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Linking research on forage germplasm to farmers: the pathway to increased adoption—a CIAT, ILRI and IITA perspective

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Abstract

The aim of most publicly funded research and development of forages in the subtropics and tropics of the developing world is to improve the livelihoods of smallholder farmers. In order to achieve this goal, technical options are sought which not only contribute to alleviation of poverty and improved food security but also protect natural resources. This paper argues that in order to enhance adoption of multipurpose forages by small farmers, there is a need to utilise participatory methods and to invest in the development of a range of forage alternatives for different environments and production systems. Approaches linking on-station research to farmer participation are described and examples for pathways to adoption presented.

Keywords: Participatory research; Multipurpose forages; Adoption; Subtropics; Tropics

1. The role of multipurpose forages and constraints to their adoption

Poverty alleviation, food security and resource conservation remain top priorities for international agricultural research in the subtropics and tropics (hitherto referred to collectively as ''tropics'') of the developing world. Through multipurpose forages, one can contribute to these goals, depending on constraints, target populations and production systems, and choice of the forage species. Though forages can benefit crop and livestock farmers, the most obvious beneficiaries are farmers that operate livestock-based systems or mixed crop–livestock systems. Thornton et al. (2002) showed that the highest densities of poor livestock keepers in the tropics are in India, South-east Asia, and many parts of Africa, Central America, Mexico, Bolivia and Peru. Many of these areas are in fragile environments, often characterised by acid, low fertility soils, hillsides with steep slopes, and/or constrained by availability of water.

Current research is being conducted to develop forages that have one or more of the following characteristics:

- Use as a feed resource for livestock to enhance milk and meat production, manure production, cash flow and financial security.
- A positive impact on increasing crop production through maintenance and improvement of soil

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fertility and soil structure, weed suppression, and breaking disease and pest cycles.
- A means for income generation through sale of value-added products e.g. sales of cowpea hay in Nigeria (Tarawali et al., 1997) or leaf meal in southern China (Liu and Kerridge, 1997).
- A positive effect on counter-acting erosion as live barriers and cover crops.
- Use in the rehabilitation of degraded lands.

For more details on the utility of forages in tropical smallholder systems and their role in alleviating poverty and conserving natural resources, the reader is referred to recent reviews by Schultze-Kraft and Peters (1997) and Peters et al. (2001).

However, despite the recognised value of forages, the potential benefits of forages, in particular legumes, have not yet been fully exploited by farmers throughout the tropics. Notable exceptions include the widespread use of *Brachiaria* in Latin America (Thomas and Grof, 1986) and the use of fodder trees in central Kenya (Wambugu et al., 2001). Major reasons given for the lack of uptake by farmers are: (a) that forage technologies being promoted may not be appropriate to specific agro-climatic, social, economic and cultural niches and (b) lack of sufficient interaction between farmers, development practitioners and researchers in the forage development and dissemination continuum (Thomas and Sumberg, 1995; t'Mannetje, 1997; Horne et al., 2000; Sumberg, 2002). Obviously these two reasons are interlinked and the aim of this paper is to suggest, without claiming exclusiveness, an approach to overcome these limitations in developing forages that are appropriate to farmer's needs and environments.

2. Available forage technologies

Forages may fulfil multiple functions in often complex and changing smallholder systems of the tropics. However, one grass or legume genotype can seldom fulfil all requirements at all times. Consequently, there is a need to draw on a portfolio of complementary options. In the sub-humid and humid tropics, forages developed by Centro Internacional de Agricultura Tropical (CIAT) and by International Institute for Tropical Agriculture/International Livestock Research Institute (IITA/ILRI) can be used in different ways:

- *Pastures*. Mainly grasses are employed but inclusion of legumes can enhance systems' performance. Examples: *Brachiaria* spp., alone or in association with *Arachis pintoi* or *Desmodium heterocarpon* subsp. *ovalifolium*.
- *Cut and carry forages*. Mainly tall grasses or shrub legumes, with the latter having a particular niche as supplements in drought-prone environments because of their high protein content and/or often high drought tolerance. Examples include: *Pennisetum purpureum*, forage sorghum, *Cratylia argentea*, *Leucaena leucocephala*.
- *Fodder banks*. Mainly herbaceous and shrub legumes for strategic feed supplementation, grazing or cut and carry. Examples include: *Stylosanthes* spp., *L. leucocephala*.
- *Utilisation of legumes as protein leaf meal or pellets*. Mainly plants with a high nutritive value and sufficient biomass. Examples include: *Vigna unguiculata*, *Lablab purpureus*, *Stylosanthes* spp., *Centrosema pascuorum*, shrub legumes.
- *Hay and silage*. Mainly for strategic utilisation in critical periods of the year. Examples include: forage sorghum, *C. argentea*, *L. purpureus*.
- *Live fences and barriers*. Mainly shrub legumes, as fences, for erosion control and feed. Examples include: *Flemingia macrophylla*, *Gliricidia sepium*, *Calliandra calothyrsus*.
- *Improved fallow and green manure*. Mainly legumes, for soil fertility maintenance. Examples include: *Mucuna pruriens*, *L. purpureus*, *V. unguiculata*, *Stylosanthes guianensis*, *Centrosema* spp.
- *Cover crops*. Mainly to control erosion and suppress weeds, with minimum of competition to the crop. Examples include: *M. pruriens*, *Pueraria phaseoloides*, *A. pintoi*, *D. heterocarpon*.

