda and Rwanda. MAS to be conducted at Kawanda lab. Proposal selected.	2004-2007	US \$ 150,000
Increasing food security and rural incomes in Eastern, Central and Southern Africa through genetic improvement of bush and climbing beans	RF	Approved to commence in 2005	2005-2008	US \$ 300,000
Bean root rot disease management in Uganda	DFID	Bilateral project with Uganda. Under review for one year extension	2005-2006	UK £ 70,443
Promotion of Integrated Pest Management (IPM) Strategies of Major Insect Pests and Diseases of <i>Phaseolus</i> Beans in Hillside Systems in Eastern, Central and Southern Africa	DFID	Under review for one year extension for partners (Tanzania, Kenya, Uganda, Rwanda, Malawi) and CIAT	2005-2006	UK £ 81,550

5.2.1.1 Regional research subprojects under SABRN

The SABRN activities are financed through PABRA, with funding from CIDA-Canada, SDC-Swiss and DFID (UK). Table 134 shows the list of sub-project activities that were carried out by NARS partners in 2003-04, in their contribution to the PABRA framework.

Table 134. Contribution of NARS partners within SABRN to selected PABRA research and development outputs.

Output	Activity	Country	Budget \$
1.1	Five improved bean varieties rich in micronutrients (Fe, Zn, or protein) and ten varieties tolerant to two or more major biotic and abiotic stresses		
	1.2.1 Continue to generate segregating bean populations for resistance to major diseases and tolerance to major pests and low soil fertility and moisture stresses (South Africa (ALS & CBB), Malawi (low soil fertility and BSM). South Africa for ALS and CBB.	South Africa	7,500
		Mozambique	800
		Zambia	800
		Swaziland	800
		Zimbabwe	800
		Tanzania	800
		D R Congo	800
		Lesotho	800
	1.4.1. Continue to support NARS partners in breeding for specific market classes (Malawi, South Africa, Tanzania, Zambia and Zimbabwe). Malawi includes ALS, CBB, BSM, aphids and low soil fertility.	Malawi	4,400
		Mozambique	2,000
		Zambia	2,000
		Zimbabwe	2,500
		South Africa	4,100
		Tanzania	3,000
1.2.	Ten new environmentally friendly options developed for managing soil productivity (fertility), and bean pests and diseases		
	2.1.1 (a). On-farm trials to verify with farmers and promote elite bean lines with multiple disease resistance	Tanzania	2,000
		D.R Congo	2,000
	2.1.1 (b). Use botanical insecticide on bean leaf beetle (<i>Ootheca</i>) using IPM approach	Tanzania	2,000
	2.1.1 (c). Test ISFM options with farmers in D R Congo, Malawi, Mozambique, Swaziland, S/H Tanzania, Zambia and Zimbabwe (7 Countries x \$2,000 each)	Malawi	2,000
		Mozambique	2,000
		Zambia	2,000
		Swaziland	2,000
		Zimbabwe	2,000
		Tanzania	2,000
		D R Congo	2,000
		Lesotho	2,000
1.3.	Increased access to 10 new and 50 existing technologies by at least 2 million households (1.5 million by year 4).		
	3.1.1. Dissemination of new bean varieties and improved production technologies through strategic alliances with NGOs in SABRN: Zimbabwe, D R Congo, Malawi, Lesotho, Swaziland, Tanzania and Zambia (7 Countries x \$3,000 each)	Malawi	1,000
		Mozambique	3,000
		Zambia	3,000
		Swaziland	3,000
		Zimbabwe	2,330
	3.1.3. Dissemination of new bean varieties and improved production technologies through strategic alliances with NGOs in SABRN	Tanzania	1,500
		D R Congo	3,000
		Lesotho	3,000

Table 134. cont'd

Output	Activity	Country	Budget \$
3.1	Increased knowledge and skills of scientists and staff from NARIs, NGOs and rural service providers to effectively address clients' needs		
	6.1.2. Produce articles for policy makers	Tanzania	1,000
	6.2.1. Support NARS to produce articles for policy makers in both networks (2 countries in each network)	Mozambique Zambia	500 500
	6.3.1. Enhance partnerships between NARIS and other stakeholders that support community interventions to institute farmer participatory research (PRIAM) activities three new sites within ECABREN (Tanzania, D R Congo and Madagascar), and Mozambique and Zambia in SABRN	Mozambique Zambia	1,500 1500
	6.4.1. Support NARS partners to conduct seminars and develop publications targeting development partners in 4 countries in each network (including participation in field days)	Malawi Mozambique Zambia Tanzania D R Congo Lesotho	1,000 1,000 1,000 1,000 1,000 1,000
3.2:	Strengthened intra-and inter-network collaboration both within and outside of networks		
	8.1.1 Impact assessment of improved bean varieties that have been widely disseminated in Malawi	Malawi	20,000

5.2.1.2 Regional research for development activities for ECABREN

During the period from October 2003 to September 2004, the ECABREN supported research-for-development activities prioritized and ranked by the stakeholders during a priority setting exercise. Moreover, breeding programs on major bean market classes continued to be managed by the lead countries as in the past. The main R4D activities implemented by the network partners to achieve ECABREN objectives are shown in Table 135. In April 2004, the network reviewed the priority setting and defined three main bean products. The implementation of the new research agenda should start once proposals are funded, but certain activities should continue to be supported with other sources of funds.

Table 135. Activities implemented in ECABREN for year 2003-2004.

ECABREN Goal: Enhanced sustainable agricultural productivity, value added and competitiveness of bean sector for increasing food security and income of rural and urban poor in ECA

Strategic Objective: Demand driven bean-based technologies and innovations utilized

Research and Development Activities

- Select, test and disseminate marketable bean varieties of bush and climbing beans that improve food and health and address the region's local and export markets
 - Develop, select and disseminate drought tolerant varieties
 - Package and disseminate effective integrated management options for the major pests and diseases of marketable bean varieties.
 - Test and disseminate improved agronomic practices for the management of soil and water for increased and lower-cost production of marketable bean varieties
 - Refine and distribute post-harvest technologies, to add value and expand bean markets.
 - Work with multiple partners to improve the availability and accessibility of good quality seed of improved and preferred marketable bean varieties.
 - Work with partners to make promotional materials and information more widely available in member countries for increased use of bean based technologies
 - Strengthen human and physical capacity of partners to innovate and to undertake research and development activities in their institutions
-

Projects submitted

- Improving competitiveness of snap beans for domestic and export markets, CN submitted to ASARECA-CGS
- Improving snap bean competitiveness for domestic and export markets, CN submitted to ASARECA-CGS
- Enhanced utilization of nutrient rich beans for improved nutrition and income in ECA, Full proposal to ASARECA/USAID-REDSO sub-grant

Consultancies:

These consultancies seek to encourage implementing organizations to reflect on seed aid and seed security issues:

- Towards More Effective and Sustainable Seed Relief” Proceedings Donor: FAO. Total budget: US 3,600 over 2 months (August/Sept, 2004)
- Agro-biodiversity and Seed Relief: leaflet. Donor: GTZ. Total budget: US 1,500

