Participatory Plant Breeding in Maize for the Chhotanagpur Plateau of Eastern India

Arun Kumar, D.K. Ganguli, S.C. Prasad, J.S. Gangwar, D.S. Virk, and J.R. Witcombe

Abstract

This paper describes a participatory maize breeding program that is a collaborative project between Birsa Agricultural University and the KRIBHCO Indo-British Rainfed Farming Project (East). At the beginning of the project, a base population was produced in the rainy season of 1997 by making nine crosses between three yellow-endospermed flint varieties (Suwan, Birsa Makka 1, and Chandan 3) and three white-endospermed flint varieties (GDRM 187, Shweta, and Rudarpur local). The parental varieties were selected either because farmers in the project area had accepted them or because they contributed complementary traits to the population. The population has been randomly mated for five cycles by hill-planting seed derived from the original nine crosses and detasseling 50% of the plants. After the initial random mating, each cycle was planted from pale yellow grains that should be heterozygous at the locus controlling endosperm color. Three composite varieties have been extracted from cycles three and four by random mating of early-maturing plants (75 to 80 days) with either yellow or white grains. Preliminary results show that these populations are superior to local checks for multiple traits. Intervarietal hybrids were also made from farmer-preferred varieties. Farmer-managed participatory research (FAMPAR) trials conducted in the rainy season of 1998 showed that farmers preferred the BM 1 x Suwan intervarietal hybrid to the local varieties. Further evaluations of hybrids in on-farm and station trials are being conducted.

Introduction

After rice, maize is the most important cereal crop in the rainy season for the largely tribal farmers of the Chhotanagpur plateau region of eastern India. However, maize is in decline and yields vary greatly from year to year. The Birsa Agricultural University (BAU), Ranchi has released several varieties, but tribal farmers have not adopted them because of their late maturity, which results in the common end-of-season droughts severely limiting yields. Therefore, a participatory maize breeding program was initiated in a collaborative project between Birsa Agricultural University, Ranchi, and the KIBHCO Indo-British Rainfed Farming Project (KRIBP) managed by KRIBHCO (Krishak Bharati Co-operative).

The major objective was to breed and test early-maturing and high-yielding open-pollinated varieties and intervarietal hybrids of maize in participation with farmers. An analysis of farmers' constraints showed that farm holdings are very small in the area and that shallow, infertile soils on sloping lands give poor yields. The crop is largely rainfed, and irrigation to mitigate the effects of drought is rarely available.

Participatory rural appraisals were used to solicit farmers' preferences in maize varieties. Farmers wanted the following:

- early maturity
- yellow-endospermed flint grains and high yield

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- long cobs with high placement on the stem
- prolificacy (two to three ears per plant)
- resistance to lodging, disease, and insect pests
- nonhybrid varieties because of the cost and difficulties of purchasing hybrid seed every year

Breeding strategies

To develop new varieties of maize, two strategies were adopted:

- breeding open-pollinated composite varieties
- breeding intervarietal hybrids

Composite breeding

To breed new open-pollinated composite varieties a base population was initiated in the main season of 1997 by making nine crosses between three yellow-endospermed flint varieties (BM 1, Suwan, and Chandan 3) and three white-endospermed flint varieties (GDRM 187 from Gujarat Agricultural University and KRIBP west, Gujarat [see Goyal, Joshi, and Witcombe, this volume]; Shweta, from Uttar Pradesh; and Rudarpur local, from Uttar Pradesh). The parental varieties were either farmer-preferred varieties or had complementary traits. The three yellow varieties are medium- to late-maturing and have a higher yield potential when water is not limiting than the three earlier-maturing white varieties. By 1999, the population had been randomly mated for five cycles by using a pseudo-random hill planting plan. In each cycle, 50% of the plants were detasseled, and pale yellow grains were harvested from the detasseled plants (Goyal, Joshi, and Witcombe, this volume). At the C_3 and C_4 cycles, two open-pollinated (C3/98-99 and C4/99) varieties were extracted from the base population.

The yellow-grained variety C3/98-99 was formed from deep yellow seed harvested from about 200 early-maturing, detasseled plants of the C_3 cycle of the base population in the post-rainy season of 1998–99. In the rainy season of 1999, the random-mating population was grown from these seeds. In the post-rainy season of 1999–00, farmers were invited to visit the research station at Ranchi to select desirable plants. Farmers graded them into three categories and the third preferences were rejected. In the rainy season of 2000, the selection will be repeated and the population will be tested in research station trials.

Similar procedures were followed for variety C4/99.

A white-endospermed population was also developed by bulking white grains from three sources: from selected plants of the C_4 cycle of the base population, from the C3/98-99 population grown in the rainy season of 1999, and from plants selected for making the C4/99 population. The first random mating will be carried out in the rainy season of 2000, and farmers will be involved in selection before and after flowering.

Intervarietal hybrid and composite breeding

Intervarietal hybrids offer a faster approach to creating new varieties for farmers than generating new composites, but they require more complex seed multiplication than open-pollinated varieties. However, the seed of intervarietal hybrids is cheaper and somewhat easier to produce than that of

single-cross hybrids based on inbred lines. If intervarietal hybrids were greatly preferred, then KRIBP would attempt to produce seed within project villages.

In single-cross hybrids, advanced generations from farmer-saved seed are considerably lower yielding than the original F_1 generation. However, the advanced generations of intervarietal hybrids may still yield well. How much hybrid vigor is lost if farmers retain the seed of hybrids is being evaluated in the rainy season of 2000 by using advanced open-pollinated generations from the F_1 intervarietal hybrid.

Some farmers have preferred the open-pollinated varieties Suwan, BM 1, and Chandan 3 to their local varieties. These varieties, along with Megha, a drought-tolerant and early-maturing variety from Punjab, were used as parents to produce three intervarietal hybrids in the rainy season of 1997: BM 1 x Suwan, BM 1 x Chandan 3, and Megha x Suwan.

Evaluation

The new open-pollinated varieties developed have not yet been tested for yield on farmers' fields. However, intervarietal hybrids were tested in farmer-managed participatory-research (FAMPAR) trials in the rainy season of 1998 as well as in research-station trials in the pre-rainy season of 1998–99 and the rainy season of 1999.

Of the three hybrids tested, BM 1 x Suwan yielded the most in trials conducted in the pre-rainy season of 1998-99 (table 1). The advantage of the intervarietal-hybrid approach is clear: the hybrid yields more than either parent and is earlier than the later, highest-yielding parent (Suwan).

FAMPAR trials in the rainy season of 1998 showed the following:

Table 1. Performance of Three Intervarietal Hybrids of Maize on the BAU-KRIBP Research Farm, Ranchi, Bihar, during the Post-Rainy Season of 1997–98 (Summer 1998)

Hybrid	50% silking (d)	50% tasseling (d)	Maturity (d)	Plant height (cm)	Ear length (cm)	Yield/ plant (g)
Suwan x Megha	102	110	148	151	17	125
BM 1 x Suwan	99	108	147	136	17	145
BM 1 x Chandan 3	94	98	139	135	16	115
Suwan	104	111	159	146	16	105
BM 1	95	99	139	127	14	100
Megha	93	96	135	137	13	93
Chandan 3	96	101	144	129	17	125
GDRM 187	86	93	132	116	13	88

- Farmers preferred BM1 x Suwan and Chandan x Suwan because of their yellow flint grains, higher yield, medium maturity, and higher fodder yield.
- Hybrid Megha x Suwan was rejected because of a high proportion of poorly developed and diseased plants.

The two farmer-preferred hybrids were further tested in the rainy season of 1999 at the BAU-KRIBP farm (figure 1). Hybrid BM 1 x Suwan, the highest-yielding entry, yielded more than both parents and was earlier than the highest-yielding parent. Chandan 3 x Suwan was earlier than either parent, and although it yielded less than Suwan, the advantage in earliness of 19 days would mean that farmers would prefer it to Suwan. Both intervarietal hybrids had cob placement equivalent to the best parent, Suwan (high cob placement protects from jackal damage).

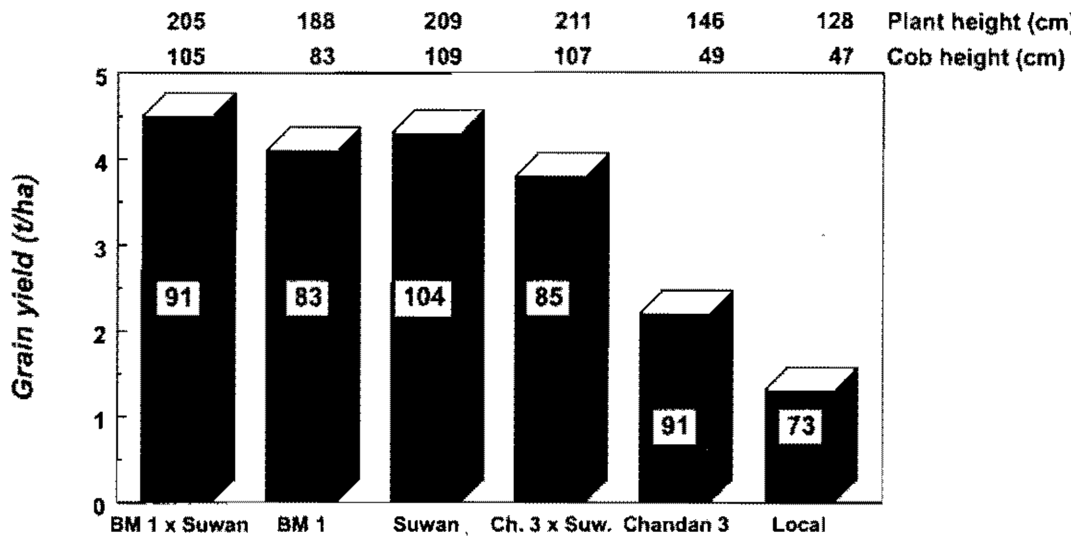

Figure 1. Performance of two intervarietal hybrids in the rainy season of 1999 at the BAU-KRIBP Research Farm, Ranchi, Bihar (Days to maturity are indicated on the bars.)

