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Enhancing BNF Research and Application for Food Security and Poverty Alleviation in Smallholder African Farming Communities.

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Increasing *Mucuna's* Potential as a Food and Feed Crop: An Effort to Deliver BNF to Farmers

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Abstract

Although *Mucuna* fallow is generally the short fallow system type that performs best agronomically, its level of adoption is relatively low because it occupies the land without a direct economic output. This was recognized by researchers and donors who initiated a project to focus on *Mucuna* as a food and feed crop. The project made progress in the areas of ruminant feeding, processing to reduce anti-nutritional factors, non-ruminant feeding, human health, and germplasm. Recently, the project participants and other collaborators met in a concluding workshop to share their progress and highlights are summarized in this document. The major achievement is the demonstration that *Mucuna* seeds and pods can be fed to small ruminants with minimal processing and with positive effects on animal growth. This has been shown in Mexico and should be tested in several African countries. The major lesson learned is that delivery of the benefits of BNF to farmers may require expertise outside the fields of agronomy and soil science. In our case we especially benefited from the input of researchers in animal science, food science, toxicology, and analytical chemistry. Soil scientists and agronomists had to promote the funding of the work of these new colleagues and now should promote the extension of the results. After farmers start to adopt the *Mucuna* system for its multiple benefits, soil scientists and agronomists should work on fine-tuning the system to maximize the benefits to the soil.

Introduction

Studies have indicated that soil degradation has reached dangerous levels in many parts of the world, including Africa (Sanchez *et al.*, 1997). Green manure/cover crops have been researched and promoted for soil fertility maintenance/improvement (through e.g., protection from erosion, recycling of subsoil nutrients, and N-fixation) and weed suppression. *Mucuna pruriens* is the most researched herbaceous cover crop (Buckles, 1995) because it has good biomass production in diverse environments, consistent positive impacts on main crop yield, and effective weed suppression (Carsky *et al.*, 2001).

In most cases where it has been tested *Mucuna* fallow has generated high hopes and, over the course of the 1990s, it attained the status of a "miracle technology". Therefore it was taken on-farm in a diversity of efforts and approaches in Africa, Latin America, and Asia. Typically, the collaborating farmers were impressed with vegetative growth and seed production but in subsequent years there was little adoption (Fig. 1). Studies indicated that low adoption was caused by the fact that *Mucuna* was occupying the land without a direct economic output. Its value as food and feed was not evident, and since it did not have other uses, there was no market for it. Disillusionment quickly followed so that by the mid-to-late 1990s many had concluded that *Mucuna* has insurmountable problems. Some researchers began to focus

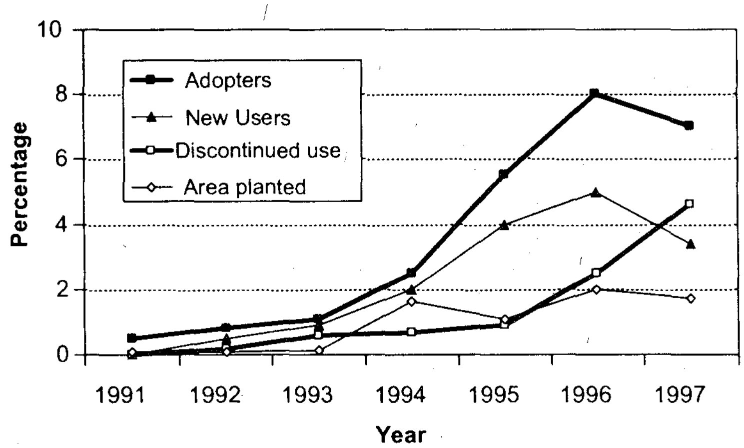

Fig. 1. Adoption and disadoption of *Mucuna* short fallow in southern Bénin (from Manyong *et al.*, 1999).

on other species such as grain legumes with a much higher adoption potential but lower benefit for the soil (Carsky *et al.*, 2003a, b). Currently, *Mucuna* fallow is still on the agenda of agronomic research but it does have a reduced role, often as the control species against which other species are tested for soil fertility impact.