5.2.2 Projects developed in Latin America

Special Collaborative projects at Headquarters

Title	Donor	Comments	Funding period	Total amount
Characterization of South American genotypes of bean for optimal use of light under abiotic stress	European Commission / Univ. of Chile	CIAT sub-contracted by U. Chile	2001-2004	831,261 euros
Integration of bio-fertilization in bean cultivation by optimizing the use of the Rhizobium-bean symbiosis	K.U. Leuven, Belgium		2001-2005	4,002,000 B. francs
Andean climbing bean improvement for the Andean Zone	IICA/BID/FONTAGRO		2002-2005	US 125,000
Mejoramiento de la nutrición humana en comunidades pobres de América Latina utilizando maíz (QPM) y frijol común biofortificados con micronutrientes	IICA/BID/FONTAGRO	Pending disbursement of funds	2004-2007	US 350,000
Increasing bean and maize agrobiodiversity as an approach for improving production systems, food security and nutrition in Nariño, Colombia	ECOFONDO/FIDAR, Colombia		2003-2006	US 8,823
Obtención de nuevas variedades de frijol común con atributos de rendimiento y potencial para nuevos mercados, utilizando selección convencional y asistida por marcadores moleculares	Universidad Nacional de Colombia		2004-2007	US 8,235
An integrated approach for genetic improvement of aluminum resistance of crops on low-fertility acid soils	GTZ, Germany		2001-2004	690,244 euros
Bean genomics for improved drought tolerance in Latin America	BMZ, Germany	Supports drought work in Nicaragua	2003-2006	US 740,000
Desarrollo de la producción y comercialización de leguminosas alimenticias en el Perú	Instituto Peruano de Leguminosas de Grano, IPL, Peru		2003-2004	US 15,000
PROMPEX-CIAT Bean Project (Peru)	SDC, Switzerland		2002-2004	US 30,000
Technical assistance to PRONALAG team (Bolivia)	SDC, Switzerland		2002-2004	US 30,000
Improved beans for Africa and Latin America	DFID, UK	Restricted core Extension expected in 2005	2004	US 260,586
Tropical Whitefly IPM Project	DFID, UK		2001-2004	US 90,000
A coordinated effort to mark and map important genes in common bean: Universities of California, Cornell, Michigan State, North Dakota, and Puerto Rico	USAID, United States		2000-2004	US 15,000
Genotyping, molecular marker development and QTL analysis of common bean	Generation Challenge Program		2004	US 266,000

Projects at Headquarters (continued)....

Title	Donor	Comments	Funding period	Total amount
Breeding staple crops for improved micronutrient value (for biofortification research)	USAID, United States		2002-2004	US 400,000
Biofortified Crops for Improved Human Nutrition – Harvest Plus Challenge Program	World Bank DANIDA, Denmark Gates Foundation, USA	Under Harvest Plus	2003-2008	US 3000,000
Combating Hidden Hunger in Latin America: Biofortified Crops with Improved Vitamin A, Essential Minerals and Quality Protein	CIDA	Complements Harvest Plus	2004-2010	US1,254,400

Projects submitted

- A full proposal on “Improving drought tolerance of grain legumes: Comparative physiological and genetic approaches to develop tools and methods for genetic enhancement” for CGIAR Challenge Program on Generation with CIAT as a lead center. Total budget: US\$892,080 over 3 years.
- A full proposal on “Realizing the benefits of underutilized legumes: Improving and diversifying production and enhancing soil quality in semiarid to sub-humid regions of Latin America” for INCO-DEV program of the European Commission with ETH, Switzerland as a lead institution. Total budget: Euros 2 million over 3 years.
- A proposal on “Gene flow analysis for environmental safety in the tropics” for BMZ. Total budget: 1.2 million Euros over 3 years (2005-2007).
- A proposal on “Increasing Food Security and Rural Incomes in Eastern, Central and Southern Africa through Genetic Improvement of Bush and Climbing Beans” was submitted to Rockefeller. Total budget: US\$ 300,000 over 3 years (2005-2007). Approved.
- A proposal on “Iniciativa Peruana de Rhizobiología : Fijación biológica de nitrógeno para el establecimiento de sistemas agrícolas sustentables y el progreso de los pequeños productores del Perú” submitted to IDRC. Total budget: CAN\$ 999 625 over 5 years. Rejected.
- A proposal on “Obtención de nuevas variedades de frijol común con atributos de rendimiento y potencial para nuevos mercados, utilizando selección convencional y asistida por marcadores moleculares” submitted to COLCIENCIAS by Universidad Nacional with CIAT. Total budget: Col\$ 22,000,000 over three years (2004-2007).

- Generation Challenge Program: “Genotyping, molecular marker development and QTL analysis of common bean” US\$ 266,000.
- A proposal on “Utilización de hierro y zinc en modelo animal y respuesta clínica al consumo habitual de frijol de alta densidad mineral en mujeres y niños” submitted to COLCIENCIAS by Universidad del Valle with CIAT. Approved.

Concept notes prepared

- A concept note on “Enhancing the resilience of production systems in the Great Lakes region: a strategy to revitalize agriculture through the integration of natural resource management and marketing opportunities” was submitted to the Belgian government.
- A concept note on “Improving livelihoods of smallholder farmers in the Great Lakes region: Overcoming major production constraints in bean-based cropping systems to assure food security and to enhance income generation” was submitted to DGDC, Belgium. Total budget: 1,355 million Euros over 5 years (2005-2009).
- A concept note on “Light, water and stomata: gene targets for multiple abiotic stress tolerance” for CGIAR Challenge Program on Generation with CIAT as a lead center. Total budget: US\$99,710 over 1 year (not approved for full proposal development).
- A concept note on “Improving the resilience of crop/livestock farming systems to enhance food security and income generation in SADC (South African Development Cooperation) countries” with European Commission funds. This is awaiting the call for proposals.
- A concept note on “Improving rural livelihoods in Rwanda: Promoting integrated crop, disease, and pest management (ICDPM) strategies for intensification and diversification of agricultural systems” was submitted as a bilateral project for Belgium. Total budget: 3 million Euros over 3 years (2005-2007).
- A concept note on “Empowering farming communities in rural Colombia: Informed decision-making regarding the use of pesticides in snap bean production” was submitted to IDRC – RoKOS. Total budget: Can\$ 120,000 over 18 months.
- An idea on “*Doubly* green beans: Sustainable income generation for smallholder Colombian and Ecuadorian snap bean farmers with an environmentally clean product for local markets” is being consulted with CFC. Total budget: 2 million Euros over 4 years.

Progress towards achieving output milestones:

- CIAT is actively supporting the evolving research structure in eastern Africa as led by ASARECA, through technical input and through the development of projects with national partners.

Activity 5.3 Strengthen international collaboration through networks (Intra- and inter-network collaboration) and/or bi-lateral relations

Highlights:

- Four Future Harvest Centers (CIAT, CIMMYT, ICRISAT, and IITA) together with SSSN organized teamed up to sensitize various stakeholders on sustainable ways to produce and distribute seed of OPV and self-pollinated crop in Tanzania and Mozambique.
- Stakeholders selected in production to consumption chain defined three bean products for ECABREN research portfolio. These were beans for food and health; canning beans for domestic and export markets; snap bean and dry beans (white and sugar beans) for domestic, regional and international markets.

5.3.1 International cooperation under the CIDA-funded biofortification project for Latin America

In 2004 CIDA and CIAT signed a contract to extend the work on biofortification to Latin America, thus filling a gap in the HarvestPlus Challenge Program. With regards to beans, the objectives of this project continue to be increased levels of iron and zinc through five broad activities:

1. Develop populations and lines for Honduras (red seeded), Guatemala (black seeded), Haiti (large red mottled), Brazil and Bolivia (cream striped) in conjunction with local breeders.
2. With populations that have been pre-selected for high mineral potential, select improved lines with organized farmer groups and local research committees.
3. Compile sets of elite lines for international distribution: red seeded to El Salvador and Nicaragua; black seeded to southern Mexico and Cuba; large red mottled to Andean countries. In years past improved genotypes were circulated widely in Latin America through a system of international trials, and more recently, the PROFRIJOL network in Central America carried out this function on a regional level. This activity will be revived to deliver improved lines to national research institutions, to farmer groups, and to NGOs in countries outside of the primary focus countries.
4. Inform and educate the health sector and NGOs about the biofortification strategy, with an eye to diffusion of improved varieties.
5. Produce and promote improved seed through the agency of NGOs in the Central American and Caribbean regions.

In September, 2004 a workshop was held to initiate the project, with the attendance of bean researchers from Guatemala, Honduras, Cuba, Brazil and the United States. Colleagues from Venezuela and Colombia who will participate in a related FONTAGRO-funded project were also

present to assure coordination. Eventually, when products are available, it is expected that a broader representation of Latin American partners will become involved.

This project represents a rare opportunity to revive international cooperation in Latin America, as was previously carried out under regional projects in Central America and the Andean Zone.