The intervarietal hybrids themselves are certainly promising. What now needs to be done is to look at the feasibility of their seed production—either with village-based organizations in the development project area or, on a more commercial level, with the public- or private-sector organizations. How important this will be will depend, in part, on how well the intervarietal hybrids compete with open-pollinated varieties derived from the composite.

References

Goyal, S.N., A. Joshi, and J.R. Witcombe. Participatory crop improvement in maize in Gujarat, India. *This volume.*

Participatory Plant Breeding in Rice in Eastern India

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Abstract

This paper describes a participatory plant-breeding (PPB) program for rice in eastern India, targeted at a range of ecosystems. Only a few crosses with large populations were used. Most resources were used on selection by farmers among F_4 progeny bulks grown on a research station, but farmers also selected within F_4 bulk populations on their fields. Farmers (both male and female) from villages served by the KRIBHCO Indo-British Rainfed Farming Project made selections among bulk progenies derived from a cross between Kalinga III and IR64 that were grown at Ranchi, Bihar, in the main (rainy) season of 1998. The three most selected progeny bulks were promoted to an All India Co-ordinated Rice Improvement Project varietal trial in the main season of 1999. One of these was Ashoka 200F, the result of selection within an F_4 bulk in a farmer's field. The performance of all three varieties in the initial varietal trial at Birsa Agricultural University (BAU), Ranchi, in the main season of 1999 was good. Ashoka 200F yielded 2.90 t ha^{-1} compared to 1.95 t ha^{-1} for Kalinga III. All three entries were as early and slender-grained as Kalinga III, and all were more resistant to lodging. In the main season of 2000, these varieties will be tested in a participatory varietal selection program in six project villages. The approach of using a low-cross-number, large-population breeding strategy with both consultative and collaborative participation has rapidly improved Kalinga III, the most widely adopted upland rice in India. Among other strategies, we have used modified-bulk population breeding to provide heterogeneous and homozygous bulks to farmers for selection.

Introduction

Bihar, a typical eastern Indian state, has 5.4 million ha planted to rice, with yields of, on average, only 1.2 t ha^{-1} of grain. More than half of the rice area is rainfed, including the drought-prone, upland ecosystem. In this ecosystem, most farmers grow traditional varieties and productivity is very low. Most farmers prefer to grow traditional varieties. Many of the varieties bred and released by the formal system, both nationally and at the state level, have not been adopted by farmers because they lack traits important to farmers (Virk and Bhasker Raj 1996). However, variety Kalinga III, which was promoted by the project in its target area covering nine districts of Bihar, West Bengal, and Orissa, has several advantages—excellent grain quality and extreme earliness, which allows it to escape end-of-season droughts. However, because it has weak straw, a major objective of the participatory plant-breeding (PPB) program was to breed varieties to replace Kalinga III that did not have this weakness.

Breeding strategies

The breeding strategy was to cross a popular, locally adapted cultivar (in this case, Kalinga III) with exotic, high-yielding cultivars from a centralized breeding program (Witcombe et al. 1996). Varieties IR64 and IR36 were chosen as the high-yielding cultivars since both are grown in large areas in eastern India. A strategy of a few crosses with large populations was used (Witcombe and Virk, in press).

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At the request of the Centre for Arid Zone Studies (CAZS), crosses were made at the International Rice Research Institute (IRRI), in the Philippines. Because only a few crosses were used, more resources could be devoted to each cross, so large population sizes and many progeny rows were employed in the breeding program. A large F_2 population was raised at Ranchi in the main season of 1997 and the F_3 was grown in the off-season at the Central Rice Research Institute (CRRI), Cuttack, in 1997–98. In the main season of 1998, the crop was grown at the collaborative research farm of Birsa Agricultural University (BAU) and the KRIBHCO Indo-British Rainfed Farming Project (KRIBP), Ranchi. Each year since then, two crops have been grown. We describe the breeding strategy for the Kalinga III x IR64 cross. Two participatory methods were used; they varied according to the main type of participation employed, i.e., consultative or collaborative (Joshi and Witcombe 1998).

Consultative breeding

In the consultative approach, breeders grew all of the trials on a research farm with moderate application of purchased inputs. Farmers from villages where the KRIBP project was operating were brought to the farm to make selections. Farmers visited the BAU-KRIBP research station farm on two occasions. There were two groups of farmers: one of 23 men and one of 12 women. Farmers observed 177 bulk-pedigree lines at the F_4 generation in 10 m^2 plots and 400 single-row plots of 2.5 m in length. Farmers selected plots for one of four ecosystems (uplands, medium uplands, medium lowlands, and lowlands) using labels of four colors. Farmers selected 68 plots; and breeders, 23. Of these, 20 were selected by both farmers and breeders.

The two most preferred entries—Ashoka 228 and Ashoka 238—were multiplied in the off-season 1998–99 at CRRI, Cuttack, and were submitted to formal trials at the F_6 generation in 1999 along with another variety derived from the same cross, Ashoka 200F (see below).

Collaborative breeding

In the collaborative-breeding program, farmers grew segregating generations in their own fields. Although we believe that the F_2 generation is usually too early a generation for farmers to make selection efficiently, given the availability of seed and as an experiment, two farmers were given F_2 seed in 1997. Neither farmer, one in West Bengal and one in Orissa, continued with the population. The F_3 generation was grown at BAU in the main season and further advanced in the off-season of 1997–1998. Ten kilograms of the F_4 bulk seed so obtained was given to four farmers in the main season of 1998. One farmer in Mehru village, Rajendra Singh, grew 2 kg of F_4 bulk seed and selected earlier-maturing plants of similar phenotype that had slender grains. This gave rise to Ashoka 200F. In Jhabrah village, West Bengal, Sakya Singh Mahto, grew 2 kg of the F_4 bulk in 1998 and its further generation in 1999. He selected for tall and dwarf types under medium land situations. Within the tall and dwarf bulks, he produced early and late bulks. These bulks will be tested in the main season of 2000 on the research station. The other two farmers did not pursue the populations further.

Performance of Ashoka entries

The three Ashoka entries were tested in the All India Co-ordinated Rice Improvement Trials, IVT E (DS), at BAU, Ranchi, in the main season of 1999 (figure 1). They were also tested in another trial at the BAU-KRIBP farm, Ranchi, under direct-seeded conditions. In both trials, all Ashoka entries yielded considerably more than Kalinga III (an average increase of over 50%). Two of them were as

early to flower as Kalinga III. Farmer-selected Ashoka 200F was the best entry in the All India Co-ordinated trial at Ranchi and the second best for yield in the BAU-KRIBP trial.

A parallel program was followed for the Kalinga III x IR36 cross. The F_4 bulks of this cross have been named Sudha and are being evaluated in formal and farmer-field trials in the main season of 2000.

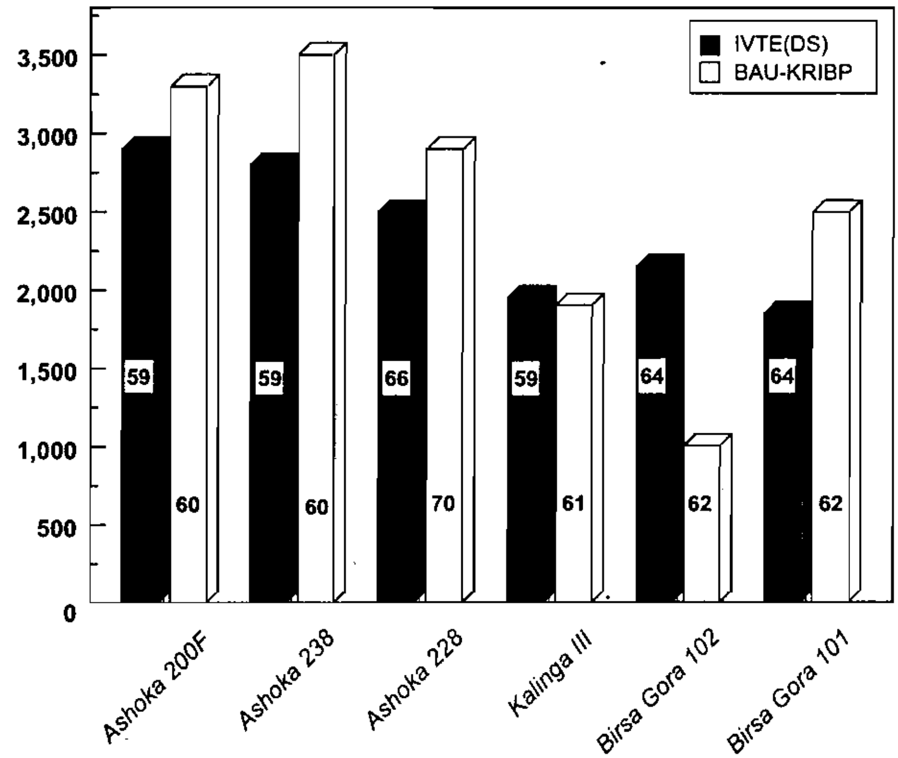

Figure 1. Grain yield (kg ha^{-1}) and time to flower (days) of three Ashoka entries derived from the cross Kalinga III x IR64 in comparison to check varieties in the All India Co-ordinated Rice Improvement Project trial (IVT E [DS]) at the Birsa Agricultural University, Ranchi, farm in *kharif* 1999, and in another trial conducted at BAU-KRIBP research farm (The numbers on the bars indicate days to flowering.)