Agronomic potential of Mucuna fallow in West Africa

Mucuna fallow is capable of fixing large amounts of N depending on growing conditions. It is also capable of increasing soil organic matter and N levels although these benefits are generally short-lived. The major body of knowledge is available for effects of *Mucuna* fallow on maize yield. A synthesis of results of trials of a *Mucuna* fallow system by Carsky *et al.* (2001) suggests several points. First, it is clear that in simultaneous intercropping systems, the yield of maize associated with *Mucuna* is decreased dramatically as the *Mucuna* smothers the maize. However, maize yield reduction from relay-intercropping of *Mucuna* at 40 to 50 days after maize planting is only about 5%.

A number of management factors influences the magnitude of yield benefit from *Mucuna* cultivation. For one, the benefit of *Mucuna* fallow increases as the interlude between slashing and planting of the subsequent crop decreases. Another important area concerns residue management. The data presented in Fig. 2 show that incorporation of *Mucuna* residues has a much greater effect on subsequent maize yields than leaving them on the soil surface as mulch.

It is clear that if *Mucuna* does not accumulate substantial biomass, then it will not accumulate sufficient N and suppress weeds. The basic requirements for ample growth of *Mucuna* can be summarised as the following:

- Length of growing period of 150 to 180 days (Carsky *et al.*, 2001)
- Non-acid soil (pH > 5.0) (Carsky *et al.*, 2001)
- Plant available P > 5 mg/kg (Carsky *et al.*, 1998)
- Density of rhizobia > 5 cells/g of soil (Houngnandan *et al.*, 2000)
- Exchangeable K > 1 mmol/kg (unpublished observations)

Finally, the *Mucuna* variety itself can influence beneficial effects, the major characteristic being its maturity cycle. Chikoye and Ekeleme (2000) found that *Imperata cylindrica* suppres-

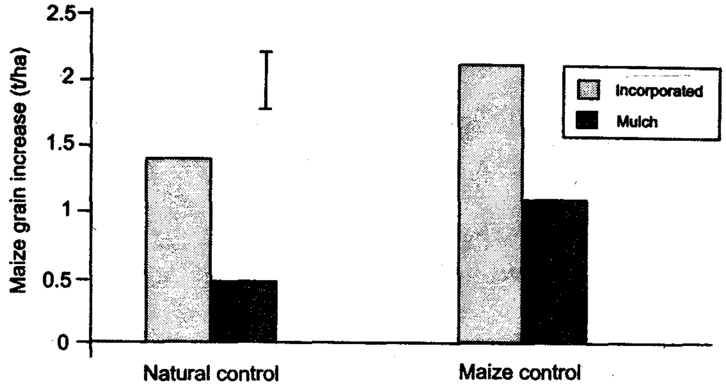

Fig. 2. Increase from maize yield from previous mucuna fallow compared to a natural vegetation control or a maize control and as a function of mucuna residue management from 12 researcher-managed trials summarized by Carsky *et al.* (2001).

sion was greater than 90% with long duration varieties and less than 70% with short duration varieties. Hauser and Nolte (2002) also found maize N uptake and yield to increase with the longer maturity cycle of previous *Mucuna* in the fallow phase.

Farmer reactions to Mucuna fallow in West Africa

Mucuna has a relatively long history in Nigeria and it was one of many cover legumes being tested in live-mulch systems at IITA in the mid-1980s (Akobundu, 1992). Douthwaite *et al.* (2002) and Eilittä *et al.* (in press) summarised the history of *Mucuna* fallow technology generation. *Mucuna* was tested in a participatory mode with several other technologies for soil fertility maintenance in southern Benin in the late 1980s. Some farmers observed that a *Mucuna* fallow weakened *Imperata cylindrica* and made it easier to control. There were subsequently many more requests to research and development agencies for seed. Initial adoption was reported by Manyong *et al.* (1996) to be relatively high in villages where it was initially tested. The fact that farmers reacted more to *Imperata* suppression by *Mucuna* indicated again that the soil fertility benefit alone is not sufficient to promote adoption of improved fallows that take land out of production.