5.3.2 Enhance regional coordination and effectiveness within and between CORAF, ECABREN and SABRN

The PABRA annual steering committee meeting was held in Bilene, Mozambique in May 2004 with the participation of most of the consortium of PABRA donor representatives (CIDA, SDC, USAID, DFID), bean networks coordinators (ECABREN and SABRN) and their steering committee chairmen and CIAT. The meeting, which was officially opened and closed by the director of INIA and deputy Minister of Agriculture of Mozambique reviewed progress, and discussed new initiatives and annual work plans. The ECABREN coordination unit hired an agricultural economist as program assistant to reinforce monitoring and evaluation of socio-economic activities in the network.

New and on-going initiatives were catalyzed at PABRA level to take advantage of economies of scale and comparative advantage of bean networks, partners and/or CIAT to foster linkages and enhance collaboration. These included implementation of the wider impact strategy (development and sharing of promotional materials, seed increase and dissemination); training and establishing of PM&E under PABRA; planning, training and execution of the Impact Assessment studies; harmonization of ECABREN and SABRN breeding strategies; application of Marker Assisted Selection using the Kawanda facilities; information exchanges and visits by pan-Africa working group resources persons (PRIAM, BILFA and IPM); bean biofortification initiatives (with support from CIAT headquarters); and enhancement of PPB skills and development of an action plan. A CIAT Africa website was launched with a PABRA sub-site. The ECABREN, SABRN and PABRA coordinators jointly reviewed progress of PABRA work plan and activities on a regular basis. The PABRA coordinator participated in SABRN and ECABREN steering committee meetings and was a resource person in ECABREN project development and technical meetings.

Contacts were initiated with IRAD in Cameroon for bean program scientists to participate in ECABRENs' regional planning meetings in April and July 2004. This was meant to give them exposure to issues, constraints and procedures for priority setting and also create contacts and profession links with colleagues in eastern Africa. It was anticipated that this would create a focus from which a West Africa (CORAF) research team would network other players in the region. ECABREN through its INERA partner in M'vuazi, D.R. Congo sent bean germplasm to CORAF countries including Central African Republic, Congo-Brazzaville, and Cameroon as these areas have similar ecologies. Germplasm was also sent to Cameroon by the ECABREN regional breeder. In addition, on PABRA request, a breeder from INERA bean program in D.R. Congo (who sent the germplasm to West Africa) and a CIAT staff (Enabling Rural Innovation) visited Cameroon and met some of the bean scientists in an effort to better understand research issues and activities and to plan future interactions.

5.3.3 Enhance partnerships within the networks (including broadening steering committee membership, more alliances between NARS, NGOs and CBOs)

A new alliance has been developed between Concern Worldwide and CIAT-SABRN to provide backstopping to Concern Worldwide in Malawi with bean-based technologies and seed multiplication. Concern Worldwide is funding the operations.

The ECABREN coordination unit continued with its strategy of inviting active partners in the bean production-to-consumption chain to its regional planning meeting, including representatives of farmers, CBOs, national and regional organizations collaborating with member countries in the ASARECA region. In addition, the network strengthened alliances by signing memorandum of understanding (MOU) with three donor-funded NGOs operating in northern Tanzania to join in the implementation of R4D activities, especially in a Farm-Africa-ECABREN funded project on dissemination and promotion of climbing bean and agroforestry interventions in northern and south-western Tanzania. ECABREN also motivated Sokoine University of Agriculture (Food department) and Lagrotech Seed Company in Kenya to be involved actively in the implementation of various aspects of newly defined network projects such as bean for food and health.

5.3.4 Implementing priority setting recommendations for achieving research for development impact in ECABREN member countries

Rationale: The ECABREN strategic objective aims at increasing utilization of demand driven bean-based technologies and innovations. Achieving this objective contributes to ASARECA's strategic objective which emphasizes enhanced agricultural productivity, value-added and competitiveness of the regional agricultural system as a means towards realizing increased economic growth and improved social welfare in East and Central Africa. To fully integrate the ECABREN research and development agenda into ASARECA's consolidated conceptual framework (CCF) and that of Pan-African Bean Research Alliance (PABRA), a review of priority setting recommendations was needed to contribute to achieving institutional goals.

Methodology: The Regional Planning and Steering Committee meetings gathered 38 stakeholders representing actors in the bean production-to-consumption continuum. The group reviewed the 11 sub-themes that were ranked and prioritized last year (see IP-1 2003 Report). Through brain-storming, the stakeholders discovered the diversity of common bean uses and potential of various market classes grown in the region. Production, post-harvest, processing, marketing, consumption, and policy factors that affect important bean markets classes were analyzed. Important bean products were defined that could lead to achieving network and partners' goals; expected results and R4D activities for each product were identified, discussed and agreed by the stakeholders for facilitating the development of project proposals.

Results and Discussion: The three main bean products agreed included beans for food and health; navy beans or canning white pea bean for domestic and export markets; snap bean and dry beans (large white and sugar beans) for export markets. The later project was thereafter separated in two distinct projects including snap bean and sugar & large white beans.

Bean for food and health was considered as the major project on which the bean network should concentrate. Due to their numerous health benefits, dry beans are not only known as a source of micronutrients and protein, but also a source of other major nutrients and components including fiber whose role in preventing health related problems is being recognized worldwide. Therefore, network partners ranked 'Bean for food and health project' as high priority (50%), followed by navy beans (26%) and finally snap bean & large white and sugar beans project (24%). The beans for food and health project has been developed and submitted for approval by the ASARECA-technical support group (TSG) of CGS for two-year funding by USAID/REDSO; whereas concept notes on snap bean and navy bean projects were developed and submitted to ASARECA-CGS through calls addressed to all NARS in the ASARECA region. The following are the projects and research aspects that should be addressed in the next three year starting October 2004 (depending on availability of funds).

Project 1: Enhanced utilization of nutrient rich beans for improved nutrition and income

- Identification and promotion of existing and new nutrient rich bush and climbing beans;
- Characterization of sustainable integrated nutrient, disease and pest management options that enhance nutrient density in existing and new bean germplasm of various market classes;
- Development and promotion of acceptable post-harvest and value adding packaging;
- Dissemination and promotion of nutrient rich beans and relevant improved agronomic practices.

Project 2: Improving navy beans for competitive local and export markets

- Identification and characterization of domestic and export market for navy beans, and improvement of linkage among market actors;
- Development, identification and adaptation of appropriate navy bean populations and varieties;
- Development, testing and adaptation of integrated disease, pest, soil nutrient and water management options for navy beans;
- Testing and adaptation of post-harvest value addition technologies for navy beans;
- Dissemination and promotion of pre-and post harvest technologies.

Project 3: Improving competitiveness of snap bean for domestic and export markets

- Characterization of potential snap bean regional and international export markets and identification of opportunities;
- Identification and adaptation of snap bean varieties that meet domestic and export quality characteristics;
- Development of improved production options for export snap bean;
- Development and promotion of post-harvest options for snap bean;
- Organization/facilitation of producers, traders, and other strategic partners to disseminate and promote snap bean technologies for ensuring growth in volume and quality of snap bean export.

Project 4: Improving competitiveness of white and sugar beans for export markets

- Research and development areas are similar to snap bean project.

Contributor: M. Pyndji, S. Kasambala and P. Kimani

Collaborators: PABRA, ASARECA MEAPU, NARIs, NGOs, CBOs, Farmers and Private sector

5.3.5 Catalyze development of a regional seed support team in collaboration with other Future Harvest Centers and the SADC Seed Security Network

Between April-September 2004, four Future Harvest Centers (CIAT, CIMMYT, ICRISAT, and IITA) together with SSSN teamed up to sensitize various stakeholders on sustainable ways to produce and distribute seed of OPV and self-pollinated crops in Tanzania and Mozambique. This involved stakeholders from various institutions including NGOs, CBOs and farmers' associations, to strengthen partnerships and collaboration.

Progress towards achieving output milestones:

- The Regional Steering Committee of Eastern and Central Africa Bean Research Network (ECABREN) ranked bean for food and health project as higher research priority in efforts to improve nutrition and health of rural and urban poor communities through increased consumption of nutrient rich beans in ASARECA region.