Other participatory plant-breeding strategies

In addition to the two crosses of Kalinga III x IR64 and Kalinga III x IR36, other crosses have been made for participatory plant breeding (PPB). Modified bulk-population breeding is being used in the cross Kalinga III x Vandana, and the F_6 bulk populations will be grown in the main season of 2000.

Conclusions

Even though, so far, the products of only a single cross, Kalinga III x IR64, have been tested in formal trials, progress has been considerable. A yield increase of 50% over the variety targeted for

replacement, Kalinga III, in only four years is an annual rate of gain far in excess of most conventional breeding programs. Moreover, the gain will reach farmers more quickly. The gains have been made without any loss in the quality of grain shape and, in two of three cases, without any increase in length of maturity. It is not possible to apportion these gains into the novel components of the breeding program, and it is over simplistic to say that the difference is due to participatory methods. This is only one component, since the breeding program also employed a strategy of low cross number, high population size, with selection in the target environment, or one very similar to it (Witcombe, Joshi, and Subedi, this volume).

The true success, or otherwise, of the breeding program awaits the results of collaborative participation (the testing of new varieties in farmers' fields in the main season of 2000), when traits other than yield and maturity will be evaluated. However, even if these entries prove to be unacceptable, the high population sizes used mean that there are many more entries from the same cross that can be tested. These entries, like Ashoka 200F, yield more than Kalinga III and have retained the desirable slender grains and early maturity of Kalinga III.

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Participatory Crop Improvement in Maize in Gujarat, India

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Abstract

This paper describes a participatory plant-breeding (PPB) program for maize in a rural development project financed by the United Kingdom's Department of International Development (DFID) and the Government of India and executed by the Krishak Bharati Cooperative (KRIBHCO). The program was targeted at low-resource farmers of the Panchmahals district of Gujarat. Farmers were given a range of maize varieties to try in a participatory varietal-selection program. However, none of these proved to be overwhelmingly popular with farmers, although maize variety Shweta from Uttar Pradesh was adopted by some farmers for more fertile fields. Hence, in 1993 a breeding program was begun by crossing yellow- and white-endospermed maize varieties, all of which had some acceptance or positive attributes identified in participatory trials. The breeding program targeted traits identified by farmers, and in some generations, selections were carried out by farmers in the populations grown on land rented by the project. Soil-fertility management was lower than that normally used on research-station land. The breeding program has produced several successful varieties. One of them, GDRM 187, has qualified for release and yielded 18% more than the local check in research station trials, while being seven days earlier to silk. In farmers' fields, where average yields were lower, the yield advantage was 28%. Farmers perceived GDRM 187 to have better grain quality than local landraces.

Introduction

The Gramin Vikas Trust (formerly the KRIBHCO Indo-British Rainfed Farming Project [KRIBP]) manages a participatory-development project in rainfed areas of western India. It is financed by the UK Department for International Development (DFID) and the Government of India. Initial surveys at the project planning stage showed that, in common with many marginal environments in India, the adoption of improved cultivars by the resource-poor farmers of the project area was extremely low. At the inception of the project, a program of participatory varietal selection (PVS) was planned. The methods of PVS employed (Joshi and Witcombe 1996) were designed to identify and overcome the constraints that caused farmers to continue to grow landraces. In the first three years of the project, PVS programs were conducted with several crops, including rice, maize, chickpea, black gram, and pigeonpea. The PVS program in maize identified varieties that were liked by farmers, but none of them were suitable for the most common agricultural environments of the project area. Given the shortcomings of the PVS program, a participatory plant-breeding (PPB) program was initiated early in the project. This paper describes some of this program.

Materials and methods

In the past, efforts to breed white-endosperm maize have been largely, or even entirely, dependent on the progeny of crosses between white-endosperm parents. However, since most maize-breeding programs have concentrated on yellow maize, the diversity and yielding ability of yellow maize parents is higher. It is, therefore, desirable that yellow-grained parents be used when breeding white-grained maize. Crossing white and yellow endosperm maize in the breeding of white maize is

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reasonably straightforward because grain color is a highly heritable trait, affected by xenia (i.e., the pollen genotype is apparent in the seed in the maize cob), which makes the trait even easier to select. Not only is access then gained to superior yellow maize as parents, but crosses between relatively unrelated yellow and white maize varieties create a very broad-based population.

Parents were chosen on the basis of adaptation to the project area in PVS trials (table 1), the results of which are summarized in Joshi and Witcombe (1998). In all cases, the varieties were within the maturity range of the maize grown by farmers in the project area.

Table 1. The Varieties Used as Parents of the Composite

White-endosperm varieties		Yellow-endosperm varieties	
Name	**Breeding institution**	**Name**	**Breeding institution**
Gujarat Makka 1	GAU[a]	Mahi Kanchan	RAU[b]
Shweta	G.B. Pantnagar[c]	Navin	G.B. Pantnagar
Chandan Safed 2	JNKVV[d]	Chandan Makka 3	JNKVV

Note: In all cases, the breeding institution was the State Agricultural University.
[a] Gujarat Agricultural University, Gujarat.
[b] Rajasthan Agricultural University, Rajasthan.
[c] G.B. Pantnagar University, Uttar Pradesh.
[d] Jawaharlal Nehru Krushi Vishva Vidhyalaya (JNKVV), Madhya Pradesh.

Selection was done in an appropriate environment: low-fertility fields under management typical of local farmers. The traits selected for were those identified by farmers. In some of the later generations, farmers were invited to carry out mass selection in the populations. Early in the breeding program, farmers were given the composite to evaluate in their fields, and as soon as varieties were produced from the composite, they were included in PVS trials.

Several white-endosperm and yellow-endosperm varieties were produced from the composite by selection for grain color after random mating was completed. Three white-endosperm varieties, GDRM 185, GDRM 186, and GDRM 187, were tested in formal trials and on farmers' fields in participatory trials.

GDRM 187 was bred as an extra-early variety of maize. Extra-early varieties, such as Chandan Safed 2, can play an important role in the farming system, particularly for growing in rows that alternate with other crops. Chandan Safed 2 had been appreciated by farmers in the participatory trials, particularly for intercropping with pigeonpea, as the maize could be harvested before it had a significant competitive effect upon the pigeonpea crop. Moreover, early varieties can escape end-of-season drought and produce a harvest at the time when grain is scarce, thereby fetching a high price. It was assumed that Chandan Safed 2 could be improved because it was a direct introduction from South America. GDRM 187 was bred from all six parents (table 1), but in the third generation of random mating, selection was made for plants that had Chandan Safed 2 as a maternal grandparent, and these lines were backcrossed to Chandan Safed 2.

Results

The white-grained maize varieties were tested by Gujarat Agricultural University (GAU) in the system of state trials that is used to identify varieties for release. The mean performance of these entries was superior for grain yield by 7%–29% (depending on the variety) in a multi-year, multi-locational trial to that of Gujarat Makka 1 (GM 1), a variety that out-yields the most widely grown local landrace by 10% for grain. They also silked two to six days earlier than GM 1.

In the rainy season (*kharif*) 1997, GDRM 185 and GDRM 187 were tested in farmer-managed participatory-research (FAMPAR) trials in Itawa and Bihar (Madhya Pradesh); Sarjumi, Bar, and Katarani Palli (Gujarat); and Khundini Rupa, Mathura Khali, and Kunda (Rajasthan). Focus-group discussions showed that both varieties were much preferred by farmers over the local varieties. Both were perceived to be earlier than the local varieties (GDRM 187 particularly so) and to be higher yielding. GDRM 187 was reported to have much better grain quality than the most widely grown local variety, and GDRM 185 was reported to have somewhat better grain. Both varieties were reported to have fewer plants that failed to produce cobs, more plants with two cobs, larger cobs, and, unlike the local varieties, cobs that were filled to the tip.

In *kharif* 1998 GDRM 187 was tested in three villages in Gujarat and one in Rajasthan (figure 1). Yield increases in farmers' fields were higher in percentage terms than those found in higher yielding research station trials. Overall, GDRM 187 was the variety most liked by farmers. Like GDRM 185 and GDRM 186, it yielded more than the local varieties, but it had the added advantage of being significantly earlier to mature. In addition, farmers commented that its cobs were tightly and completely enclosed by the husk, reducing insect attacks, and they also commented on the superior quality of its grain.