In Benin *Mucuna* seed was generally given to farmers for trials and, because the fallow system was an expanding technology, there was often an artificial market for *Mucuna* seed. Manyong *et al.* (1996) calculated the temporal trend of benefit/cost ratio for an adopting farmer who uses *Mucuna* and found that sale of seed doubled the benefit-cost ratio. This showed the importance of a direct economic product from the fallow system. Subsequent survey in southern Benin after major efforts by development projects (Honlonkou *et al.*, 1999) showed that adoption rates were actually decreasing and abandonment was increasing (Fig. 1) probably because the market for *Mucuna* seed was decreasing. There have been no subsequent adoption studies in Benin but informal discussions with farmers indicate the discontinuation of seed markets as important in their decision to abandon *Mucuna*.

In many systems the niche occupied by *Mucuna* is that of a food crop grown during the less favourable time of year – it therefore replaces that crop. In a comparison with grain legumes in Kaduna, maize yields after *Mucuna* were higher than after cowpea but the latter system was more beneficial economically and farmers in the study site eventually abandoned *Mucuna* in favour of cowpea (Oyewole *et al.*, 1999). Thus with *Mucuna* – as with an earlier experience with alley cropping - it became clear that soil fertility improvement is not enough to drive adoption of the system, at least in the conditions of West Africa but that a direct economic benefit is needed by resource-poor farmers.

These experiences led Carsky *et al.* (2001) to predict relatively limited adoption in West Africa. However, benefits other than soil improvement and weed suppression (e.g., animal feed and suppression of the parasitic weed Striga) could induce *Mucuna* adoption beyond the zone predicted by Carsky *et al.* (2001). Particularly noteworthy are other opportunities that may come from specialized production. For example, *Mucuna* fallow may be found to be the best way to supply N and suppress weeds in organically produced cotton systems for the European market.

Efforts to increase Mucuna's food and feed uses

In 1998–99 the Rockefeller Foundation (RF) supported researchers and development specialists from diverse institutions and regions to systematize and analyze information on green manure cover crop (GMCC) systems so that future research and development efforts could be improved. The group found that multiple uses for GMCC species are imperative for their adoption. It does not suffice just to improve soil fertility and enhance weed control. They did agree that, given the high biological potential of *Mucuna*, additional resources were justified to add value to past efforts and recommended that a workshop on food and feed uses of *Mucuna* be conducted.

The Workshop *Mucuna* as a food and feed: current uses and the way forward" was held in April, 2000, in Tegucigalpa, Honduras. It was organized by the Honduras-based CIDICCO (International Center for Information on Cover Crops) with the help of Judson College (Illinois, USA), resource for L-dopa analyses, and CIEPCA (Center for Cover Crops Seed and Information Exchange in Africa) based at IITA in Bénin. The premise of the meeting was that *Mucuna* is a promising food and feed crop as shown by its use in the past and today. In the early twentieth century, it was utilized as a feed crop on 1–2 million ha in the southeastern USA in the early 20th century, and currently, it is a minor food crop in many countries (e.g., Ghana, Nigeria, Malawi, and Zambia). The workshop studied the current state of knowledge of *Mucuna* as a food and feed, recognizing that knowledge of harmful compounds in *Mucuna* is limited and that the impact of processing on harmful compounds is largely unknown. The workshop participants therefore identified a future research agenda as well as the individuals who could conduct the work. The proceedings of this meeting (Flores *et al.*, 2002) are published by CIDICCO as a book entitled *Food and feed from Mucuna: Current uses and the way forward* which is available as hard copy from CIDICCO and online at *www.cidicco.hn.*

The subsequent *Mucuna* Food and Feed project was coordinated and facilitated by CIEPCA during 2001–2002. Thematic experts (approximately 20 in seven countries) pursued the objectives established at the Honduras meeting. The outputs included the following:

- Use of *Mucuna* in the diets for ruminants
- Processing methods for food and feed from *Mucuna* beans
- The use of *Mucuna* in diets for non ruminants
- Impact of *Mucuna*'s secondary compounds on human health
- Characterization and improvement of *Mucuna* germplasm

The facilitators reached out to individuals who were not part of the project but who worked with *Mucuna* as a food or feed crop to promote sharing of knowledge outside the project. In addition to email, the major mechanism for information exchange was a bulletin, *Mucuna* News, which can be found at *http://ppathw3.cals.cornell.edu/mba_project/moist/home2. html*.