Publications:

Book Chapters

- Amede, T., E. Amézquita, J. Ashby, M. Ayarza, E. Barrios, A. Bationo, S. Beebe, A. Bellotti, M. Blair, R. Delve, S. Fujisaka, R. Howeler, N. Johnson, S. Kaaria, S. Kelemu, P. Kerridge, R. Kirkby, C. Lascano, R. Lefroy, G. Mahuku, H. Murwira, T. Obertur, D. Pachico, M. Peters, J. Ramisch, I. Rao, M. Rondon, P. Sanginga, M. Swift and B. Vanlauwe. 2004. Biological nitrogen fixation: A key input to integrated soil fertility management in the tropics. *In: R. Serraj (ed.) Symbiotic Nitrogen Fixation: Prospects for enhanced application in tropical agriculture.* Raju Primlani for Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, India, p. 113-143.
- Blair, M.W., S. Beebe, M. Grusak, J. Tohme, I. Rao. 2003. Development of genetic and genomic tools to study nutritional quality and aluminum tolerance in common bean. *In: Summaries of legume genomics projects from around the globe. Community resources for crops and models. Legume Genomics. Special issue, G. Stacey, K Vendenbosch (eds.). Plant Physiology 131: 862-863.*
- Broughton W.J., G. Hernandez, M.W. Blair, P. Gepts, J. Vanderleyden. 2003. The Phaseomics International Consortium. *In: Summaries of legume genomics projects from around the globe. Community resources for crops and models. Legume Genomics. Special issue, G. Stacey, K Vendenbosch (eds.). Plant Physiology 131: 860-862.*
- Cardona, C. 2004. Common beans – Latin America. *In: Hodges R.J. and G. Farrell, (eds). Crop Post-harvest: Science and Technology Volume 2: Durables. Blackwell Science Ltd. London. ISBN 0632057238.*
- Crouch, J.H., H.K. Buhariwalla, M.W. Blair, E. Mace, J. Balaji, R. Serraj. 2004. Biotechnology-based contributions to enhancing legume productivity in resource-poor areas. *In: Serraj R. (ed.) Symbiotic Nitrogen Fixation: Prospects for Enhanced Application in Tropical Agriculture.* Oxford & IBH, New Delhi, India.
- Kimani, P.M., R. Buruchara and L. Sperling. 2004. Participatory plant breeding: Case of common bean improvement in East and Central Africa (Chapter submitted to editor).
- Mahuku, G.S. 2004. Angular leaf spot. *In: Compendia of Bean Diseases. American Phytopathological Society, St. Paul. MN. (in press).*
- Morales, F.J. 2004. Detection, diagnosis and identification of plant viruses based on physical, biochemical and biological properties. *In: Handbook of Plant Virology. The Howarth Press, Inc. N.Y.*
- Morales, F.J. 2004. Bean viruses. *In: Compendia of Bean Diseases. American Phytopathological Society, St. Paul. MN. (in press).*

- Morales, F.J. 2004. Common bean viruses. *In: Plant virus diseases of major food crops in developing countries*. Kluwer Academic Publishers, The Netherlands. (in press).
- Morales, F.J. 2005. Natural resistance mechanisms to viruses in common bean (*Phaseolus vulgaris* L.). *In: Natural Resistance to Plant Viruses*. G. Loebenstein and J.P. Carr (eds.). Kluwer Academic Publishers, The Netherlands (submitted).
- Rao, I.M. 2004. Minerals: function. *In: A. S. Raghavendra (ed.). Crop Physiology*. The Haworth Press, Inc., Binghamton, USA (in review).
- Rychter, A.M. and I.M. Rao. 2004. Role of phosphorus in photosynthetic carbon metabolism. *In: M. Pessaraki (ed.). Handbook of Photosynthesis*. 2nd Edition. Marcel Dekker, Inc., New York (in press).

Refereed and non-refereed Journals

- Aggarwal, Vas D., M.A. Pastor-Corrales, R. Chirwa, R. Buruchara. 2004. Andean beans (*Phaseolus vulgaris* L.) with resistance to the angular leaf spot pathogen (*Phaeoisariopsis griseola*) in southern and eastern Africa. *Euphytica*. 136:201-210
- Anderson, P.K., A.A. Cunningham, N.G. Patel, F.J. Morales, P.R. Epstein, and P. Daszak. 2004. Emerging infectious diseases of plants: pathogen pollution, climate change and agrotechnology drivers. *Trends in Ecology and Evolution* 19: 1-10.
- Asfaw, A.D. Dauro and P.M. Kimani. 2004. Improving genetic diversity of common bean in farmer's fields in Southern Ethiopia. (submitted).
- Asfaw, A. and P. M. Kimani. 2004. Genetic analyses of some metric traits in small-seeded bean line crosses. *Ann. Rep. Bean Improvement Cooperative* 47: 295-296.
- Blair M.W., F. Pedraza, H.F. Buendia, E. Gaitán-Solís, S. Beebe, P. Gepts, J. Tohme. 2004. Development of a genome-wide anchored microsatellite map for common bean (*Phaseolus vulgaris* L.) *Ann. Rep. Bean Improvement Cooperative* 47:71-73.
- Blair, M.W., O. Checa, S, Beebe. 2004. Yield components measured in a climbing x bush bean RIL population. *Ann. Rep. Bean Improvement Cooperative* 47:297-298.
- Blair, M.W., M.C. Giraldo, H.F. Buendia, E. Tovar, A.F. Guerrero. 2004. Evaluation of microsatellite diversity in common bean parental surveys. *Ann. Rep. Bean Improvement Cooperative* 47:187-188.
- Blair, M.W., F. Pedraza, H.F. Buendia, E. Gaitán-Solís, S. Beebe, P. Gepts, J. Tohme. 2003. Development of a genome-wide anchored microsatellite map for common bean (*Phaseolus vulgaris* L.) *Theor Appl Genet* 107: 1362-1374.

- Checa, O., M.W. Blair, S. Beebe. 2004. Genotypic variation in climbing ability traits in a common bean RIL population. *Ann. Rep. Bean Improvement Cooperative* 47: 301-302.
- Durán, L.A., M.W. Blair, M.C. Giraldo, R. Machiavelli, E. Prophete, J.C. Nin, J.S. Beaver. 2004. Morphological and molecular characterization of common bean (*Phaseolus vulgaris* L.) landraces from the Caribbean. *Crop Sci.* (accepted)
- Frei, A., J. M. Bueno, J. Díaz-Montaño, H. Gu, C. Cardona, and S. Dorn. 2004. Tolerance as a mechanism of resistance to *Thrips palmi* in beans. *Entomol. Experim. et Appl.* 112: 73-80.
- Frei, A., M. W. Blair, C. Cardona, S. E. Beebe, H. Gu, and S. Dorn. 2004. QTL mapping of resistance to *Thrips palmi* in common beans. *Crop Sci.* (accepted).
- Frei, A., H. Gu, J. M. Bueno, C. Cardona, and S. Dorn. 2003. Antixenosis and antibiosis of common beans to *Thrips palmi* Karny (Thysanoptera: Thripidae). *J. Econ. Entomol.* 96: 1577-1584.
- Gomez, O.J., M.W. Blair, B.E. Frankow-Lindberg, U. Gullberg. 2004. Molecular and phenotypic diversity of common bean landraces from Nicaragua. *Crop Sci.* 44: 1412-1418.
- Henriquez, M.A., G. Mahuku, J.E. Muñoz, G. Castellanos, C. Jara. 2004. Determinaciones de la diversidad genética del agente causal de la mancha angular del frijol, *Phaeoisariopsis griseola* (Sacc.) Ferraris, mediante el uso de marcadores moleculares. (ASCOLFI Newsletter).
- Ishitani, M., I. Rao, P. Wenzl, S. Beebe and J. Tohme. 2004. Integration of genomics approach with traditional breeding towards improving abiotic stress adaptation: drought and aluminum toxicity as case studies. *Field Crops Res.* 90: (in press).
- Kang M.S., V.D. Aggarwal and R.M. Chirwa. 2004. Adaptability and stability of bean cultivars as determined via Kang's yield-stability statistic and GGE biplot analysis. Submitted to *Euphytica*, September 2004.
- Kelemu, S., G. Mahuku, M. Fregene, D. Pachico, N. Johnson, L. Calvert, I. Rao, R. Buruchara, T. Amede, P. Kimani, R. Kirkby, S. Kaaria, and K. Ampofo. 2003. Harmonizing the agricultural biotechnology debate for the benefit of African farmers. *Afr. J. Biotech.* 2: 394-416.
- Kimani, P.M., I. Wagara and M. Blair. 2004. Selection of climbing bean lines tolerant to common bacterial wilt, bean common mosaic virus and web blight. *Ann. Rep. Bean Improvement Cooperative* 47:309-310.
- Kimani, P.M. and S. Beebe. 2004. Screening for drought tolerance in Eastern Africa. *Ann. Rep. Bean Improvement Cooperative* 47: 311-312.
- Liao H, X. Yan, G. Rubio, S. Beebe, M.W. Blair, J.P. Lynch. 2004. Basal root gravitropism and phosphorus acquisition efficiency in common bean. *Functional Plant Biology* 31:959-970.

