Improving and diversifying planted forages through selection, breeding and inclusion in local production systems -Examples of South-South learning

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Background

Livestock based systems provide livelihoods to 1 billion people and account for 40% of global agricultural gross domestic product. Animal-source foods provide 14% of the calories and 33% of the proteins consumed globally and provide essential micronutrients, such as vitamin A, B-12, riboflavin, calcium, iron and zinc. In addition, livestock has high cultural and social values. Producing feed for livestock uses about 84% of the world's agricultural land (Erb et al. 2007; Foley et al. 2011). The share is even higher in developing countries (FAO 2009). Producing enough animal feed is a challenge, especially in ruminant systems, accounting for 50 to 60% of the total production costs (Swanepoel et al. 2010). Land resources that can be used for feed production are increasingly constrained.

In the face of climate change and its expected negative impacts on livestock systems, adaptation and increasing the resilience of livestock production systems should be a priority. Regions identified as the most vulnerable, e.g. Sub-Saharan Africa, are also regions where rural communities rely the most on livestock for nutrition security, income and livelihoods. Well-adapted forages with high productivity and nutritional quality can provide animal feed throughout the year while mitigating GHG emissions. They are amongst the most promising innovations in the livestock sector.

The Tropical Forages Program of the Alliance of Bioversity International and CIAT (the Alliance) and its partners contributes to the wide-scale implementation of multiple-win forage interventions. The forages program started working in Africa in the late 1980s, expanding the Latin American Tropical Pastures Evaluation Network (RIEPT, its Spanish acronym) to West Africa under the name of RABAOC (Réseau de Recherche en Alimentation du Bétail en Afrique Occidentale et Centrale). RABAOC was a collaborative research effort between CIRAD-EMVT, ILCA, CIAT and NARS to conduct adaptive research on forage species in humid and sub-humid West and Central Africa.

However, more intensive on the ground presence of the Alliance started only about a decade ago, through the development of a systems approach to forage based crop-livestock-tree systems. That prompted closer interaction with forage improvement through selection and with the breeding of forage grasses of the *Urochloa* and – more recently – the *Megathyrsus* genera to target specific lines and their management for Africa. By integrating improved forages in local livestock production systems, the Alliance's tropical forages program explicitly aims to simultaneously enhance livestock production, natural resource use efficiency, biodiversity and climate change resilience, and mitigate GHG emissions.

Tropical forages provide an opportunity to intensify and diversify livestock-crop-tree systems in rainfed environments (with more than four to five months of rain). They could be extended to drier areas if irrigation and/or conservation measures are taken. Until recently, forage production relied on the selection of wild relatives, using only a few species and accessions, e.g. in the case of *Urochloa* in Brazil 50 million ha are planted to only one cultivar, *Brachiaria brizantha* cv. Marandu (Jank et al. 2014). For tropical grasses, breeding is more important, most notably for *Urochloa* spp. (formerly *Brachiaria*), *Megathyrsus maximus* (formerly *Panicum maximum*) and *Cenchrus purpureus* (formerly *Pennisetum purpureum*).

Theory of action/change

The aim to simultaneously diversify and intensify existing systems relies on using enhanced diversity through either breeding and/or selection, targeting specific production niches, increasing at the same time productivity and water use efficiency, avoiding soil degradation and reducing GHG emissions per unit livestock product. The intensification of systems can create opportunities for scaling forages in partnership with both the public and private sectors. Specific benefits for women and youth exist in terms of reducing time to source feeds and developing small-scale business opportunities, such as the multiplication of planting material, and production of hay, silage or fresh fodder, and forage sales. In Africa, the Alliance currently focuses on a few selected countries where there is a defined and increasing demand for improved forages, and where intensified systems are solidly linked to growing markets for animal-source foods (Coulibaly 2009). These countries are Benin, Ethiopia, Kenya, Madagascar, Mali, Nigeria, Rwanda, Tanzania, Uganda, Zambia, and Zimbabwe. Further scaling to other Sub-Saharan African countries is expected in the near future.