3. Overcoming constraints to adoption of multipurpose forages

To overcome constraints to deliver forage technologies and to respond to the needs of farmers, research and development should work hand in hand. Over the past decades, participatory methodologies such as Participatory Rural Appraisal (PRA), Farmer Participatory

Research (FPR), Participatory Learning and Action (PLA), and Participatory Technology Development (PTD) have been developed with the main objective of increasing the involvement of local people in the design, implementation and evaluation of technologies (for example, Chambers et al., 1989; Chambers, 1997; Cramb, 2000; Douthwaite, 2002). More recently such methods are being utilised and adapted for forage technology development and promotion (Horne et al., 2000) and are reported in this paper.

3.1. Key elements of forage development with farmers

3.1.1. Thorough assessment of farmers' priorities relevant to often complex systems

Although farmers themselves can express demands to resolve specific problems, researchers can play an important role in facilitating the analysis of constraints and opportunities. This also includes the recognition that the identification of solutions and opportunities depends on generating information that is accessible to farmers, i.e. increased information flow to farmers on forages and their potential utilisation in farming systems. Publications directed towards farmers and/or development and research practitioners, which are developed in direct interaction with farmers will facilitate this process. An example includes the publication series developed by the Forages for Smallholders Project in South-east Asia (Cheng and Horne, 1997; Horne and Stür, 1999).

3.1.2. Enhancement of farmer's knowledge of the secondary benefits of forage legumes

Experience from IITA/ILRI in West Africa has shown that having multiple benefits (as fodder as well as for weed suppression and improving soil fertility) is a prerequisite for farmer acceptance of forage-based technologies within complex farming systems. Forages introduced as single or simple technologies to address single constraints may be less acceptable to farmers than if they possess multiple benefits (Tarawali et al., 1999; Sumberg, 2002; de Haan et al., 2001).

3.1.3. Definition of niches and entry points for forages in smallholder systems

The most obvious entry point for forages is as feed for livestock. For example, in South-east Asia, improved grass species for cattle and buffaloes are a particularly good entry point, as they are easy to establish in a variety of niches, show rapid growth and high biomass production within a short time, and are highly palatable to animals (Roothaert and Kerridge, 2002). However, many forage species have multiple uses in addition to providing fodder. These include their use as live barriers, for human nutrition, soil improvement etc. Through a thorough analysis of opportunities and constraints of farming systems with farmer participation, the most likely niches and entry points can be defined. This is a dynamic process as incorporation of improved forages in smallholder systems is likely to open new, often not-anticipated uses in farming systems (Tuhulele et al., 2000).

3.1.4. Farmer inclusion

The inclusion of farmers in the forage evaluation and selection processes right from the start and, as well, including feedback loops to on-station research is essential to successfully seeking and developing forage options with high likelihood of demand, application and adoption in diverse production systems. By including farmers, interventions are more likely to respond to social, economic and biophysical environments.

3.1.5. Establishment of functional seed delivery systems to match demand and supply

As importation procedures for forage seed are often difficult and lengthy, seed multiplication and distribution systems are needed in each country where high demand exists. With the exception of a few forage species, for example *Brachiaria* spp. and other grasses in Latin America and dual-purpose crops in India, large-scale private seed production of tropical forages is still rare, particularly for legumes (see Loch and Boyce, this volume). Even if seed is available, often access by small-scale farmers is limited. Under such conditions, it is necessary that seed multiplication by the private and public sectors be complemented by farmer-led seed systems, in particular for forage legumes. Management of seed systems by farmers enhances sustainability, provides farmers with an extra source of income, and ensures that seed will be available at local level. In many parts of the tropics, seed production is often hampered by climatic conditions such as excessive rainfall or limited day length variability. Farmers in Indonesia, the Philippines and

Vietnam, for example, have coped with these problems by successfully establishing mechanisms of trading vegetative planting materials (Roothaert et al., 2001).

3.1.6. Promotion of synergies and efficient use of resources (i.e. land, feed and food)

Forage crops are often used as supplements to existing feed resources such as crop by-products and local vegetation. At the animal level, synergies exist through improved rumen functioning when such feeds are fed together. At the farm level, forage production can be synergistic by producing feed on land during the season when no other crops can be grown, and at the same time improving the structure and fertility of the land.