- Mahuku, G., C. Montoya, M.A. Henríquez, C. Jara, H. Teran, S. Beebe. 2004. Inheritance and characterization of the angular leaf spot resistance gene in the common bean accession, G 10474 and identification of an AFLP marker linked to the resistance gene. *Crop Sci.* 44: 1817-1824.
- Mahuku, G.S. 2004. A simple extraction method suitable for PCR-based analysis of plant, fungal, and bacterial DNA. *Plant Molecular Biology Reporter* 22: 71-81.
- Mahuku, G.S. and J.J. Riascos. 2004. Virulence and molecular diversity within *Colletotrichum lindemuthianum* isolates from Andean and Mesoamerican bean varieties and regions. *European Journal of Plant Pathology* 110: 253-263.
- Manzano, M.R., J. van Lenteren, and C. Cardona. 2003. Comportamiento de búsqueda de *Amitus fuscipennis* (Hymenoptera: Platygasteridae): Tiempo de permanencia en la planta hospedera y actividad de búsqueda. *Rev. Colombiana Entomol.* 29(2): 221-226
- Mbikayi, N and P.M. Kimani. 2004. Participatory selection of yellow, brown, sugar and tan bean market classes in Eastern Congo. *Ann. Rep. Bean Improvement Cooperative* 47: 305-306.
- Mukalazi, J. E. Adipala, R. Buruchara, J. Carder, F. Opio, Pettitt and N.J Spence. Quantification of *Pythium* species pathogenic to beans and the impact of organic amendments on soil pathogen populations in Uganda (submitted).
- Mukalazi, J. E. Adipala, R. Buruchara, J. Carder, F. Opio, Pettitt and N.J Spence. Variation, identification and detection of *Pythium* species associated with bean root rot disease in Uganda (submitted).
- Muñoz, L.C., M.W. Blair, M.C. Duque, W. Roca, J. Tohme. 2004. Level of introgression in inter-specific (*Phaseolus vulgaris* x *P. acutifolius*) congruity-backcross lines. *Crop Sci.* 44: 637-645.
- Murray, J. D., T. E. Michaels, K. P. Pauls, C. Cardona, and A. W. Schaafsma. 2004. Yield and insect injury in leafhopper (*Empoasca fabae* Harris and *Empoasca kraemeri* Ross & Moore) infested dry beans in Ontario and Colombia. *Canadian J. of Plant Science* 84: 891-900.
- Namayanja, A., R. Buruchara, P. Rubaihayo, G. Mahuku, P. Kimani, S. Mayanja and H. Eyedu. 2004. Inheritance of resistance to angular leaf spot in cultivars Mexico 54 and BAT 322. (submitted to *African Crop Science J.*)
- Namayanja, A., R. Buruchara, G. Mahuku, Mayanja, P. Rubaihayo, P. M. Kimani, and H. Eyedu. 2004. Validating the utility of the angular leaf spot resistance markers for marker-assisted selection outside the original mapping population (submitted).
- Otsyula, R., R. Buruchara, P. Rubaiyo. 2003. Genetic mode of resistance in bean genotype MLB 49-89A to *Pythium* root rot. *Ann. Rep. Bean Improvement Cooperative* 46:219-220.

- Riascos, J.H., G. Mahuku, and H. Cárdenas. 2004. Diversidad genética del agente causal de la antracnosis del frijol común (*Colletotrichum lindemuthianum*) (ASCOLFI News letter).
- Rodríguez, I., H. Morales, J. M. Bueno, and C. Cardona. 2004. El biotipo B de *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) adquiere mayor importancia en el Valle del Cauca. Rev. Colombiana de Entomología Vol 30 (accepted).
- Santana, G.E., M.W. Blair, F. Morales, G. Mahuku, C. Jara, C. Castaño. 2004. Uso de técnicas clásicas y avanzadas para identificar genotipos de frijol resistentes a antracnosis y mosaico común. Fitotecnia Colombiana (accepted).
- Tusiime, G., R.A. Buruchara, J. Carder, N. Spence, F. Opio and E. Adipala. 2004. Genetic variation in *Fusarium solani* isolated from beans and soil associated with Fusarium root rot disease in southwestern Uganda (submitted).
- Tusiime, G., R.A. Buruchara, E. Adipala, J. Carder, N. Spence, and F. Opio. 2004. Amplified fragment length polymorphism (AFLP) derived primers detects *Fusarium solani* f. sp. *phaseoli* in common beans (submitted).
- Yan X, H. Liao, S. Beebe, M.W. Blair, J.P. Lynch. 2004. Molecular mapping of QTLs associated with root hairs and acid exudation as related to phosphorus uptake in common bean. Plant and Soil (accepted).

Workshop and Conference

- Amane M. and R.M. Chirwa. 2004. Good production practices for quality bean seed in Mozambique. A paper presented at a seed workshop organized by Future Harvest centers (CIAT, CIMMYT, ICRISAT and IITA) and the SADC Seed Security Network, for stakeholders in community-based seed production of OPV and self-pollinated crops, held in Maputo, Mozambique, September 2004.
- Blair, M.W., G. Iriarte. 2003. Ampliación de la base genética del frijol (*Phaseolus vulgaris*) cultivado. 1^o Congreso Venezolano de Mejoramiento Genético y Biotecnología Agrícola. Universidad Central de Venezuela, Maracay, Venezuela. October, 15-17, 2003.
- Blair, M.W., F. Pedraza, H.F. Buendia, E. Gaitán-Solís, S. Beebe, P. Gepts, J. Tohme. 2003. Development of a genome-wide anchored microsatellite map for common bean (*Phaseolus vulgaris* L.). Paper presented at Bean Improvement Cooperative Meeting, Sacramento, California. October 26-30, 2003.
- Blair, M.W. 2003. Options for increasing iron content in bean: USAID funded Bean Biofortification Project and CGIAR HarvestPlus Challenge Program. 3rd Annual Conference: USAID-African Partnership in Biotechnology. Ibadan, Nigeria. November 17-19, 2003.
- Blair, M.W., J. Tomkins. 2004. Bean genomics. SLO / USAID linkage program conference. Davis, California, USA. June 8-10, 2004.