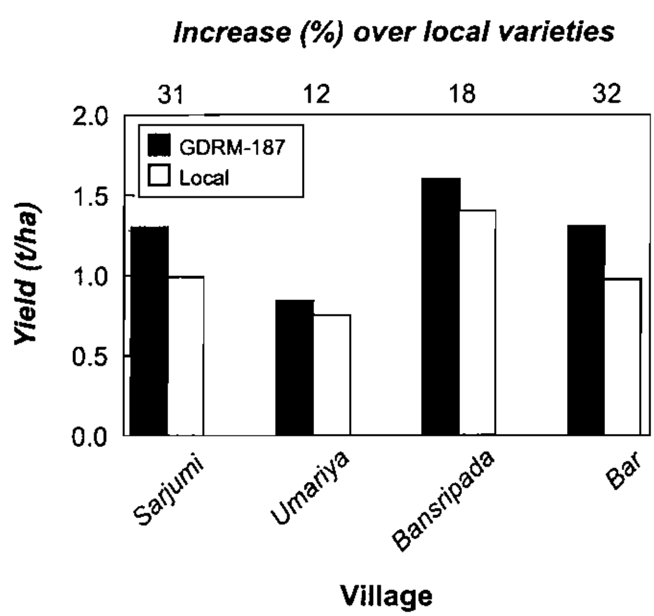

Figure 1. The performance of GDRM 187 in FAMPAR trials compared to the local varieties in four villages: Sarjumi, Gujarat (20 trials); Umariya, Gujarat (5 trials); Bansripada, Rajasthan (6 trials); and Bar, Gujarat (15 trials)
(The advantage of GDRM 187, averaged over 46 trials, was 28%.)

Discussion

PVS does not always work but it builds the foundation of a sound PPB program

The PVS in maize was not very successful. Perhaps this is not surprising since most of the varieties that were tested were not bred in the target environment. Gujarat Makka 1, the only cultivar that was bred in the area, was selected from the local landrace "Farm Sameri." Although this selection was successful in producing a statistically higher-yielding variety in trials, the difference was insufficient. On farmers' fields its 10% yield advantage was not noticed by farmers.

Even a PVS program that does not identify highly successful varieties is of use. In this case, it enabled target traits to be identified—for example, the preference for white grain and extreme earliness. Most important, it allowed the identification of parental genotypes.

Was this a participatory plant-breeding program?

Biggs (1989) classified participation into four types, two of which are collaborative and consultative participation. *Collaborative* participation by farmers mass selecting in the populations in their own fields was attempted, but failed. It was difficult for farmers to prevent cross-pollination of the composite with locally grown material by, for example, planting the crop in an isolated plot. Farmers were reluctant to mass select by uprooting undesirable plants because of the loss of yield this would entail. The alternative of detasseling undesirable plants and rejecting them at harvest time would be possible but difficult. However, the breeding program did involve *consultative* participation—farmers were involved in the identification of parental material and target traits, and in the evaluations of the breeding generations on the research farm. Of major importance was the *decentralization* of the breeding program. Although selection was not in farmers' fields, it was in the target geographical area. The composite was grown under lower input levels than normally found in a research station and closer to the levels used by farmers.

The breeding program also had innovative aspects that were not related directly to farmer participation. Wide crosses were made between yellow- and white-endosperm maize with reselection for white. Quite elaborate designs during the random mating of the composite were employed: hill planting and detasseling was done to increase the pollination between progeny of the original nine crosses and reduce sibbing within them. In the random-mating generations, grains with pale yellow were selected to advance the next generation. This color is the most probable phenotype of heterozygotes and selecting for it maximized the possibility of recombination around the locus controlling grain color.

It is not possible to know which component was most important in the success of the program—collaborative selection of parents by PVS, consultative PPB, decentralization to the target environment, or innovative breeding techniques. However, part of the breeding philosophy in PPB, argued by Witcombe et al. (1996), is the need to concentrate on only a few crosses or populations, which allowed the required resources for the novel techniques used in the breeding program.

Was PPB cost effective?

Conventional breeding had never produced a cultivar that was preferred by even a significant minority of the farmers in the project area. In about five years, PPB had produced at least one cultivar, GDRM 187, that was liked by most farmers for most of their fields. It yielded significantly more grain (about 15%–30% more) even though it was significantly earlier to flower (about one week earlier). This combination of higher yield and earlier flowering is extremely valuable for farmers

and is normally a difficult combination to achieve in any maize-breeding program. GDRM 187 also had other advantages, including improved grain quality, that should increase its speed of adoption and its adoption ceiling. All this was achieved with modest resources, since only a single composite was created and only a few varieties were derived from it.

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Towards a Practical Participatory Plant-Breeding Strategy in Predominantly Self-Pollinated Crops

J.R. Witcombe, M. Subedi, and K.D. Joshi

Abstract

There is a limit to the capacity of any breeding program, and the more crosses that are made, the smaller the size of each cross. The theory of the optimum number of crosses in inbreeding crops is briefly reviewed. The theory is unsatisfactory in determining the optimum number of crosses, but models that take linkage into account show that very large populations are needed to recover specified genotypes. Hence, one possible strategy is to select a small number of crosses that are considered favorable and produce large populations from them. This strategy is ideally suited to the particular constraints and advantages of participatory plant breeding (PPB). When a breeding program is based on few crosses, the choice of parents is crucial and farmer participatory methods are highly effective in narrowing the choice. Modified bulk-population breeding methods are desirable strategies in the participatory plant breeding of self-pollinating crops when combined with a low-cross-number approach, and a participatory breeding program for rice in Nepal is described.

Introduction

In most, perhaps all, conventional breeding programs for inbred crops on research stations, breeders deal with many crosses each season. Even with fairly limited resources many hundreds, or even thousands, of F_4 or F_5 lines can be tested. Unless there is considerable researcher input into the layout of trials in farmers' fields, participatory plant breeding (PPB) has to employ many fewer crosses and entries than conventional or classical breeding. In farmer-designed, farmer- managed trials, each farmer usually grows only one entry (e.g., Joshi and Witcombe 1996) and the number of participating farmers thus limits the number of entries. However, a very large population of any entry can be grown, with little or no cost, or even with a benefit. In PPB, a farmer replaces his or her cultivar with a population for PPB on land that would normally have been devoted to the crop. The cost of this replacement is any decrease in value of the harvest caused by the replacement and the benefit is any increase in harvest value. In contrast, in classical breeding all the costs of any increase in the area of the cultivated crop are borne by the breeding program. We briefly review the theoretical evidence on the number of crosses that are required in a breeding program. We describe a rice breeding program in Nepal that is using a low-cross-number, high-population-size strategy.

Theory on the number of crosses in a breeding program

The optimum number of crosses required in an inbreeding crop was reviewed by Witcombe and Virk (forthcoming) and only a summary is presented here. To calculate the optimum number of crosses, crucial assumptions are required on the rate of the inevitable decline in the potential value of each cross as more and more crosses are made. If the decline is very significant (e.g., a few

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crosses can be identified as having a higher probability of giving desirable segregants than others), then only a few crosses are needed. If the decline cannot be predicted, then many are required. The lack of quantitative data to support assumptions on the rate of decline limits the role of theory in deciding the optimum number of crosses. However, to recover specified genotypes, large population sizes are needed that, given a limit to the overall size of any breeding program, will limit the number of crosses. Whether a high-cross-number or a low-cross-number approach should be used depends greatly on the judgment of the researcher as to whether the value of crosses can be predicted with any certainty. In a decentralized breeding program, the target environment and the required traits in a finished variety are known, and the knowledge of existing adapted germplasm is considerable. This allows such predictions to be made, so a low-cross-number strategy appears sensible. Many fewer crosses than are common in most breeding programs will be used, and for all of them there will be logical reasons as to why the cross should have a high probability of producing favorable segregants. There will be many fewer crosses than commonly suggested from theoretical calculations that invariably assume there is no prior information on the value of any cross, i.e., that all crosses are considered to have an equal chance of success (Yonezawa and Yamagata 1978; Wricke and Weber 1986; Huehn 1996).

In a large-cross-number strategy, population sizes are likely to be limited to a few hundred rather than several thousand. In a low-cross-number strategy, population sizes can be larger and increase the probability that desirable segregants that are an improvement over the best parent are recovered. All that is needed is that the two parents differ significantly for an important trait (a practical certainty) at some point in the genome. A segregant that has a genome substitution from the other parent at this point will be superior, providing the sum of the rest of the genome is equal to the best parent. The existence of a cross that cannot give rise to superior segregants is theoretically impossible, although the population size required to recover desirable segregants may be impracticably large. However, choosing complementary parents increases the likelihood that there will be a sufficiently high frequency of desirable segregants for them to be selected.

Towards a practical participatory breeding strategy

PPB is ideally suited to the strategy of rigorously selecting parents, using a small number of crosses and employing large populations. Participatory varietal selection (PVS) is the first step in selecting desirable parents. It allows local and introduced germplasm to be evaluated using participatory approaches; it identifies candidate varieties having suitable traits and determines their acceptability to farmers.

A PPB program in an inbreeding crop can start on the basis of one cross or very few crosses. Even with a low-cross-number strategy, the number of crosses covered will gradually increase over time if one, or a few, new crosses are made each year. This will help to maintain the farmers' interests by a supply of novel germplasm and allows a continuing incorporation of new genetic material from more centralized breeding programs.

Pedigree breeding generates a large number of lines (the selection units) that can only be accommodated with difficulty in a PPB program. The most effective methods keep the number of selection units to a minimum, thus allowing one, or an acceptably low number, of selection units per farmer. However, large population sizes can be used because the marginal costs to the program of increasing population size are very low (figure 1). Hence, bulk-population breeding is ideal for PPB, in either its pure form or modified by dividing the population into sub-populations according to

Figure 1. A very large population grown by a farmer, Chitwan, October 1998. The only possible cost to the farmer is that there might be a reduction in the yield of the F_4 bulk of Kalinga III x IR64 (right) compared to Masuli (left).

farmer-important traits. Bulk-population approaches have been used with success in classical breeding, e.g., Carver and Bruns (1993) report that 30% of wheat releases from a breeding program resulted from bulk population breeding that took less than 8% of the resources.