3.1.7. Enhanced utilisation of useful tools

Utilising modern databases, Geographic Information Systems (GIS) tools, and socio-economic studies for documentation, analysis, synthesis and extrapolation of results can increase the likelihood of impact of research results generated by research and development practitioners, especially if this is done in close collaboration with farmers (e.g. O'Brien et al., 2002).

3.1.8. Good monitoring and evaluation systems

Establishing and maintaining good monitoring and evaluation systems, including participatory approaches, to define progress and channel feedback is important if constraints to adoption of forages are to be successfully overcome (CIAT, 2001). In many cases, forages for particular environments and production niches are already available. In such cases the aim should be to facilitate farmer access. As production environments (including social, economic and biophysical parameters) of smallholders are highly variable, the entry point should be to offer a basket of options for assessment and selection by farmers rather than to promote a single option. The interaction with farmers is then expected to lead to further development and adaptation of forages in collaboration. Similarly, it is important to understand that most tropical farming systems including livestock are dynamic and therefore the demands on forages might change over time. As a result there may be on-going changing demands for different species from the basket of options. Feedback from farmers on existing forage options and identification of production constraints is needed to design appropriate research activities for further development of forage options, through either on-farm or on-station experimentation.

4. Linking on-station, on-farm and participatory research and development

Agricultural production systems in the tropics are highly variable and complex in terms of biophysical (i.e. climate, soil and altitude) and socio-economic (e.g. land tenure, cultural practices, market access, available resources) variables. Moreover, opportunities and constraints change over time and space. Hence the need for continuous identification, adaptation and development of forage options that respond to existing and evolving demands is fundamental. As a consequence, there is a need to link on-station research with on-farm participatory research for the efficient identification, selection, development and adoption of new forage options.

To illustrate the importance of developing forages with multiple purposes, several recent cases of forage germplasm development, with high likelihood of wide-scale adoption by farmers are presented. The development of these forage options was based on the identification of particular opportunities and needs in smallholder farming systems for which only limited options were then available. The success of these forage options was not always obvious from the beginning and at least, in some cases, required a shift from established research (and development) paradigms.

4.1. Adoption of dual-purpose cowpea in West Africa

The adoption of dual-purpose (grain/forage) cowpea (*V. unguiculata*) in West Africa, resulted from a fruitful collaboration between farmers, NARES, ILRI and IITA that began in the mid-1990s (see Singh et al., this volume). Crop breeding efforts of IITA were matched with the selection of forages by ILRI. A shift was made in the emphasis of the cowpea breeding and selection programme to include both grain yield and forage quantity and quality. This was in response to farmers needs. Farmers were already utilising cowpea haulms as feed supplements for livestock or for sale

(Tarawali et al., 1997). By 2001, through farmer–farmer diffusion, almost 9000 farmers were using the improved dual-purpose cowpea varieties in northern Nigeria (see Singh et al., this volume; Tarawali et al., 2002). Similar efforts on evaluation and promotion of dual-purpose cowpea, *L. purpureus* and sorghum and pearl millet are underway in other parts of the world such as East and Southern Africa (B. Pengelly, R. Delve, B. Vanlauwe, personal communications), India (Hash et al., this volume; Blummel et al., this volume) and Latin America.

4.2. Adoption of *C. argentea* in Colombia

C. argentea is a shrub species with drought tolerance and excellent adaptation to acid, infertile soils. Farmers in the savannahs and hillsides of Colombia and Central America are increasingly adopting this shrub legume as it contributes to alleviating the problem of lack of dry season feed (Van den Ouwelant, 2001; CIAT, 2002). The success of *C. argentea* also illustrates the need to identify options that respond to particular production constraints even if farmers do not express explicit demand. This is often due to lack of knowledge of the potential of specific technologies. In such cases, it is important to embark on a dialogue including demonstration plots and feedback loops. Farmer group meetings are ideal occasions to discuss new technologies that other members have tested. Field workers or researchers need to be part of these meetings on a regular basis. The important issues arising from the meetings need to be recorded. Similarly, individual farm visits can reveal promising innovations that deserve follow-up by farmer research committees and scientists. In the Colombian savannahs, for example, though reluctant at the beginning, farmers are now rapidly—i.e. in the course of 1 year—expanding their areas of *C. argentea* once they have recognised the benefits from this legume and the different utilisation options it offers, including cut and carry, direct grazing, and silage (CIAT, 2002). Despite the success of *Cratylia* in these particular niches, it has limitations in areas above 1200 m and on soils of high pH. Moreover, though no major diseases and pests of *Cratylia* are presently known, it could be dangerous to rely only on one species. Thus development of dry season options to complement *Cratylia* is underway at CIAT.