- Bueno, J. M., C. Cardona, P. Chacón. 2004. Fenología, desarrollo de métodos de muestreo y distribución espacial de *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae) en habichuela y frijol. p. 29 *In*: Resúmenes XXXI Congreso Sociedad Colombiana de Entomología, Bogotá, Julio 28-30, 2004.
- Buruchara, R., R. Otsyula, P Kimani and F. Opio. 2004. Resistance in common beans (*Phaseolus vulgaris* L.) to *Pythium* root rot caused by *Pythium* spp. South African Plant Breeding Workshop, 17-18 March 2004, Durban, South Africa.
- Cardona, C. 2004. Tendencias actuales y futuras en el manejo de insectos plaga de importancia agrícola. pp. 38-44 *In*: Memorias I Seminario Internacional y II Nacional de Control Biológico de Plagas y Enfermedades de los Cultivos. Abril, 2004. Escuela Politécnica del Ejército, Quito, Ecuador.
- Grusak, M.A., C.L. Burgetti, S.J.B. Knewton, A.F. López-Milláni, D.R. Ellisi, C.M. Li, V.M. Musetti, M.W. Blair. 2004. Novel approaches to improve legume seed mineral nutrition. Presented paper AEP/ICLGGII.
- Henríquez, M.A., G. Mahuku, M. Navia. 2004. Cebadores específicos para la detección y diferenciación de *Xanthomonas campestris* pv *phaseoli* y *Xanthomonas campestris* pv. *phaseoli* var *fuscans* en el frijol común. . XXV Congreso de la Asociación Colombiana de Fitopatología y Ciencias afines (ASCOLFI), Agosto 11-13 de 2004, CIAT, Palmira.
- Hernandez, G, M. Ramírez, M.W. Blair, M. Lara, L. Blanco, M. Muñoz, S, Barazesh, E. Verdoorn, M. Graham, C.P. Vance. 2003. Comparative analysis of common bean (*Phaseolus vulgaris*) nodule, root, pod and leaf expressed sequence tag (EST) libraries: a platform for “Phaseomics” research. Presented paper AEP/ICLGGII.
- Jara, C., G. Castellanos, J.B. Cuasquer, G. Mahuku. 2004. Determinación de la variabilidad patogénica en diferentes cepas de *Xanthomonas capestris* pv. *phaseoli* y *Xanthomonas campestris* pv. *phaseoli* var *fuscans* en 56 genotipos de frijol común. XXV Congreso de la Asociación Colombiana de Fitopatología y Ciencias afines (ASCOLFI) , Agosto 11-13 de 2004, CIAT, Palmira.
- Kimani, P., L. Lubanga, G. Rachier, V. Ruganzu, A. Namayanja. S. Beebe and I. Rao. 2004. Screening and participatory evaluation of germplasm for aluminium resistance in low fertility acid soils in East and Central Africa. Acid Soils Workshop, 25-27 February, 2004, CIAT, Cali, Colombia.
- Kimani, P.M., M. Pyndji., R. Chirwa, J.C. Rubyogo and R. Buruchara 2004. A strategy for creating wider impact for bean in Africa. National Bean Workshop, 25-29 May 2004, Nakuru, Kenya.
- Kimani, P.M. 2004. Creating wider impact for bean in Africa: Case study of Kenya. National Bean Workshop, 25-29 May 2004, Nakuru, Kenya.

- Kimani, P.M. 2004. Rationale for working with farmers. Participatory breeding workshop, 17-25 May 2004, Kakamega, Kenya. Pan African Bean Research Alliance, Kampala, Uganda.
- Kimani, P.M. 2004. Analysis of quantitative data in participatory breeding experiments. Participatory breeding workshop, 17-25 May 2004, Kakamega, Kenya. Pan African Bean Research Alliance, Kampala, Uganda.
- Kimani, P.M. 2004. Germplasm issues in participatory bean breeding in Africa. Participatory breeding workshop, 17-25 May 2004, Kakamega, Kenya. Pan African Bean Research Alliance, Kampala, Uganda.
- Kimani, P.M. 2004. New orientation of the East and Central Africa bean research network breeding program. Participatory breeding workshop, 17-25 May 2004, Kakamega, Kenya. Pan African Bean Research Alliance, Kampala, Uganda.
- Lubanga, L., P.M. Kimani, G. Rachier and V. Ruganza. 2004. Progress in bean improvement for low soil fertility in Africa. Acid Soils Workshop, 25-27 February, 2004, CIAT, Cali, Colombia.
- Madata C. and R.M. Chirwa. 2004. Good production practices for quality bean seed in Tanzania. A Paper presented at a Seed Workshop organized by Future Harvest centers (CIAT, CIMMYT, ICRISAT and IITA) and the SADC Seed Security Network, for stakeholders in community-based seed production of OPV and self-pollinated crops, held in Arusha, Tanzania April 2004.
- Montoya, C., G. Mahuku, M.A. Henríquez, C. Jara. 2004. Identificación de marcadores moleculares ligados a genes de resistencia a mancha angular de fríjol. . XXV Congreso de la Asociación Colombiana de Fitopatología y Ciencias afines (ASCOLFI), Agosto 11-13 de 2004, CIAT, Palmira.
- Muthoni, R. 2004. Development of the PABRA performance framework. Presentations at the ECABREN, Steering Committee Meeting, 14th April 2004, Nairobi, Kenya.
- Muthoni, R. 2004. Establishing the PABRA monitoring and evaluation framework. 2003 – 2008. Paper presented to the PABRA Steering Committee in Beline, Mozambique.
- Muthoni, R. 2004. Establishing the PABRA performance framework. Presentations at the PABRA SC Meeting. 20th May 2004, Beline, Mozambique.
- Muthoni R, and R. Buruchara. Establishing participatory monitoring and evaluation in PABRA. 3rd June 2004, Jinja, Uganda.
- Muthoni.R and S. Kaaria. 2004. Establishing participatory monitoring and evaluation in NARs. Presentation during the launching PM&E for R&D in Tanzania, 7th May. 2004, Arusha, Tanzania.

- Navia, M., G. Mahuku, J.A. Arroyave. 2004. Evaluación del proceso de infección de *Phaeoisariopsis griseola* en interacciones compatibles e incompatibles con el frijol común, *Phaseolus vulgaris*. XXV Congreso de la Asociación Colombiana de Fitopatología y Ciencias afines (ASCOLFI), Agosto 11-13 de 2004, CIAT, Palmira.
- Ortiz, R. and R. Buruchara. 2004. The role of agricultural biotechnology in crop production and improvement in the developing world. 2004. Workshop on capacity building in agricultural biotechnology for improved productivity and livelihoods in Ethiopia. July 5–8 Addis, Ethiopia.
- Pyndji, M.M. 2003. Report on ECABREN priority setting process. Presented to ASARECA 27th CD meeting, Nairobi, Kenya, 16-18 October.
- Pyndji, M.M. 2004. ECABREN conceptual framework. Presented at the Regional Planning & Steering Committee meetings. Nairobi, Kenya, April 13-17.
- Pyndji, M.M. 2004. ECABREN conceptual framework in relation with PABRA framework. Presented to Participatory M&E systems workshop at Selian ARI, Arusha, Tanzania.
- Pyndji, M.M. 2004. ECABREN Annual progress report. Presented to the PABRA Steering Committee held in Bilene, Mozambique, May 19-21
- Pyndji, M.M. 2004. ECABREN and suggested topics for competitive grant system. Presented at ASARECA-CGS Inception Call Planning and Writing Workshop, Nairobi, Kenya.
- Rubyogo, J.C. and R.M. Chirwa. 2004. Business skill development for small-scale seed producers with reference to decentralized bean seed business enterprise. A paper presented at a Seed Workshop organized by Future Harvest Center (CIAT, CIMMYT, ICRSISAT and IITA) and the SADC Seed Security Network for stakeholders in community based seed production of improved open pollinated varieties held in Arusha, Tanzania. April 2004.
- Rubyogo, J.C. and R.M. Chirwa. 2004. Business skill development for small-scale seed producers with reference to decentralized bean seed business enterprise. A paper presented at a Seed Workshop organized by Future Harvest Center (CIAT, CIMMYT, ICRSISAT and IITA) and the SADC Seed Security Network for stakeholders in community based seed production of improved open pollinated varieties held in Maputo Mozambique September 2004
- Rubyogo, J.C., T. Remington, and R. Jones. 2004. Seed systems for reaching a broad range of users, quickly and efficiently. A paper presented at a workshop organized by HarvestPlus Challenge Programme of Future HarvestPlus Centre for stakeholders interested in engaging and reaching end –users more efficiently. W/shop held at IPGRI Headquarters Rome, May 2004.