We are conducting a PPB program in rice, targeted at a range of environments in Nepal. These vary from the *Terai* (alluvial, low-altitude, flat land in the southern part of Nepal at about 150 m altitude) in both the main season (sown in June) and the *chaite* season (sown in February). The breeding program is also targeting a range of irrigated environments up to 1500 m altitude. Only a few crosses have been made during the course of this breeding program, which commenced in 1996 with two crosses made by the International Rice Research Institute (IRRI) at the request of the project and one cross made at the Center for Arid Zone Studies (CAZS), Bangor, by Dr. D.S. Virk.

All three crosses involved the upland rice variety Kalinga III as one of the parents. Kalinga III was identified in western India in a PVS program (Joshi and Witcombe, 1996). Farmers like it for its very short duration and, an unusual trait for an upland rice variety, its slender grains. Although it is an upland rice variety adapted to marginal conditions, it is widely adapted even though it was rejected from All-India Co-ordinated Crop Improvement Program multilocational trials. It was released for rainfed, drought-prone, cold-susceptible environments only in Orissa, on the basis of trials in that state, but is now widely grown in Bihar, West Bengal, Madhya Pradesh, Rajasthan, and Gujarat. In PVS trials, it performs extremely well as a *chaite* rice in the Nepal *Terai* under partially irrigated conditions and can be grown as a main-season rice in the low hills of Nepal up to 1000 m under rainfed conditions.

One of the crosses made at IRRI was Kalinga III x IR64. IR64 is a longer duration, high-yielding variety adapted to irrigated conditions. At one time it was the most widely grown rice genotype in the world and has occupied the majority of the rice-growing area in the Philippines and Indonesia. It has also been released in India for Tamil Nadu but is widely grown in other states as well, e.g., West Bengal and Haryana. It has wide adaptability, multiple pest and disease resistance, and slender, translucent grains.

It is clear that in this low-cross-number strategy, an enormous amount of information is available on the parents. Kalinga III has weak straw and a low yield potential. IR64 has complementary traits: a very high yield potential and it is highly resistant to lodging. It can also contribute pest and disease resistance to Kalinga III, even though this variety has few susceptibilities. In targeting high-yield-potential environments, Kalinga III can contribute earliness to IR64, and because of its extreme genetic divergence from IR64, it is reasonable to expect transgressive segregation for yield in these environments. For the *chaite* season and somewhat higher-altitude, high-yield environments, Kalinga III contributes cold tolerance.

In PPB, an essential part of the strategy of selecting appropriate parents is that one of them is locally adapted. Kalinga III has been adopted by farmers for partially irrigated conditions in the *chaite* season. However, it is a niche variety and other crosses have been made involving the most popular *chaite* rice, CH45, and the most popular main-season variety, Masuli.

In the early stages of creating the bulk populations, the breeding program for the cross Kalinga III x IR64 was entirely researcher managed on land rented from a farmer. Initially 290 F_3 lines of the cross were grown in the *chaite* season of 1998. The progeny rows were highly diverse and they were grouped into six bulks based on their height (tall or dwarf) and maturity classes (early <110 days seed to seed; medium 110-125 days; and late >125 days). The bulks were named as follows: ED = early dwarf; ET = early tall; MD = medium dwarf; MT = medium tall; LD = late dwarf and LT = late tall. Of these, the performance of the early dwarf proved to be unsatisfactory and it was dropped. The performance of the MT bulk was good but highly variable, so it was further divided into four: MT1 = earlier shorter; MT2 = earlier taller; MT3 = later shorter; and MT4 = later taller (figure 2).

After dropping the ED bulk and dividing the MT bulk into four, there were eight bulks. Three were then advanced without further division (the two dwarf bulks and the late bulk). However, in five of the bulks, further division was made among the F_5 seed into grain type, i.e., long, intermediate or short in length. In the F_6 generation, the resultant bulks were grown by researchers and evaluated by farmers (consultative participation). Combinations of maturity and grain types were selected and rejected. For example, in later-maturing bulks that more or less matched the maturity of CH45, only nonslender types were acceptable. For rice of this maturity, the harvest of which coincides with the rains, it is only economic to produce roasted, flattened rice, for which only less-slender-grained varieties are suitable. In contrast, in the earlier groups, all grain types were acceptable.

By the F_6 generation the bulks were recognizable by farmers, because most of the plants shared common traits, but the bulks still had significant genetic heterogeneity within them for farmers to be able to make selections. In the *chaite* season of 2000, farmers were given the bulks at the F_7 stage and the results of this farmers' selection will be evaluated.

As well as the modified bulk populations breeding approach, we are also trying variants of single-seed descent (SSD) such as equal-seed descent. In classical breeding programs, SSD is increasingly employed to rapidly and cost-effectively produce homozygous lines. It concentrates

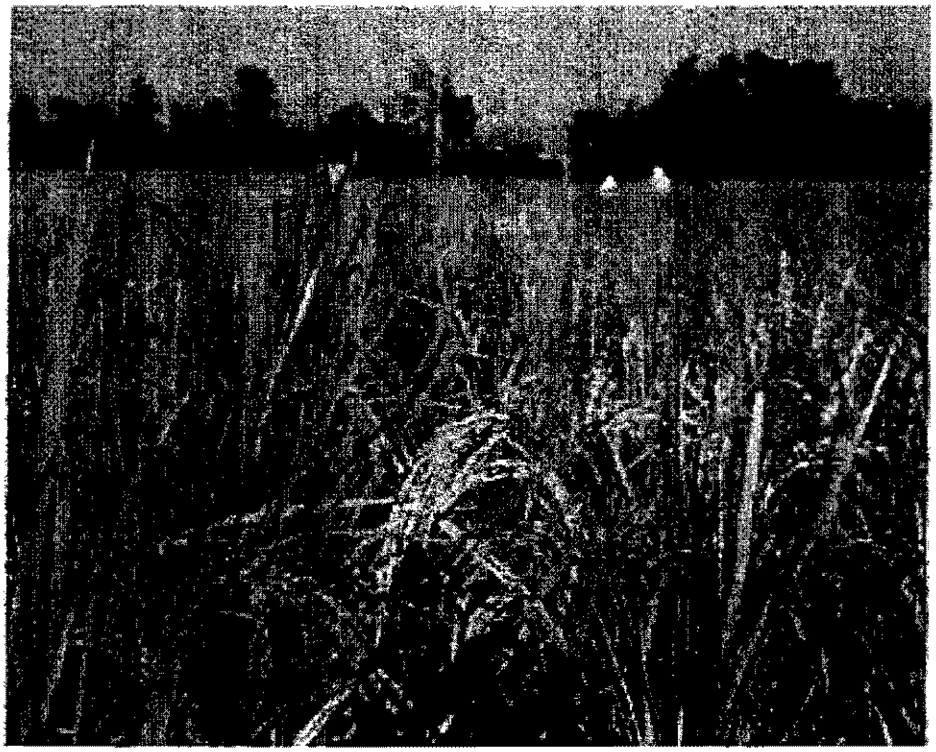

Figure 2. An example of rice sub-bulks at the F_5 stage in the cross Kalinga III x IR64, Chitwan, October 1999. Note the large population sizes (the people in the background are working in the same bulk as the one seen in the foreground) and the two bulks—earlier-maturing bulk MT2 (right) and a later-maturing bulk MT3 (left).

selection in advanced generations that are highly homozygous and where selection is more effective than in earlier, more heterozygous generations (e.g., Delzer, Busch, and Hareland [1995] and Van Oeveren [1992] in wheat; Fahim et al. [1998] in rice). We have modified SSD to retain even more variation by using equal- rather than single-seed descent in the earlier selfing generations. It also allows multiplication so that by the F_5 or F_6 generation, large quantities of seed of each bulk (or sub-bulk) can be supplied to many farmers. The probability of selecting desirable segregants is increased when the entire selection process is replicated across farmers.

Participatory techniques must complement and cannot replace classical breeding. Some low-heritability traits can only be selected under controlled environments, and modern techniques that facilitate wide crossing, such as embryo rescue, are confined to the laboratory. No single participatory plant breeding program can hope to screen more than an insignificant proportion of the germplasm available in collections of genetic resources or, for example, attempt to create populations with novel resistance traits. Classical breeding is a strategic approach that creates improved parents for the cost-effective, adaptive approach of participatory plant breeding.

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Participatory Crop Improvement for Intercropped Maize on *Bari* Land Terraces with Trees

T. P. Tiwari, Daljit S. Virk, and Fergus L. Sinclair

Abstract

Maize (*Zea mays* L.) is the most important crop in the middle hills of Nepal and is mostly grown in association with finger millet (*Eleusine coracana* Gaertn) and fodder trees. Seven maize varieties have been recommended for the hills but few farmers have adopted them. As a prerequisite to designing a participatory maize-improvement program for the middle hills that could reverse declining yields, local knowledge and practice were investigated and combined with micro-meteorological measurements at three sites, each with 20 participating farmers.