Methodology

The key methodological approaches employed are:

- Identification of target production areas and markets in West and East Africa through foresight, ex-ante assessments and spatial analyses
- From genebanks to improved hybrids: a multidisciplinary path to deliver genetic gain
- Assessment of local adaptation and promotion through multi-locational trials addressing constraints in forage seed supply systems
- Quantification of environmental impacts and trade-offs/synergies
- Use of social and gender analysis to understand gender-disaggregated barriers and to develop incentives for wide-scale adoption
- Identification of business opportunities around cultivated forages and forage seeds
- Engage in awareness creation and capacity building through media, traditional and digital extension and outreach
- Engagement in policy-making processes to support the adoption of forages and efforts for sustainable intensification

Results

Identification of target production areas and markets in West and East Africa through foresight, ex-ante assessments and spatial analyses

A study by Schiek et al. (2018) defined the role of forages to close the gap between rising demand for livestock products and sustainable production. For all but the lowest levels of adoption and production increases, improved forages have the potential for positive return on investment. A more focused scaling scan analyzing possibilities for adoption in Kenya, Uganda and Ethiopia confirmed this potential; work on reaching 100,000 forage users in four years is in progress (Notenbaert et al., unpublished). Notenbaert et al. (2018) applied a suitability mapping tool to the case of tropical forages in Rwanda, Ethiopia, Tanzania, Kenya and Vietnam.

Although different forage crops have various reactions to climate change, in general, a negative impact of climate change on forage crops was projected. Smallholder dairy farmers in Kenya, Tanzania, Rwanda and Ethiopia used these maps for selecting context-specific no-regret forage species and varieties (Mwendia et al. 2019).

The maps also point to the gaps and opportunities for improving and expanding the choice of adapted forage options. This can then be translated to breeding objectives and forage breeding and selection programs can help future generations of farmers by developing a more diversified portfolio of germplasm suitable to future climate conditions.

From genebanks to improved hybrids: a multidisciplinary path to deliver genetic gain

The identification of the multiple uses and alternatives offered by the diversity hosted in genebanks is a challenge. When trying to use promising accessions in agroecosystems, challenges are how to deal with diverse abiotic conditions and (new) pests and diseases. In the context of climate change, extreme abiotic conditions are expected to worsen, which demands the selection/breeding of more tolerant cultivars. Forage breeding allows combining in the same cultivar different desired characteristics. Over time, forage breeding evolved from answering fundamental questions of basic biology (1970s), to establishing an appropriate breeding scheme in which apomixis rather than being a barrier to reproduction became an advantage to the stability, multiplication and dissemination of the hybrid (1980s) (Figure 7).

Combining multiple rounds of crosses of recombination and selection, Mulato, the first *Urochloa* hybrid launched worldwide, reached the market in 2001. Papalotla now commercializes the grass hybrids developed by the Alliance in 72 countries, with over 1 million hectares planted, as indicated by seed sales.

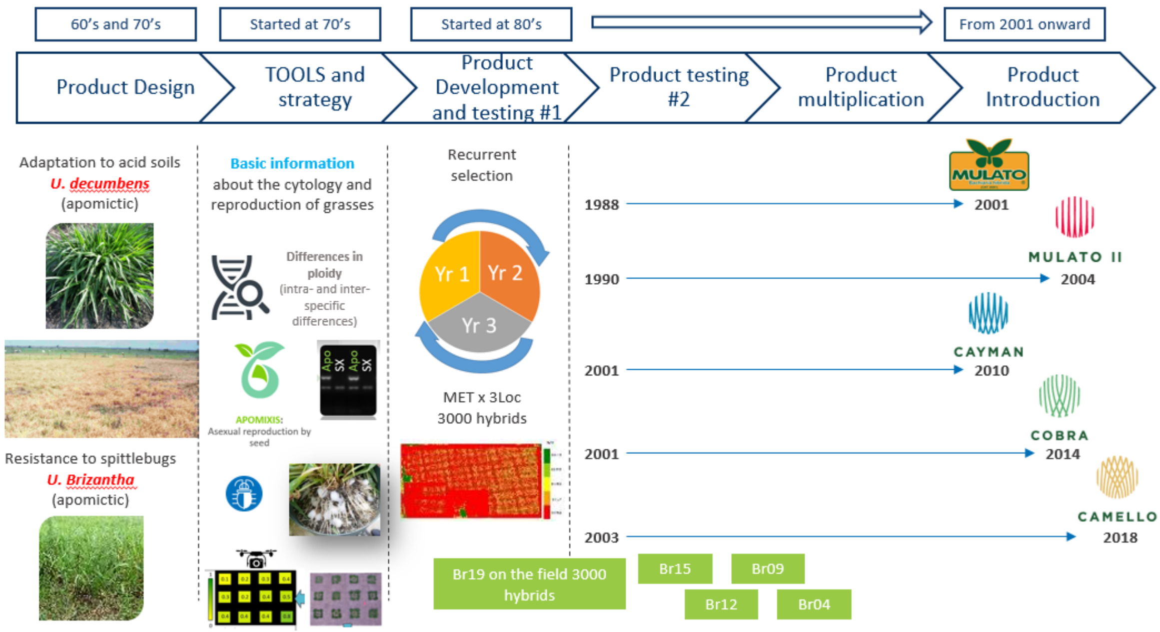

Figure 7: Variety development process for *Urochloa* (syn. *Brachiaria*) employed by the Alliance