4.3. Adoption of *Brachiaria* in Latin America

Different species of *Brachiaria* originating from East and Central Africa are sown over millions of hectares of pastures in Latin America. The most common species/variety is *Brachiaria decumbens* cv. Basilisk as it has excellent adaptation to acid, infertile soils that predominate in neo-tropical savannahs. However, *B. decumbens* is highly susceptible to spittlebug, a devastating pest. This contributes to extensive pasture degradation and incurs huge economic losses (Holmann and Peck, 2002). In collaboration with Papalotla, a Mexican seed company, CIAT is developing *Brachiaria* hybrids tolerant to different species of spittlebug with dry season tolerance, high seed quality and high forage digestibility. This again is an example of how research can contribute to alleviate a serious constraint affecting many producers which was not apparent until the introduction and wide diffusion of this forage species in Latin America. The benefits of Brachiaria germplasm and hybrids are seen as independent of farm size and wealth. However, introduction and selection of *Brachiaria* spp. in Central America and hybrid development is targeted towards smallholder farmers including artisanal seed production in two pilot sites in Honduras and Nicaragua (CIAT, 2002).

4.4. Adoption of *A. pintoi* and *D. heterocarpon* in Colombia and Central America

Experiments on genotype × environment interactions with *A. pintoi* and *D. heterocarpon* ssp. *ovalifolium* in Colombia have led to the definition of accessions for particular environmental and utilisation niches in Colombia, Central America and beyond. As a result, *D. heterocarpon* CIAT 13651 will be released as cultivar Maquenque in Colombia in 2003, for pasture recuperation, grass–legume associations and ground cover in plantations. In the case of *A. pintoi*, accessions CIAT 18744, 18746, 18747, 18751, 22160 and 22268 were identified as the most promising options across environments, with good seed production. In areas where vegetative propagation is an option, accessions with low seed production CIAT 22236, 22238 and 22241 can be added. Emphasis was placed on selection for dry matter production and soil cover given that differences in forage quality were small among accessions (Peters et al., unpublished). In the Philippines, *A. pintoi* CIAT 22160 was more preferred by farmers than CIAT 17434, because of its fast-spreading character and shade tolerance. This accession is being planted by cuttings in native and improved grass pastures. Currently, early adoption of *A. pintoi* is documented for Costa Rica (Wünscher, 2001) and the Philippines (Roothaert, unpublished).

4.5. Adoption of forages in South-east Asia

In 1992, CIAT and CSIRO initiated the evaluation of over 500 forage species and accessions in seven countries in South-east Asia in agronomic experiments to assess genotype × environment interactions. In 1995, farmers became important stakeholders in the evaluation of these forages, through participatory diagnosis, planning and evaluation. About 40 grass and legume species and accessions are now widely grown by farmers in the Philippines, Indonesia, Vietnam, Lao PDR, China and Thailand. Preferences vary according to the location and farming system (Roothaert et al., 2000). For instance, *Panicum maximum* CIAT 16031 is the most popular grass in Tuyen Quang province in Vietnam. It is fed to fish, which find it more palatable than any other species, and it is highly productive. In northern Mindanao, Philippines, *Setaria sphacelata* var. *splendida* is appreciated widely for its dual role: it provides high amounts of good quality fodder for cattle and it is the best species for growing on contours to protect the cropland from erosion. In East Kalimantan, Indonesia, *Paspalum atratum* CIAT 26986 out-yields any other forage on farmers' fields. It is harvested frequently by 'cut and carry', resulting in a young forage with high digestibility for cattle, buffaloes and goats. Its ease of propagation by splits provides an additional income for farmers who sell planting materials.

5. Synthesis of case studies

It is important to stress that all the efforts described above required several years of research in developing technologies appropriate to particular niches in tropical smallholder farming systems. Often the development of specific forage germplasm required new research methodology and new collaboration with diverse organisations. It is clear that facilitating stronger farmer involvement, either through expression of direct demand and/or interactive identification of constraints and opportunities, will strengthen the development of forage technologies and ensure that they respond to current and future farmers needs (see below for further illustration). In many cases, appropriate forage options still need to be identified and developed, keeping in mind that farmers should receive the best available accessions for particular niches. CIAT therefore is conducting work on core collections—sets of accessions representing the genetic diversity of a species—to define genotype × environment interactions in key species to select genotypes with wide adaptation or with adaptation to specific environmental and production niches. Donor support is crucial to support further development of new forage technologies and to make these technologies accessible to the maximum number of smallholder farmers.