In a participatory maize-improvement program, both participatory varietal selection (PVS) and participatory plant breeding (PPB) were carried out side-by-side with varieties selected on the basis of criteria derived from farmers' knowledge. Four different varieties were tested (Manakamana-1, Arun-1, BA-93-2126#2, Population-22) with local varieties at each site. Participatory trials, where each farmer grew a new variety alongside local varieties, were combined with display trials of all the varieties at five locations. Questionnaires and focus-group discussions were used to assess farmers' evaluation of varieties. Population-22, despite its late maturity, was liked by farmers for disease tolerance, higher yield potential, white and large grains, and its stay-green characteristics. Statistical analysis of grain yield confirmed farmers' preference for Population-22, since this out-yielded the other new varieties ($p<.05$), which were similar in yield to local varieties. A seed-multiplication program of this preferred variety has been initiated by participating farmers. As part of the PPB program, the best four local varieties (Marga local, Muga local, Madi local, and Fakchamara local) were collected from various parts of the middle hills and crossed with adapted exotics (Manakamana-1, Arun-1, Population-22, and Pool-21). Five composites have been created by random mating so as to offer choices to farmers in the coming seasons, thus increasing the genetic diversity they are able to evaluate and utilize.

Introduction

Maize (*Zea mays* L.) is the most important crop grown in association with finger millet (*Eleusine coracana* Gaertn) and fodder trees in Nepal. About 80% of maize is grown in the hills, which constitutes 20% of the total cereal production of the country with productivity of slightly more than 1.5 t ha^{-1} (CBS 1997). There has been a decline of 20% in maize productivity in the hills since the mid-1970s (Palikhe 1996; Adhikari 1998; NMRP 1997). This is proof of the inefficiency of the traditional approach to maize improvement. The problem with the present approach is that it has assumed that biophysical and socioeconomic factors are commonly shared. The nature and importance of farmers' knowledge is poorly understood, and farmers' involvement in the research process has not been realized. The complex system of growing maize/millet with trees has been overlooked and farmers have not been recognized as research partners in the process of maize

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technology generation. Consequently, the impact of seven newly released maize varieties has been insignificant.

It is not surprising that most of the maize-growing areas in the middle hills of Nepal are covered by the traditional varieties. Either new varieties are not reaching a majority of farmers or those farmers with access to them are not continuing to use them (Khadka et al. 1993). Pham, Waddington, and Crossa (1989), in their review report on the impact of germplasm from the International Institute for Wheat and Maize Improvement (CIMMYT), mentioned that in most developing countries, maize farmers are, by and large, growing the old established landraces.

It was therefore realized that it is necessary to develop a more efficient and effective approach where researchers, maize breeders, and farmers can work together for a common goal. The need to bridge the gap between local and scientific knowledge is a necessary prerequisite to developing an effective maize-improvement strategy. A farmer-participatory approach would involve developing a community-based adaptive research capacity, achieved by working with groups of farmers, maximizing the use of rural resources, and utilizing farmers' knowledge in parallel. This approach can bring farmers' knowledge (farmers' perspectives) and scientific ideas (researchers' perspectives) together (Walker et al. 1997; Sinclair and Walker 1998; Wagner 1993; Joshi 1997). Besides the acquisition of local knowledge, a fuller understanding of the maize-growing environment and how farmers manage scarce resources are major prerequisites for investigation.

Farmer participatory maize improvement

During the early 1970s, when research on maize started, there were high expectations that the development of maize in Nepal would offer better varieties to farmers. However it has been realized that the adoption of new varieties by farmers was not as simple as the researchers and development workers had thought. The farmer-participatory approach began in response to the inefficient, traditional, top-down approach, where more focus was paid to a few researchers' traits of interest rather than to the needs of farmers managing complex and heterogeneous systems.

There are many good reasons to encourage farmers' participation in the process of agricultural research and development (Farrington and Martin 1988; Farrington 1998; Witcombe et al. 1996; Joshi and Witcombe 1996; Witcombe and Joshi 1996; Witcombe and Virk 1997; Sperling and Scheidegger 1995; Sthapit, Joshi, and Witcombe 1996; Subedi, Rana, and Joshi 1997). The complexity of the system is only understood by the farmers. The traditional approach is deficient both in understanding such systems and in using farmers' talents. The participatory approach will help empower local groups of farmers by enhancing production (through the acceptance of preferred varieties), genetic diversity, and "togetherness" (Sperling and Scheidegger 1995; Eyzaguirre and Iwanaga 1996; Chambers and Mascarenhas 1990).

As part of farmer-participatory maize improvement, both participatory varietal selection (PVS) and participatory plant breeding (PPB) were carried out side-by-side, although the latter is usually initiated when PVS fails to identify farmers' preferred genotypes (Witcombe et al. 1996; Joshi and Witcombe 1996). The two activities were carried out at the same time in order to create broad, genetic-based populations simultaneously with PVS activities so as to offer choices to the farmers as quickly as possible.

Materials and methods

Participatory varietal selection

Farmers' criteria for selecting maize genotypes were based on local knowledge. Suitable varieties were sought to meet the important traits that were identified as preferred by farmers, particularly those relating to grain size, color and type, plant height, suitability for agroecological niches, and compatibility with the system. Varieties were selected as suggested by Witcombe et al. (1996) from the releases for the same domain (Manakamana-1), for one other domain (Arun-1 for lower hills but for the middle hills a new introduction), and from pre-releases (Population-22 and BA-93-2126#2).

Sites were chosen where maize is the important crop for household income, in farming systems that were representative in terms of agroenvironmental and socioeconomic conditions, and where there were no political or social obstacles to effective researcher-farmer interactions. Marga, Patle and Fakchamara were selected for the farmer-managed, participatory-research (FAMPAR) trials.

A total of 60 packets (15 of each variety) containing 500 g of seed were distributed randomly to 20 farmers at each site to compare with their local varieties. Therefore, FAMPAR trials of one variety were replicated over five participating farmers at each site. Farmers were asked to grow the new varieties alongside their local variety in the same field and under the same management conditions. However, fields for the FAMPAR trials were to be selected mutually by farmers and researchers for their representativeness (not too sloping, not too marginal or too fertile, and with some degree of tree shade, if possible). Periodic farm visits and interactions with farmers were made so as to observe performance of varieties at different stages. Assessments of the pre-harvest traits of test varieties were made by joint visits between researchers and farmers to each participating farmer's fields. A wide range of issues, covering field management and performance of varieties in the complex and heterogeneous environment, were discussed. Farmers' observations of experimental varieties and their own local varieties were discussed at greater length and were recorded using household-level questionnaires (HLQs). Farmers were asked to harvest both new and local varieties separately and to measure grain yield using their local measurement units. They were also requested to store the harvests separately using existing practices and to assess/evaluate other postharvest characteristics, such as grit-to-flour ratio, grain type and color, cooking quality, taste, and market value. They were also asked to assess fodder quality.

Also as part of the PVS program, demonstration trials were conducted in five different sites (Marga, Patle, Fakchamara, Murtidhunga, and Parewadin). The same four FAMPAR varieties were given to one farmer at each site to grow together with his/her local variety for comparison; 500 g of seed of each variety was given to farmers to grow on their own farms.

Group visits were organized to see FAMPAR trials in the field grown by individual farmers in various growing conditions. The performance of the FAMPAR varieties was assessed jointly, and finally, farmers were brought to see varietal demonstrations to compare all varieties at one site. At the end of the session, focus-group discussions were organized and views were collected as per questionnaires developed for the discussions. Male and female farmers were grouped separately and discussions were initiated accordingly. Based on the performance of FAMPAR varieties, farmers were asked to rank the varieties.

Participatory plant breeding

The germplasm that farmers felt was best adapted to the eastern middle hills of Nepal was collected.[1] Before collection, the fields where these varieties were grown were visited and their performance was assessed. Individual growers and local farmers were consulted in order to identify the best-adapted local germplasm. The varieties Muga local, Madi local, Fakchamara local, and Marga local from local varieties and Manakamana-1, Population-22, and Arun-1 (white) and Pool-21 (yellow) from the improved varieties were used in the PPB program. A total of five composites were prepared with different crossing combinations of farmer-preferred varieties (table 1).

Sowing time was staggered according to the maturity class of the variety so as to synchronize flowering. A purposive randomization was followed to equalize the chances of random mating. Three seeds per hill were sown and later thinned to one. At the vegetative stage, individual plants were tagged to detassel later. Diseased and other abnormal plants were removed as soon as the tassel appeared. These composites were sown on-station with irrigation, because the previous year there had been a severe drought (the longest in 35 years). Seed priming was practiced for early establishment. Final selection was done by farmers from tagged and detasseled plants. Laboratory selection was done for flinted and white grains, rejecting yellow, dented, and diseased grains.

Farmers prefer white-grained maize varieties; however, some yellow-grained types possess desirable traits. A novel PPB program was followed to exploit yellow-grained types in composite breeding, where pale yellow grains are used for further cycles of random mating (Goyal, Joshi, and Witcombe, *this volume*). Pale yellow grains represent a cross between white- and yellow-grained varieties. All other grain types, being more likely to be parental types, are rejected.

Results and discussion

Unlike PPB, which requires a long phase of breeding before its products can be tested in FAMPAR trials, PVS provides a means for immediate identification of farmer-preferred varieties. The products of PPB are not yet ready for such an evaluation but the results of the PVS program are available and are presented in this paper.