- Rubyogo, J.C. 2004. Decentralized seed systems: required support services and opportunities in Africa. Presentation made at workshops organized by seed sector stakeholders in PABRA countries: Kenya- Nakuru (28-30/5/04), Rwanda –Kigali (12/6/04), Ethiopia-Melkassa (9-10/6/04), Northern Tanzania –Arusha (17/08/04), Swaziland –Melkerns (6/10/04) and Lesotho –Maseru (8/10/04).
- Sperling, L. 2004. Germplasm restoration in Rwanda? Analysis and Lessons Learned. Presentation at the Workshop “Seed Aid and Germplasm Restoration in Disaster Situations: Synthesis of Lessons Learned and Promotion of More Effective Practices”
- Sperling, L. 2004. Germplasm restoration(?) in the Cagayan Valley, the Phillipines: IRR/PhilRice. Presentation at the Workshop “Seed Aid and Germplasm Restoration in Disaster Situations: Synthesis of Lessons Learned and Promotion of More Effective Practices”
- Sperling, L. 2004. Cassava Mosaic Disease and Seed Aid: NARO/Uganda. Presentation at the Workshop “Seed Aid and Germplasm Restoration in Disaster Situations: Synthesis of Lessons Learned and Promotion of More Effective Practices”
- Sperling, L. 2004. Seed aid: lessons in the making. Presentation at the Workshop “Bridging the gap between relief and development: Best practices in seed stress situations”
- Sperling, L. 2004. Assessment of seed system and seed needs in emergencies. Presentation at the Workshop “Bridging the gap between relief and development: Best practices in seed stress situations”

Proceedings, Posters, Abstracts and Others

- Amede, T., P. Kimani, W.Ronno, L. Lubanga and N. Mbikayi. 2004. Coping with drought: Strategies to improve genetic adaptation of common bean in drought prone areas of Africa. CIAT Occasional Publication Series No. 38. CIAT, Cali, Colombia.
- Asrat, A. and R. Buruchara. 2004. Climbing beans: Another opportunity for Ethiopia. Poster.
- Blair, M.W., H.F. Buendia, M. Castaño, G.E. Santana, F. Morales. 2004. Adaptation and use of SCAR markers for BCNMV resistance (*bc-3* and dominant *I* genes) in an Andean bean breeding program. Poster presented at the South African Plant Breeding Conference, Durban, South Africa. March 14-18, 2004.
- Blair, M.W. 2004. Progress in genetic mapping of microsatellite markers for common bean (*Phaseolus vulgaris* L.). Abstract presented at Phaseomics III, Geneva, Switzerland. June 13-15, 2004.

- Broughton, W.J., Y.Y. Aung, M.W. Blair, G. Hernandez, C.E. Pankhurst. 2004. Variation in *Rhizobium* host-specificity in various *Phaseolus* accessions. Abstract presented at Phaseomics III, Geneva, Switzerland. June 13-15, 2004.
- Buruchara, R. 2004. Bean root rot damage (in English, Rukiga, & Rufumbira).
- Buruchara, R.A., R.A. Kirkby, H. Gridley and P.M. Kimani. 2004. Decentralized and participatory breeding strategies for bean in Africa: Evolution and potential. *In*: Sperling, L, J. Lancon and M. Loosevelt (eds.). Participatory Plant Breeding and Participatory Plant Genetic Resource Enhancement. An Africa-wide exchange of experiences. WARDA/CIRAD/PRGA. CGIAR Program for Participatory Research and Gender Analysis, Cali, Colombia
- Kimani, P.M., H.Gridley, R. Buruchara and R. Kirkby. 2004. Decentralized and participatory breeding strategy for beans in Africa: its role and potential for institutionalization. *In*: Sperling, L, J. Lancon and M. Loosevelt (Eds). Participatory Plant Breeding and Participatory Plant Genetic Resource Enhancement. An Africa-wide Exchange of Experiences. WARDA/CIRAD/ PRGA. CGIAR Program for Participatory Research and Gender Analysis, Cali, Colombia.
- Michelsen, H., A. Mbabu, B. Lemega, I. Minde, P. Mukishi, S. Ferris, D. Mukhebi, C. Ngichabe, B.W. Khizzah. 2004. Priority setting within networks: Experiences from East and Central Africa. ISNAR Briefing Paper 72. 12 pp.
- Pankhurst, C.E., M.W. Blair, W.J. Broughton. 2004. TILLING in beans. Abstract presented at Phaseomics III, Geneva, Switzerland. June 13-15, 2004.
- Ramirez M, G. Hernandez, M.W. Blair, M. Lara, L. Blanco, M. Muñoz, S. Barazesh, E. Verdoorn, M. Graham, C.P. Vance. 2004. Comparative analyses of common bean (*Phaseolus vulgaris*) expressed sequence tag libraries. Abstract presented at Phaseomics III, Geneva, Switzerland. June 13-15, 2004.
- Rangel, A. F., M. Mobin, I. M. Rao and W. Horst. 2004. Aluminum-induced callose formation is not a suitable parameter for assessing genotypic differences in aluminum resistance in *Phaseolus vulgaris*. Proceedings of the 6th International Symposium on Plant-Soil Interactions at Low pH (PSILPH) held in Sendai, Japan from 31 July to 5 August, 2004. Japanese Society of Soil Science and Plant Nutrition, Sendai, Japan, pp. 264-265.
- Rao, I. M., S. Beebe, J. Ricaurte, H. Teran and S. Singh. 2004. Common bean (*Phaseolus vulgaris* L.) genotypes tolerant to aluminum-toxic soils in the tropics. Proceedings of the 6th International Symposium on Plant-Soil Interactions at Low pH (PSILPH) held in Sendai, Japan from 31 July to 5 August, 2004. Japanese Society of Soil Science and Plant Nutrition, Sendai, Japan, pp. 272-273.
- Sperling, L., J. Lancon, and M, Loosvelt. 2004. Participatory Plant Breeding and Participatory Plant Genetic Resource Enhancement. An Africa-wide exchange of experiences (Sélection participative et gestion participative des ressources génétiques en Afrique: Échange

d'expériences). Proceedings of a workshop held on M'Be, Ivory Coast. May 7-10, 2001. Cali Colombia: PRGA (425 pages).

Sperling, L, T. Osborn and D. Cooper. 2004. Toward more effective and sustainable seed relief. Rome, Food and Agriculture Organization of the United Nations (130 pages).

Sperling, L. 2004. "En cas de catastrophe, les semences locales sont disponibles, mais souvent inaccessibles". La Revue Durable, 12: Septembre-Octobre 2004. 26-27 (written anonymously).

Rubyogo, J.C., L. Sperling and T. Remington. 2004. Seed Systems and Seed Relief: an Annotated Bibliography.

Rubyogo, J.C. 2004. Ethiopian partnership for improving farmers' access to quality seed of preferred new varieties of bean.

Teshale A. and R. Buruchara. 2004. New bean varieties for Ethiopia.

Extension Bulletins & Brochures

Buruchara, R.A. and E. Minja. 2004. Scaling-up of bean integrated pest and disease management technologies.

Minja, E.M., H.A. Mziray, and S.P. Kasanbaka. 2004. Report on field day for IPDM farmer groups in Shari Village, Hai District, Northern Tanzania, March 2004, CIAT, Arusha, Tanzania, 13pp. [English] [Booklet for distribution to Village Information Centres in bean growing areas in eastern, central and southern Africa].

Minja, E.M., C.S. Madata, E. Ulicky, D. Kabungo, W. Mushobozi, N. Lyimo, A. Temu, A. Mbwaga, and H.A. Mziray. 2004. Report on visit by CPP programme managers to bean IPDM project sites in Tanzania, March 2004, CIAT Arusha, Tanzania, 53pp. [English] [Booklet for distribution to Village Information Centres in bean growing areas in eastern, central and southern Africa].

Minja, E.M., F. Opio, M. Ugen, and H.A Mziray. 2004. Visit by NARO and CIAT scientists to Bushenyi and Kabale bean IPDM sites in western and south western Uganda. June 2004, CIAT Arusha, Tanzania, 24pp. [English] [Booklet for distribution to Village Information Centres in bean growing areas in eastern, central and southern Africa].