Our central argument in this paper is that insufficient links between on-station and on-farm work as well as lack of interaction with farmers has limited wider uptake of forages and feedback on demands for particular niches. Hence, IITA, ILRI and CIAT in recent years have increased research in this area (Horne et al., 2000; de Haan et al., 2001; Hernández and Peters, unpublished). In Fig. 1a model used by CIAT in Asia is presented. Similar methods are applied by IITA and ILRI in West Africa (de Haan et al., 2001) and CIAT in Central America (Hernández and Peters, unpublished). It is most important that the procedures include: (a) the recognition of the iterative nature of the processes and (b) that they build on many feedback loops between farmers and researchers and development agents.

The principles behind the methods utilised by IITA, ILRI and CIAT are similar, since a common aim is to link formal forage germplasm knowledge and evaluation methods (i.e. G × E experiments) with farmers needs through participatory approaches. After diagnostic and site characterisation tools are adapted to the particular environments in West Africa, South-east Asia and Central America, farmers are then offered a basket of forage options for selection, further testing and adaptation in their farms. This is followed by development of criteria for specific forage ideotypes and recommendation domains for extrapolation and targeting forage options (for more details, see Horne et al., 2000; Peters and Lascano, 2003; de Haan et al., 2001).

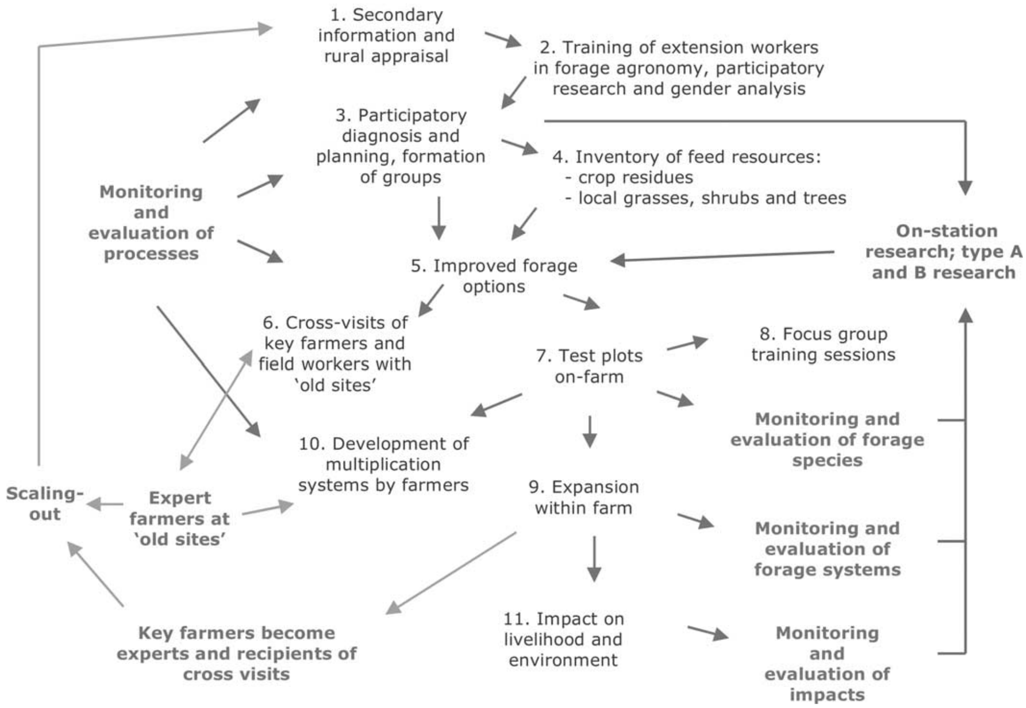

Fig. 1. Participatory research and development processes. Steps 1–11 reflect the research process with smallholder farmers; arrows at the far left reflect the scaling-out process; and arrows at the far right indicate the role of strategic research (Source: Roothaert and Kerridge, 2002).

It is anticipated that improving the linkages between farmers, development workers and researchers will help define and refine demands for forage options for particular niches. In some cases such forages have applicability to meet a wide range of farmers' needs; in other cases they will apply to more specific environments and niches. A good example is *Brachiaria* breeding. Whereas in Latin America, priority is given to developing spittlebug resistant material, this is of limited importance in Asia or Africa, where other issues are more important. As a result, only the integration and strengthening of strategic and applied forage research and development will respond to the variety of farmers needs in diverse tropical regions in the longer term.

6. Scaling-out forage technologies

In South-east Asia through the Forages for Smallholders Project, which began in 1995, there are currently about 3000 farmers testing and adopting forage options. In Table 1, we show results for 2001 for new farmers involved in participatory diagnoses and planting forages on their farms. This shows that although initially many farmers participated in the early activities, such as participatory diagnoses, not all decided to plant the new forages. Cross-visits facilitated by the project proved educational and convincing for new farmers, as they heard other experienced farmers talk about the innovations, and had a chance to see practical management activities. Farmers collected planting material and started small test plots at home (Fig. 1). The formation of groups provide an exchange forum for other farmers who had not participated in the cross-visits, but were curious to test the innovations themselves.