It is now easier to confront new challenges, such as emerging pest and diseases. For instance, in Eastern Africa, spidermite (*Tetranychus urticae*) has been found affecting *Urochloa*. Hybrids with tolerance to spidermite need to be developed targeting a potential market of close to 2 million ha.

Assessment of local adaptation and promotion through multi-locational trials

Due to the heterogeneous nature of livestock production systems (given temporal and spatial agroclimatic attributes), the most effective selection and targeting strategy is to subject identified forages to real conditions through participatory engagement of livestock producers.

Efforts across several countries in East Africa (e.g. in the southern highlands of Tanzania and in Rwanda), resulted in several good performing forage technologies in terms of high yield and acceptability to livestock producers. In western Kenya, evaluation of *Urochloa* hybrids and cultivars revealed a performance gradient showing differences within a species.

In Ethiopia, *Urochloa* hybrid Mulato II yielded highest at low, medium and high altitudes compared to other *Urochloa* accessions (Adnew et al. 2019), asserting the need to match forage germplasm to the local environment.

Addressing constraints in forage seed supply systems

Seed is one of the most crucial elements to meet demand for forages, both for bred materials as well as selections. A sustainable seed system will ensure that high quality seeds of a diversified range of suitable forage are accessible, available in time and affordable to farmers and other stakeholders. The need to support the forage seed sector has been identified by many stakeholders as an important bottleneck (Njarui et al. 2017; Assefa et al. 2017). The development of business models for economically sustainable seed production (including vegetative propagation) and marketing requires concerted action at both demand and supply levels, to ensure a minimum market security for forage seed producers and distributors.

The Alliance is supporting a reliable seed distribution network involving public-private partnerships and incorporating international, national and local seed suppliers. For the hybrids originating from its breeding program, the Alliance collaborates intensively with the private sector partner Papalotla/Tropical Seeds. Sizeable quantities of seed are made accessible and combined with awareness creating activities. Import and distribution of seeds led by Tropical Seeds is complemented by supporting small- to medium-scale businesses in the distribution of vegetative planting material.

Business opportunities for small-scale seedling producers are identified and training provided to strengthen agronomic and business skills. NARS support National Performance Trials (NPTs) and certification/registration processes of new promising forage varieties. While for tropical grasses there is defined interest of the private sector to engage, this is still more limited for tropical legumes, the latter with a few exceptions relying much stronger on propagation and dissemination through e.g. farmer to farmer distribution, development actors and small to medium scale business involving farmers through contract farming.

Quantification of environmental impacts and trade-offs/synergies

Despite the opportunities and benefits that increased livestock production could bring, it is widely observed that livestock systems are key drivers of global environmental degradation (Foley et al. 2011). Efforts to maximize production and profitability need to be balanced with long-term sustainability and environmental stewardship. It is therefore important to assess potential environmental impacts before embarking on large-scale development projects geared towards livestock production intensification and value chain transformation (Notenbaert et al. 2020).

Alliance researchers developed an indicator framework for ex-ante assessments of environmental impacts of development interventions in livestock VCs, i.e. the Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development (CLEANED). It estimates biomass, water and nutrient flows and assesses three dimensions of environmental impacts across different spatial and temporal scales: (1) water use, (2) soil health and (3) greenhouse gas emissions. The CLEANED framework is intended to support decision-making and help prioritizing the development actions of governments, donors, NGOs and farmer organizations in data-scarce environments (Notenbaert et al. 2014).

The application of the CLEANED tool to the dairy VC in Tanga, Tanzania (Notenbaert et al. 2020), revealed that milk production increases associated with the introduction of improved feeding strategies are projected to go hand-in-hand with increases in land requirements for feed production and associated increases in absolute soil loss. Under unchanged fertility management systems, it would result in an increasing negative N balance. The land productivity (kg FPCM/ha) is, however, expected to increase. In the mixed crop-livestock systems, the absolute total water use is expected to increase due to larger feed requirements. The water appropriated per unit of milk would decrease. The animal herds with bigger and more productive animals are estimated to cause higher GHG emissions.