Participatory varietal selection

Group interviews were conducted to compare all experimental varieties with local varieties at the end of the growing season. The objective and expected outcome of the project was reviewed once again as a reminder to the group members, since they are the ultimate users. Groups of farmers visited each other's fields to see all the FAMPAR varieties grown by different farmers, which may be under different management but were grown under similar growing conditions (with respect to altitude and system). Each trait they mentioned was recorded. Most of the traits were compared against local varieties; however, the overall ranking of the acceptability of the varieties was made among test entries, including local varieties. Farmers' perceptions of major pre- and postharvest traits are summarized in figures 1a and 1b. It was noted that most of the farmers could not make confident contributions regarding cooking quality and taste. Assessment of problems with pest in the stored grain is continuing because it has not yet been taken out of the *thangkro* (maize crib).

1. Descriptions based on farmers' knowledge about and experience with varieties were prepared but not included in this report.

Table 1. Farmer-Participatory Maize Breeding Plan

Parent selection: Well-adapted landraces with good phenotypic traits were selected by farmers.

Locally adapted new varieties identified from the search program as suggested by Witcombe et al. (1996).

A.White composite

	First year, Season-1 (March sowing, hill)	**Season-2 (September, teral)**	**Second year**	**Third year**	**Fourth year**
<u>Composite 1</u> Population-22 Muga local F/mara local	Sowing time adjusted according to maturity class. Purposive randomization done to allow equal chance for random mating. 50% plants detasseled and selection concentrated only from those. Good maize growers invited during the field selection. Lab selection for healthy, white-flinted grains.	<u>Broad-based composite</u> First 3 composites grown together to prepare broad-based composite. Sown by purposive randomization to allow equal chance for random mating at Rampur during winter. Other techniques not changed.	Upgrading continued at station. Good maize growers invited for field selection. FAMPAR trials. Seed increase in farmers' fields.	Upgrading continued. FAMPAR trials. Co-coordinated multilocational trials (CVTs). Disease nurseries. Seed increase in farmers' fields.	Formal on-farm trials.
<u>Composite 2</u> Manakamana-1 Marga local, F/mara local	ditto				
<u>Composite 3</u> Arun-1, Madi local Marga local	ditto				
<u>Composite 4*</u> all above four locals	ditto	ditto	ditto	ditto	ditto
<u>Composite 5</u> FAMPAR varieties	Best ears from the respective farmers' fields selected by farmers and collected from three different sites.	Seed of different varieties mixed and sown as composite. Good maize growers invited to select in field. 50% of plants detasseled for random mating.	Bulk sowing. Random mating as other composites. FAMPAR trials.	Upgrading continued. FAMPAR trials. Co-coordinated multilocational trials. Seed increase in farmers' fields.	ditto

Table 1. Farmer-Participatory Maize Breeding Plan (continued)

B. Composite breeding using yellow types

Pool-21 yellow (Female) Arun-1, Madi local Manakamana-1 Population-22	Female parent sown in alternate rows with other varieties. All female and undesirable and diseased plants from male rows detasseled. Good maize growers invited for field selection. Deep yellow and white seeds and other diseased grains discarded. Only pale yellow seeds (being hybrids) from yellow female parent continued.	Pale yellow seeds sown at Rampur. 50% plants detasseled. Field selection. Lab selection; only white seeds selected to continue. Other colors discarded.	White seed continued by random mating. Good maize growers invited for plant selection. FAMPAR trials.	Upgrading continued. FAMPAR trials. Co-coordinated multilocational trials. Seed increase in farmers' fields.	ditto

Note: Two years on-farm testing to satisfy variety release committee is to be conducted before proposing variety to be released.
* Adapted local germplasm from various parts of the middle hills should be continuously collected, evaluated, and combined in local composite so as to make broad genetic base which could be used for future crossing programs. Recurrent selection of these composites (randomly mated) should be continued

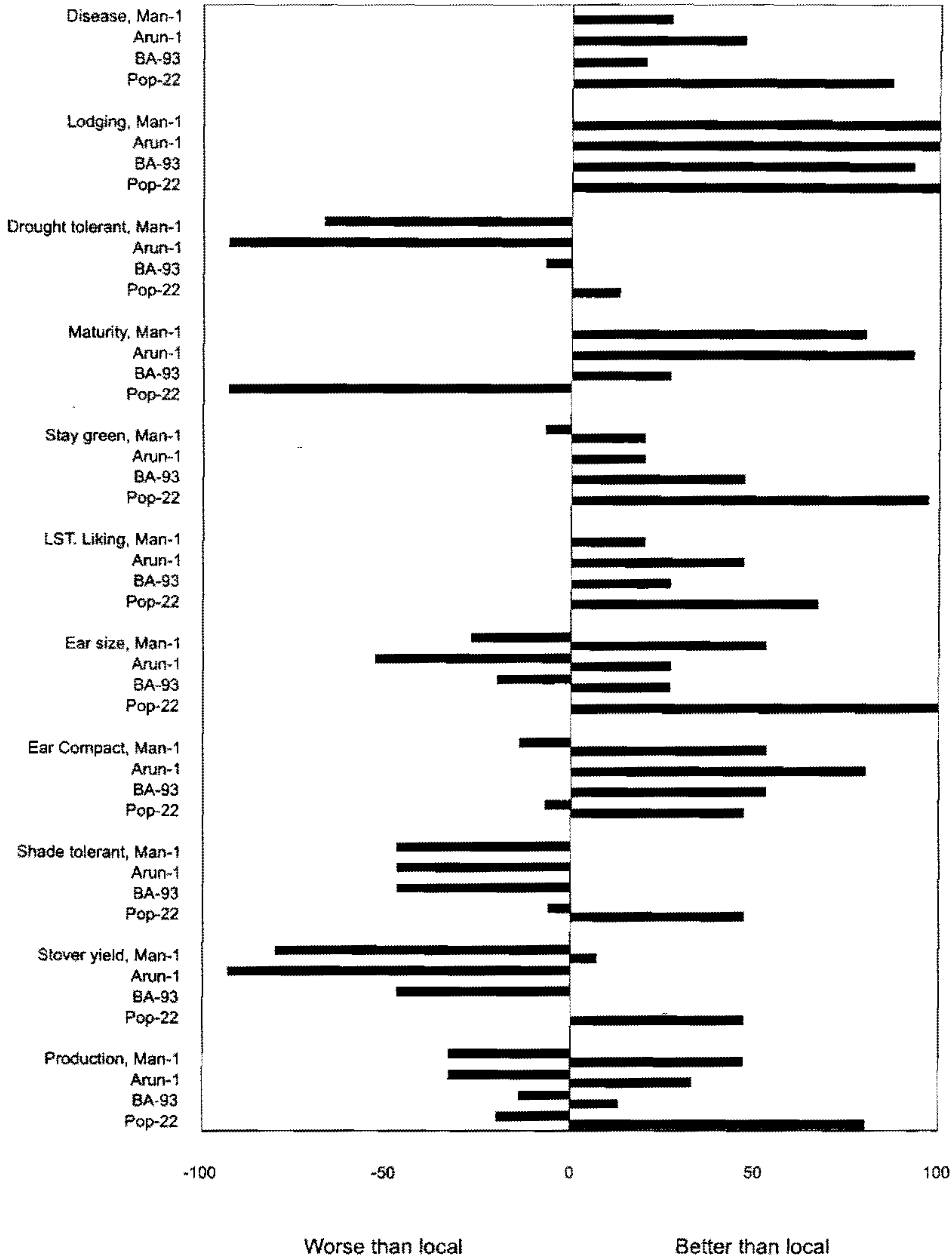
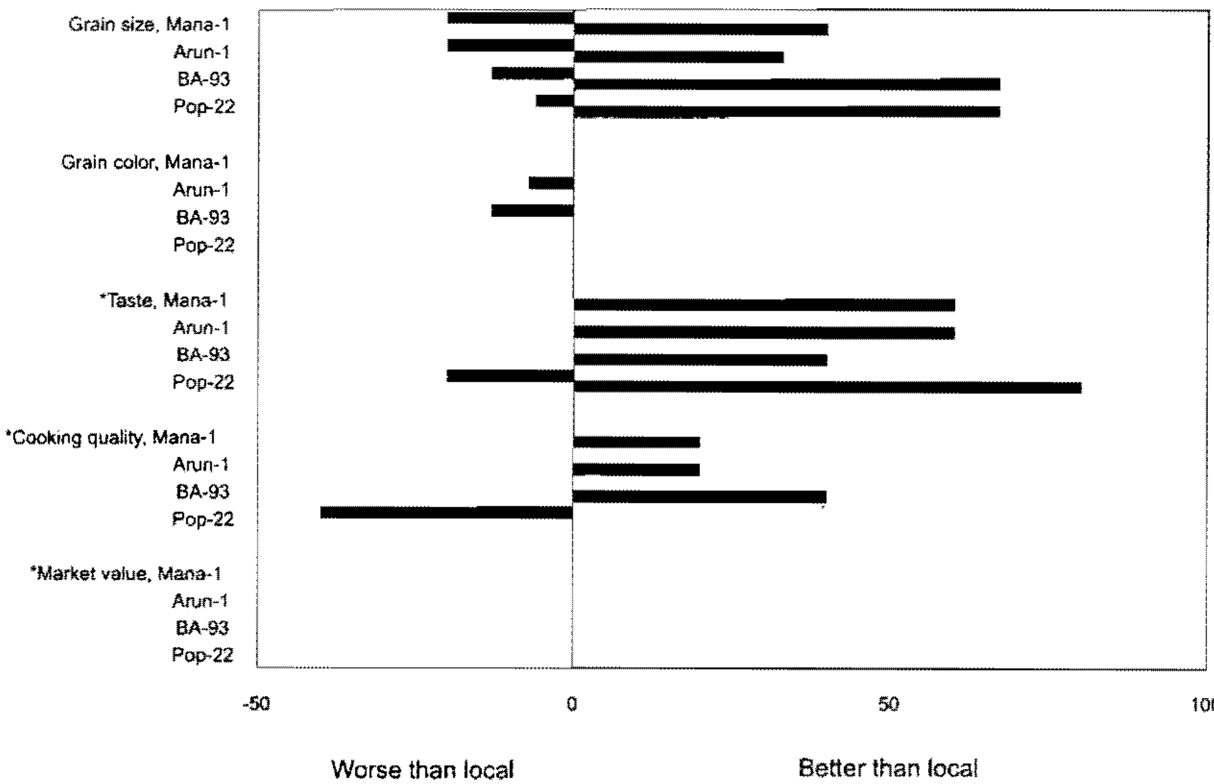


Figure 1a. Farmers' perceptions of pre-harvest traits of four new maize varieties (Farmers' perceptions as to whether the test varieties were better or worse than the local varieties are indicated by lines. The shorter the line, the more similar the variety is to the local varieties.)