In Fig. 2, we show distribution of forage seeds to farmers in West Africa in 2000 and 2001 through an ILRI/IITA project that began in 1999. The main species distributed have been *V. unguiculata* (cowpea), *Glycine max* (soyabean) and *Arachis hypogea*

Table 1
Results of scaling-out of the Forages for Smallholders Project in 2001 (Roothaert and Kerridge, 2002)

Country	Number of PDs[a] conducted	Number of farmers participating in PDs	Number of groups (old and new)	Number of cross-visits organised	Number of farmers participating in cross-visits	Number of new farmers planting forages
Vietnam	19	380	92	19	330	664
Indonesia	16	396	16	12	83	272
Thailand	3	30	4	10	54	143
China	5	90	10	11	93	73
Philippines	46	797	57	40	734	320
Lao PDR	24	480	n.a.[b]	5	36	65
Total	151	2173	179	97	1330	1537

[a] Participatory diagnosis.
[b] Not applicable.

(groundnut) along with several forage legumes such as *Aeschynomene histrix* and *C. pascuorum*. Currently, there is a preference for the grain legumes, however farmers are experimenting with the forage legumes, and interest is increasing.

In Central America, since 2000, CIAT has been leading a project on participatory selection of forages in smallholder farms. Currently and after 2 years, about 400 farmers are directly linked to the project in evaluating and selecting forage germplasm. About 200 farmers are testing new forage options on their farms utilising their own resources and about 150 farmers are in the process of early adoption of selected species. There is a preference for grasses, mostly for *Brachiaria* spp., but legumes are also being increasingly accepted, in particular *C. argentea* (Peters et al., unpublished data). Two groups of farmers have embarked on seed production of selected materials, currently concentrating on *Brachiaria brizantha* cv. Toledo and *C. argentea* cv. Veraniega. In Honduras, about 50 kg of seed of cv. Toledo was produced by farmers during 2001. For 2002, production of 400 kg is anticipated (CIAT, 2002). In Nicaragua, farmers recently have expressed interest in multiplying seed of green manure legumes and CIAT is facilitating this process (A. Schmidt, personal communication). Moreover, a process has started to reach farmers from other locations through collaboration with research and development workers.

Results from West Africa, South-east Asia and Central America are encouraging. They show promise of accelerating processes of scaling-out with

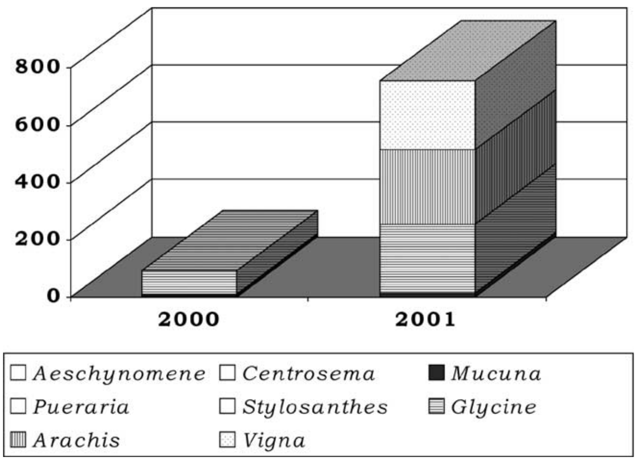

Fig. 2. General trends in farmer choices for forages in West Africa vs. 2000 (kg of seed).

forage-based technologies to reach farmers using participatory approaches. In a study in West Africa, Elbasha et al. (1999) reported a time lag of 15 years for wide-scale adoption of forages utilising traditional extension methods. It is anticipated that, particularly due to more recent activities in participatory research and promotion of forage technologies, that the adoption processes for forage legumes will be further accelerated through farmer-to-farmer extension, once farmers are convinced of the application of new forage technologies in their farms.

7. Conclusion and outlook

Linking on-station, on-farm and participatory research on forage-based technologies seems to be a successful way of responding to constraints and opportunities in smallholder systems, with potential to improve the livelihoods of rural populations. Most of the experiences reported in this paper are based on results from a limited number of sites though in some cases steps have been taken to scale-out technologies with farmers. New initiatives have been initiated for extrapolation of results and targeting of forage germplasm to particular production systems through GIS-based tools and databases. One example is Selection of Forages for the Tropics (SoFT), which is a new collaborative initiative between the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Queensland Department of Primary Industries (QDPI), ILRI and CIAT. This is attempting to compile and make widely available knowledge on forages in the tropics to extension agents.

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References

Chambers, R., 1997. Whose reality counts? Putting the First Last. Intermediate Technology Publications, London, 318 pp.