Use of social and gender analysis to understand gender-disaggregated barriers and incentives for wide-scale adoption

Rough estimates indicate that the economic benefits of improved forages outweigh the costs. Ready markets are available for many inputs and outputs, save for lack of seeds and low prices for milk. Access to credit remains a big challenge with negative consequences for adoption, as is the access to capacity

building measures. Our research indicates that most farmers are motivated to adopt improved forages because of their tangible benefits.

Amplifying and demonstrating such advantages to farmers would therefore promote adoption. Oulu et al. (2020) analyzed factors that influence the adoption of improved forage varieties in Western Kenya. The results indicate that the choice of which variety to recommend for adoption is complex depending on physiology and genetics, agroecological conditions, agronomic practices, knowledge and skills of the farmers, costs and benefits, availability of resources and challenges with existing forages.

While some aspects can rely on perceptions of farmers and other stakeholders, some can only be conclusively determined through field trials and assessments addressing forage production as well as effects on quantity and quality of milk.

Results indicate that improved forages are mostly superior to local ones, e.g. in terms of increased milk production, nutrition/protein content and disease resistance. However, traditional forages have attributes that complement improved ones. This explains why most farmers who have adopted improved forages also retain traditional forages.

A portfolio approach that promotes the adoption of diverse improved forages with the retention of some of the existing traditional forages is thus recommended and pursued to enhance resilience to climatic and other shocks while promoting agrobiodiversity (photo 13).

Gender influences adoption in many ways, with men still key decision-makers even though a more nuanced understanding of the soft power of women is important. Group membership enhances adoption due to informational and other benefits.

Photo 13: A buffalo enjoying a forage meal in Vietnam. Credit: The Alliance of Bioversity International and CIAT/M.Otieno

Identification of potential business opportunities around cultivated forages and forage seeds

Like other crops, forages present potential business opportunities along the value chain: sale of forage seeds, seedlings, vegetative splits and forage products, e.g. hay (Mwangi and Onyango, 2019), but also end product differentiation and price premiums (e.g. sustainable beef). Businesses in turn spur market pull, catalyzing adoption and scaling.

Engage in awareness creation and capacity building through media, traditional and digital extension and outreach

In order to get forages to be used at scale, awareness creation and capacity building, especially for the smallholder dairy producers, are needed (Mwangi and Onyango 2019). Usually, farmers acquire information through various sources and modes; efforts that incorporate multiple outreach approaches are more likely to have greater reach, e.g. field days, radio and television programs, ICT platforms and farmer visits. Digital extension services should be expanded, and capitalize particularly on the lessons learned due to the COVID-19 contraction of traditional face-to-face extension.

Engagement in policy-making processes to support the adoption of forages and efforts for sustainable intensification

Engagement in policy-making processes is crucial to support the adoption of improved forages and sustainable intensification. Our experience from Latin America, in particular Colombia, shows that contributing to multi-stakeholder platforms or sector roundtables with scientific advances helps in validation and awareness creation. It also enriches facts-based public policy-making processes, private sector initiatives along the value chains (e.g. capacity building, development of sustainable products), the development of particular value chain services (e.g. credit schemes for investments in forages) and dialogue among a broad range of actors. Scaling can be realized through linking such national level efforts to international sector platforms and initiatives, such as the Global Roundtable for Sustainable Beef or the Global Agenda for Sustainable Livestock.

Prospects

Demand for planted forages is rapidly increasing, with an estimated 30,000 to 35,000 farmers currently having adopted planted forages and a target of 100,000 adopters over the next four years in Eastern Africa, for example. The increased demand for improved forages is due to higher productivity, higher quality and prolonged survival in the drought period, in this combination mostly not available in comparison to forage alternatives currently employed at farm level.

In many regions of the world, planting forages is only recently emerging e.g. Sub-Saharan Africa and parts of Asia. To respond to new social, economic and environmental challenges, a system's change is needed. This includes maintaining a portfolio of currently used forages, exploring the diversity of forages – e.g. grasses in tropical Africa and legumes in tropical Americas and Asia – in their center of origin and amplifying the diversity of forage options through introduction of germplasm selected from wild relatives and breeding.

To be successful, this will require parallel work on the sustainable management of forages to build the much needed capacity. Forage conservation (e.g. silage, hay and densified forages) will play an increased role as land resources decrease and vulnerability increases. Thus, in summary, diversity in plant genetic resources will need to go hand in hand with diversification and intensification of management.

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