Mukishi, P. 2004. Panda mbegu bora (1000 copies printed and distributed). Climbing bean posters (50 copies printed and distributed).

Mukishi, P. 2004. Bean dishes (English & Swahili), Tanzania (2010 copies printed and distributed).

Mukishi, P. 2004. Mapishi mbali mbali ya maharage, Tanzania (2138 copies printed and distributed).

Mukishi, P. 2004. Kilimo bora cha maharage kamba, Tanzania (1910 copies printed and distributed).

Mukishi, P. 2004. La culture du haricot volubile sous-bananeraie, DR Congo (1000 copies printed and distributed).

Mukishi, P. 2004. Kilimo bora cha maharage, Tanzania (1156 copies printed and distributed).

Mviha, P., N. Sangole, L. Soko, H. Chidaya, H. Mlenga, E. Minja, H. Mziray, and E. Ngallo. 2004. Report on visit by Kasungu farmers to Bembeke EPA in Dedza district. Malawi, 17 p. [English] [Booklet for distribution to Village Information Centres in bean growing areas in eastern, central and southern Africa].

Mviha, P., H. Mlenga, B. Chibambo, E. Minja, and H. Mziray. 2003. Report on Bembeke bean IPDM stakeholders' Workshop, November 2003, Dedza, Malawi, 22 p. [English] [Booklet for distribution to Village Information Centres in bean growing areas in eastern, central and southern Africa].

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BID/IICA Project approved by FONTAGRO
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COSUDE-PROMPEX CIAT Bean Project, Peru.
COSUDE-PRONALAG Technical Assistance, Bolivia.
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*Left in 2004

Acronyms and Abbreviations used

ACTA	Asociación Colombiana de Ciencia y Tecnología de Alimentos
ADRA	Adventist Development and Relief Agency
AFLP	Amplified Fragment Length Polymorphism
AHI	African Highlands Ecoregional Programme (led by ICRAF)
ARC/GCRI	Agricultural Research Council, Grain Crops Research Institute, South Africa
ASA	American Society of Agronomy
ASARECA	Association for Strengthening Agricultural Research in East and Central Africa
ATDT	Agricultural Technology Development and Transfer Project
AU	Alemaya University, Etiopía
BGMV	Bean Golden Mosaic Virus
BGYMV	Bean Golden Yellow Mosaic Virus
CARE	(International NGO in Ethiopia, Rwanda, Uganda)
CBOs	Community Based Organizations
CG	Consultative Group
CGIAR	Consultative Group on International Agricultural Research
CGS	Competitive Grant System
CIAL	Comité de Investigación Agrícola Local
CIAT	Center for International Tropical Agriculture
CIDA	Canadian International Development Agency
CIMMYT	International Maize and Wheat Improvement Centre
CIPRES	Centro de Investigación y Promoción de Desarrollo Rural y Social
CMAD	Community Mobilization Against Desertification
COLCIENCIAS	Instituto Colombiano para el Desarrollo de la Ciencia y la Tecnología “Francisco José de Caldas”
CORAF/ WECARD	Conférence des Responsables de Recherche Agricole en Afrique de l’Ouest et du Centre/West and Central African Council for Agricultural Research and Development
CORFOCIAL	Corporación para el Fomento de los Comités de Investigación Agrícola Local
CORPOICA	Corporación Colombiana de Investigación Agropecuaria
COSUDE	Cooperación Suiza para el Desarrollo
CRSP	Collaborative Research Support Project
CRS	Catholic Relief Services
CSSA	Crop Science Society of America
CU	Concern Universal, Malawi
DANIDA	The Danish Agency for Development Assistance
DAO	District Agricultural Office
DARTS	Department of Agricultural Research and Technical Services, MoA, Malawi
DNA	DeoxyriboNucleic Acid
DR Congo	Democratic Republic of Congo

DRD	Directorate of Research and Development
EARO	Ethiopian Agricultural Research Organization
ECA	East and Central Africa
ECABREN	Eastern and Central Africa Bean Research Network
EEA	Estación Experimental Agrícola
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria
ESA	East and Southern Africa
ETIAH	Estación Territorial de Investigaciones Agropecuarias de Holguín
FA	Farm Africa
FAO	Food and Agriculture Organization
FENALCE	Federación Nacional de cultivadores de Cereales
FIDAR	Fundación para la Investigación y Desarrollo Agrícola
FONTAGRO	Fondo Regional de Tecnología Agropecuaria
FOFIFA	Centre National de la Recherche Appliqué au Développement Rural, Madagascar
HAAS	Harbin Agricultural Academy of Sciences
HEM	Himo Environmental Management Trust
HRI	Horticultural Research Institute (UK)
IACR	Rothamsted (UK)
IBFA	Ikulwe Bean Farmers Association (Uganda)
ICIPE	Centre for Research in Agro-Forestry
ICRISAT	International Crops Research Institute for Semi-Arid Tropics
IDRC	International Development Research Center
IITA-SARRNET	International Institute for Tropical Agriculture - Southern Africa Regional Root Crops Research Network
INERA	Institut National des Etudes sur la Recherche Agronomique, DR Congo
INIA	Instituto Natiocional de Investigacao Agronomica (Mozambique)
INM	Intergrated Nutrient Management
INRA	Institut National de Recherche Agronomique
INTA	Instituto Nacional de Innovación y Transferencia en Tecnología Agropecuaria, Costa Rica
INPRHU	Instituto de Promoción Humana
IPGRI	International Plant Genetic Resources Institute
IPM	Integrated Pest Management
IPRA	Investigación Participativa en Agricultura/ Participatory Research in Agriculture of CIAT
ISAR	Institut des Sciences Agronomiques du Rwanda
ITA	Instituto Técnico Agrícola
KARI	Kenya Agricultural Research Institute
MAC	Medium Altitude Climbers
MAFP	Ministério de Agricultura, Florestas e Pescas (República Democrática de Timor-Leste)
MAS	Marker Assisted Selection
MIP	Manejo Integrado de Plagas/Integrated Pest Management
MoA	Ministry of Agriculture
MU	Makerere University, Uganda

NAARI	Namulonge Agricultural and Animal Production Research Institute
NARI	National Agricultural Research Institute
NARO	National Agricultural Research Organization, Uganda
NARS	National Agricultural Research Systems
NBPGR	National Bureau of Plant Genetic Resources
NEPAD	The New Partnership for Africa's Development
NGOs	Non-Governmental Organizations
NRI	Natural Resources Institute (UK)
OFDA	Office of Foreign Disaster Assistance
OPV	Open Pollinated Variety
PABRA	Pan-Africa Bean Research Alliance
PCCMCA	Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios
PPB	Participatory Plant Breeding
PRGA	Participatory Research and Gender Analysis
PROFRIZA	Proyecto Regional de Frijol para la Zona Andina
PROMPEX	Comisión para la Promoción de Exportaciones
PRONALAG	Programa Nacional de Leguminosas Alimenticias
REDSO/ESA	Regional Economic Development Services Office for East and Southern Africa
RF	The Rockefeller Foundation
SABRN	SADC Bean Research Network
SACCAR	Southern African Centre for Cooperation in Agricultural and Natural Resources Research and Training
SADC	Southern Africa Development Council
SARBEN	Southern Africa Regional Bean Evaluation Nursery
SARBYT	Southern Africa Regional Bean Yield Trial
SARI	Selian Agricultural Research Institute
SDC	Swiss Development Cooperation
SENA	Servicio Nacional de Aprendizaje
SENASEM	Service National des Semences
SGRP	Systemwide Genetic Resources Programme
SSSA	Seed System Security Assessment
SSSN	SADC Seed Security Network
TSG	Technical Support Group
UAGRM	Universidad Autónoma Gabriel René Moreno
UMATA	Unidad Municipal de Asistencia Técnica Agropecuaria
UN	United Nations
USAID	United States Agency for International Development
VICARIBE	Vivero Caribeño de grano Andino
VIVA	Vivero Internacional de Volubles Andinos
WV	World Vision