Chambers, R., Pacey, A., Thrupp, L.A. (Eds.), 1989. Farmer First: Farmer Innovation and Agricultural Research. Intermediate Technology Publications, London, 240 pp.

Cheng, Y., Horne, P., 1997 Field Experiments with Forages and Crops: Practical Tips for Getting it Right the First Time. ACIAR, Canberra, Australia, 48 pp.

CIAT, 2001. Project sustainable systems for smallholders: integrating improved germplasm and resource management for enhanced crop and livestock production systems. Annual Report. Centro Internacional de Agricultura Tropical, Cali, Colombia, pp. 136.

CIAT, 2002. Tropical Forages Project. Annual Report. http://www.ciat.cgiar.org/forrajes/index.htm.

Cramb, R.A., 2000. Processes influencing the successful adoption of new technologies by smallholders. In: Stür, W.W., Horne, P.B., Hacker, J.B., Kerridge, P.C. (Eds.), Working with Farmers. The Key to Adoption of Forage Technologies. Proceedings of an International Workshop held in Cagayan de Oro City, Mindanao, Philippines, 12–15 October, 1999. ACIAR Proceedings No. 95, pp. 11–22.

de Haan, N.C., Tarawali, S.A., Akouegnon, G.E., Amadji, F., Odunze, A.C., Schultze-Kraft, R., Hoffman, V., 2001. Understanding adoption of herbaceous legumes by smallholder farmers in West Africa. Paper presented at the International Workshop on Forage Demand and Adoption by Smallholder Livestock Keepers, co-sponsored by ILRI, FAO and CIAT, June 2001.

Douthwaite, B., 2002. Enabling Innovation. Zed Books, London, 266 pp.

Elbasha, E., Thornton, P.K., Tarawali, G., 1999. An ex post economic assessment of planted forages in West Africa. International Livestock Research Institute (ILRI) Impact Assessment Series 2. ILRI, Addis Ababa, Ethiopia, 61 pp.

Holmann, F., Peck, D., 2002. Economic damage of grassland spittlebugs (Homoptera: Cercopidae) in Colombia: a first approximation of impact on animal production in *Brachiaria decumbens*. Neotrop. Entomol. 31, 275–284.

Horne, P.M., Stür, W.W., 1999. Developing Forage Technologies with Farmers—How to Select the Best Variety to Offer Farmers in Southeast Asia. ACIAR, Canberra, Australia, 80 pp.

Horne, P.M., Magboo, E., Kerridge, P.C., Tuhulele, M., Phimphachanhvongsod, V., Gabunada Jr., F., Bin, L.H., Stür, W.W., 2000. Participatory approaches to forage technology development with smallholders in Southeast Asia. In: Stür, W.W., Hacker, J.B., Kerridge, P.C. (Eds.), Working with Farmers: The Key to Adoption of Forage Technologies. Proceedings of an International Workshop held in Cagayan de Oro City, Mindanao, Philippines from 12 to 15 October, 1999. ACIAR Proceedings No. 95, pp. 23–31.

Liu, G., Kerridge, P.C., 1997. Selection and utilization of *Stylosanthes guianenis*, for green cover and feed meal production in China. In: Proceedings of the XVIII International Grassland Congress Session 19, pp. 49–50.

O'Brien, R., Cook, S., Peters, M., Corner, R., 2002. Targeting forages to niches at farm scale using GIS, socio-economic data and expert knowledge. Paper presented at the Sixth Annual Conference on Precision Agriculture and other Precision Resources Management, July 14–17, 2002, Minneapolis, MN.

Peters, M., Lascano, C.E., 2003. Linking on-station research with participatory approaches: forage development as the pathway to forage technology adoption. Paper presented at the International Workshop on Forage Demand and Adoption by Smallholder Livestock Keepers, co-sponsored by ILRI, FAO and CIAT, June 2001. Tropical Grasslands Special Issue, in press.

Peters, M., Horne, P., Schmidt, A., Holmann, F., Kerridge, F., Tarawali, S.A., Schultze-Kraft, R., Lascano, C.E., Argel, P., Stür, W., Fujisaka, S., Müller-Sämann, K., Wortmann, C., 2001. The role of forages in reducing poverty and degradation of natural resources in tropical production systems. AGREN Network Paper no. 117. http://www.odi.org.uk/agren/publist.html.

Roothaert, R., Kerridge, P.C., 2002. Adoption strategies for forages—experiences of the Forages for Smallholders Project. In: Proceedings of the Workshop on Research and Development Strategies for the Livestock Sector in South East Asia through National and International Partnerships, 11–15 March, 2002. ILRI, Bangkok, pp. 140–152.