*Results based on single site.

Figure 1b. Farmers' perceptions on postharvest traits of four new maize varieties (Farmers' perceptions as to whether the test varieties were better or worse than the local varieties are indicated by lines. The shorter the line, the more similar the variety is to the local varieties.)

Preharvest traits. Farmers observed that the germinative ability of the new varieties was better than that of the local varieties since better quality seed was given to them. During the group discussion, one of the participating farmers said that if the quality of seed of the new varieties was as poor as the usual inferior (insect attacked) quality of the the local varieties, then the germination percent of the local varieties would be higher under stressed situations (drought and soil capping). Additionally, the farmers said that when the maize was sown, there was sufficient moisture in the soil, and as a result, there were no germination problems this year.

Farmers also perceived that the new varieties had stronger stems and shorter plant height than the local varieties, resulting in reduced lodging. The test entries were better with respect to foliar diseases, particularly turcicum blight, but they had problems with ear rot. Within the new varieties, Population-22 was preferred. This was mainly because it had larger ears and lower rates of infection with turcicum blight. Farmers thought this was because it was less affected by tree shade. New varieties matured earlier than local varieties except for Population-22 (figure 1a). The new varieties had similar requirements for fertilizer and water as the local varieties; however, their drought tolerance was less. There were mixed responses from farmers on ear size, production estimates, shelling percent, and grain size. Despite the desirable thinner stems of the local varieties for livestock

stover, farmers preferred the new varieties for this purpose because they had improved stay-green characteristics. Except for Population-22, the new varieties were not shade-tolerant.

Postharvest traits. Assessment of postharvest traits revealed that the local varieties were better with respect to grain color and type, taste, grit-to-flour ratio, stored-grain pest infestations, and cooking quality. The farmers who were able to comment on taste reported that Manakamana-1 was good but still inferior to the local varieties. The taste of Population-22 was inferior to local varieties and to Manakamana-1. However, these varieties all fetch good market prices compared with yellow types (figure 1b).

The overall ranking of the tested varieties from different sites with different groups of farmers revealed that despite its lateness, farmers liked Population-22 in field conditions (table 2). The traits farmers liked were higher yielding potential, taller plants with multiple ears, stay-green characteristics, freedom from foliar diseases, and tolerance to lodging. Because of the taller plant height, there was less shading of millet when the lower leaves are stripped by farmers to harvest fodder and reduce competition with the millet. However, at the Murtidhunga and Parewadin sites, farmers said it affects millet because of its larger leaves and late maturity.

Table 2. Overall Rank of Varieties from Different Sites with Different Groups of Farmers (1999)

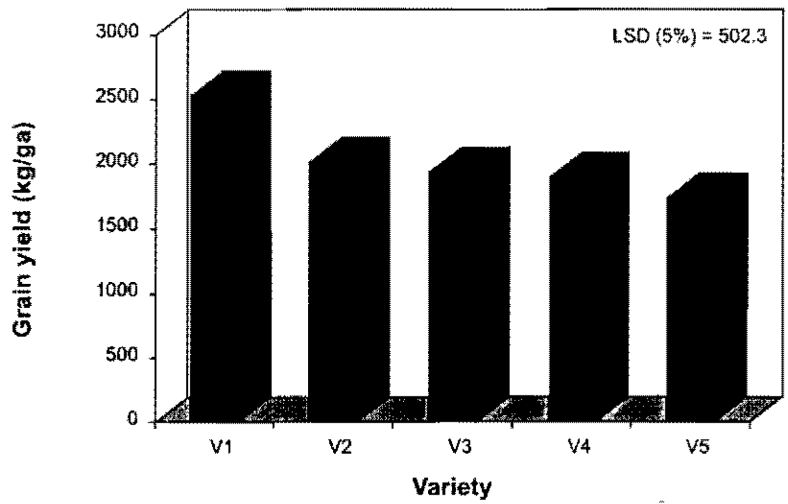
	Marga		Patle		Fakchamara		M/Dhumga	Tankhuwa
CVs\sites	Male	Female	Male	Female	Mixed	Mixed	Mixed	Mixed
Mana-1	2	5	3	2	5	4	3	3
Pop-22	1	1	1	1	1	1	1	1
BA-93	4	3	5	5	4	3	5	2
Arun-1	2	2	2	4	2	2	4	4
Locals	3	4	4	3	3	5	2	5

There was little distinction between the preferences of male and female farmers. It was rather surprising that the late variety Population-22 scored the highest (40), followed by Arun-1 (26). The score of Mana-1, local varieties, and BA-93 was similar (21). This was supported by the observed grain yield from FAMPAR trials, where Population-22 was found to be significantly superior ($p<.05$) to local varieties (figure 2). Other entries were on par with local varieties for grain yield.

As in the FAMPAR trials, Population-22 was found to be the highest yielder in the multilocational varietal display trials, although this result was not statistically significant ($p=.38$). The mean grain yield, irrespective of site, ranged from 2294 kg ha^{-1} to 2949 kg ha^{-1}. Arun-1 was the lowest yielder. Most of the farmers who grew Arun-1 commented that because of its early maturity, birds and rodents were attracted to it. A further problem was the theft of ears. Thus, there was no seed to keep for the following year or to assess for postharvest traits. However, because of its earliness and other desirable traits, farmers were willing to continue to use it. Some farmers also expressed the opinion that it provided early food and that demand for it would increase in the future when green ears were marketed locally for roasting.

Impact of FAMPAR varieties

The impact of any variety is assessed by looking at the area covered by that variety in a particular location and how confidently farmers have taken to that variety. Although it is too early to assess



Note: V1=Population-22; V2= Manakamana-1; V3=BA-93; V4=local varieties; V5=Arun-1.

Figure 2. Summary results of grain yield of FAMPAR varieties

impact, most of the participating farmers stated that they had saved seeds from some of the FAMPAR varieties that they grew last year, thus confirming the potential of PVS to increase biodiversity. The amount of seed saved for this year's sowing was 31 kg of Population-22, 29 kg of Manakamana-1, 24.5 kg of BA-93, and 13.5 kg of Arun-1 across all sites. Most farmers stated that one or two years' experimentation was not sufficient to fully understand the performance of a variety, so a few more years would be needed to have a more complete picture. According to the farmers, the seed demand from other farmers for FAMPAR varieties was limited except in a few cases (there was some demand for Population-22, Manakamana-1, and Arun-1) because of less exposure. A participatory seed-multiplication program for Manakamana-1 and Population-22 has been launched. Farmers were briefed about the selection of maize seeds in the field and the relative advantages of the field selection techniques.[2]

Conclusions

The basis for farmers' decisions to either accept or reject a variety is complex.

- Farmers' interest in growing new maize varieties without replacing existing local varieties confirmed that participatory crop improvement is a means of increasing genetic diversity.
- No ideal variety that satisfies all the criteria set by farmers has been developed so far by research. Varieties generated by following the top-down approach provide only a few traits that farmers required, but the participatory approach is more satisfactory because it offers more choices and gives the new varieties more exposure.

2. This refers to detasseling of 50% of phenotypically desirable maize plants from the terraces, which mostly lie in the central part of the field. Tassels from detasselled plants can be used as fodder. This operation is also expected to reduce the shading effect on the maize crop, reduce the degree of lodging, and stabilize yield through regeneration of heterosis. This operation also creates interest among farmers for testing the variety in the next season. This is a very simple and easy technique; however, care should be taken not to damage the flag leaf, which is important for photosynthesis.

- Farmers' interest in taking an active part in the selection process indicated that the success of this approach could be sustainable in the future.
- Farmers who had only one year's experience with a variety felt that this was not sufficient for precise feedback on a variety. This could have resulted in inconsistent opinions during the assessment of pre- and postharvest traits.
- Women farmers need to be encouraged to participate in the program because most of the field work in maize is carried out by women. It was noted that feedback received from women farmers was of better quality.
- The participatory approach provides a reciprocal educational experience between farmers and researchers because each recognizes the other's opinions and taken them into account.
- Despite its lateness, farmers liked Population-22 in field conditions (table 2). The traits farmers liked were higher yielding potential, taller plants with multiple ears, stay-green characteristics, freedom from foliar diseases, and tolerance to lodging.

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