Roothaert, R., Kerridge, P., Samson, J., Magboo, E., Binh, L.H., Phaikaew, C., Phengsavanh, P., Kexian, Y., Ibrahim, Khanh, T.T., Asis, P., Nacalaban, W., Saguinhon, J., Nakamanee, G., Schermesser, A., 2000. RETA 5866: Fourth Agriculture and Natural Resource Research at CGIAR Centres: Developing Sustainable Forage Technologies for Resource Poor Upland Farmers in Asia—Six Monthly Report, 1 July to 31 December 2000. CIAT, Los Banos, Laguna, Philippines, p. 31.

Roothaert, R., Asis, P., Binh, L.H., Bosma, R., Gabonada, E., Gabunada, F., Ibrahim, Kerridge, P., Kexian, Y., Khanh, T.T., Magboo, E., Moneva, L., Nakamanee, G., Phaikaew, C., Phimphachanhvongsod, J., Saguinhon, J., Samson, J., Yen, V.H., 2001. RETA 5866: Fourth Agriculture and Natural Resource Research at CGIAR Centres: Developing Sustainable Forage Technologies for Resource Poor Upland Farmers in Asia—Six Monthly Report, 1 July to 31 December 2001. CIAT, Los Banos, Laguna, Philippines, p. 37.

Schultze-Kraft, R., Peters, M., 1997. Tropical legumes in agricultural production and resource management: an overview. Giessener Beiträge zur Entwicklungsforschung 24, 1–17.

Sumberg, J., 2002. The logic of fodder legumes in Africa. Food Policy 27, 285–300.

t'Mannetje, L., 1997. Potential and prospects of legume-based pastures in the tropics. Trop. Grassl. 31, 81–94.

Tarawali, S.A., Singh, B.B., Peters, M., Blade, S.K., 1997. Cowpea haulms as fodder. In: Singh, B.B., Mohan Raj, D.R., Dashiell, K.E., Jackai, L.E.N. (Eds.), Advances in Cowpea Research. Co-publication of the International Institute of Tropical Agriculture (IITA), Japan International Research Center for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria, pp. 313–325.

Tarawali, G., Manyong, V.M., Crasky, R.J., Vissoh, P.V., Osei-Bonsu, P., Galiba, M., 1999. Adoption of improved fallows in West Africa: lessons from Mucuna and stylo case studies. Agrofor. Syst. 47, 93–122.

Tarawali, S.A., Singh, B.B., Gupta, S.C., Tabo, R., Harris, F., Nokoe, S., Fernandez-Rivera, S., Bationo, A., Manyong, V.M., Makinde, K., Odion, E.C., 2002. Cowpea as a key factor for a new approach to integrated crop–livestock systems research in the dry savannas of West Africa. In: Proceedings of the World Cowpea Research Conference III held at IITA, Ibadan, Nigeria, 4–7 September, 2000, pp. 233–251. http://www.iita.org/info/cowpea.pdf.

Thomas, D., Grof, B., 1986. Some pasture species for the tropical savannas of South America. III. *Andropogon gayanus*, *Brachiaria* spp. *Panicum maximum*. Herb. Abstr. 56, 557–565.

Thomas, D., Sumberg, J.E., 1995. A review of the evaluation and use of tropical forage legumes in sub-Saharan Africa. Agric. Ecosyst. Environ. 54, 151–163.

Thornton, P.K., Kruska, R.L., Henninger, N., Kristjanson, P.M., Reid, R.S., Atieno, A.N., Ndegwa, T., 2002. Mapping Poverty and Livestock in the Developing World. International Livestock Research Institute (ILRI), Nairobi, Kenya, 124 pp.

Tuhulele, M., Le Van, A., Phengsavanh, P., Ibrahim, Nacalaban, W., Vu Thi Hai, Y., Kanh, T.T., Tugiman, Heriyanto, Asis, P., Hutasoit, R., Phimmasan, H., Sukan, Ibrahim, T., Bui Xuan, A., Magboo, E., Horne, P.M., 2000. Working with farmers to develop forage technologies—field experiences from the FSP. In: Stür, P.M.H.W.W., Hacker, J.B., Kerridge, P.C. (Eds.), Working with Farmers: The Key to Adoption of Forage Technologies. Australian Centre for International Agricultural Research, Canberra, pp. 54–62.

Van den Ouwelant, E.P., 2001. Early evaluation of *Cratylia argentea* by smallholder farmers in Costa Rica and their perspectives on its use. Master of Science Thesis. University of Wageningen, Wageningen, The Netherlands, 51 pp.

Wambugu, C., Franzel, S., Tuwei, P., Karanja, G., 2001. Scaling up the use of fodder trees in central Kenya. Dev. Practice 11, 487–494.

Wünscher, T., 2001. Early Adoption of *Arachis pintoi* as a Forage Legume by Farmers in Huetar Norte, Costa Rica. Diplomarbeit Universität Hohenheim, Germany, 124 pp.