An end-of-project meeting was held at Mombasa to assess status of knowledge and future directions on *Mucuna*'s food and feed uses; participants were not only project investigators but also other relevant researchers. It was organized in 2002 by the Kenya Agricultural Research Institute (KARI) with help from CIEPCA. The proceedings (Eilittä *et al.*, 2003a) can be found at *www.uady.mx/sitios/veterina/servicios/ journal*. Highlights of results presented at the meeting follow for each output; further details on the project recommendations can be found in Eilittä *et al.* (2003b).

The use of Mucuna in the diets for ruminants

Animal studies with goats, sheep and dairy cows - both detailed on-station work examining physiological responses as well as more adaptive, on-farm efforts - were conducted. Seed, husk, and foliage were found to promote weight gain and sustain milk production without the ill effects commonly seen in monogastric animals and in humans. Whole pods were fed to goats (Mendoza-Castillo *et al.*, 2003) and sheep (Castillo-Caamal *et al.*, 2003) in Mexico without any apparent ill effects and have resulted in increased milk or meat production. For example, when growing sheep fed with Napier grass-based diet were supplemented with *Mucuna* at the level of 15 g kg LW^{-1} d^{-1}, their daily average weight gain (60 g) was greater than that of animals fed with 300 g d^{-1} of commercial feed (32 g) (Castillo-Caamal *et al.*, 2003). Further studies on husk confirmed its potential as a feed (Sandoval-Castro *et al.*, 2003; Ayala-Burgos *et al.*, 2003) and its digestibility is higher than most tropical grasses (Sandoval-Castro *et al.*, 2003). Also, foliage feeding was done in Kenya with no ill effects in cattle (Muinga *et al.*, 2003; Nyambati and Sollenberger 2003). Supplementation of Napier grass-based diet with fresh *Mucuna* or Gliricidia forage enabled similar total dry matter intake and milk yields (7.7 and 8.0 and 5.2 and 5.5 kg d^{-1} cow^{-1} for Gliricidia and *Mucuna*, respectively) (Muinga *et al.*, 2003). In Zimbabwe, milk yield of sheep fed with unensiled (614.3 mL d^{-1}) and ensiled (624.0 mL d^{-1}) beans was acceptable, although lower than that with a commercial concentrate (956.6 mL d^{-1}) (Matenga *et al.*, 2003). The nutritional analyses clearly indicate that *Mucuna* is, indeed, a high-quality feed for ruminants. Workshop participants concluded that future work should therefore focus on development efforts, location-specific research to verify these results under local conditions and to support the development efforts, and research to fill in knowledge gaps.

Processing methods for food and feed from mucuna beans

Studies led to an improved knowledge base on issues affecting *Mucuna*'s potential as a food source for humans. First, they elucidated ways to decrease L-Dopa content in beans to a level that would be acceptable to human consumption. In a two-year trial involving 4 (year 2000) or 8 (2001) accessions of *Mucuna*, the L-Dopa content of the seeds varied between 2.5 and 6.4% (Capo-chichi *et al.*, 2003b). If eaten in ordinary quantities, such high levels typically cause neurological and gastroinstestinal problems (Szabo and Tebbett, 2002). Soaking flour at 66°C for two hours in water reduces L-dopa to below safe level of 0.1% (Teixeira *et al.*, 2003). Also, 'tempe' (a fermented food) made from *Mucuna* has 0.2% L-dopa (Egounlety, 2003). The studies also led to an improved understanding of the factors impacting cooking and eating quality of *Mucuna* beans, including cooking time, water absorption, protein quality, and consumer acceptability. Additionally, the processing studies – whether conducted as a part of the food or non-ruminant feed studies - revealed promising processing options on which future efforts should be based (Bressani *et al.*, 2003; Wanjekeche *et al.*, 2003) and the surveys conducted resulted in improved understanding of the traditional utilization of *Mucuna* as a food (Onweluzo and Eilittä, 2003). Future work should focus on improving understanding of the processes involved in the development of *Mucuna* foods, on bioavailability of its nutritional components, on product development, and on furthering understanding of traditional uses of *Mucuna* as a food.

The use of Mucuna in diets for non ruminants

Studies with poultry gave less encouraging results than those with ruminants. The workshop participants were able to establish a target level of L-dopa that can be considered safe based on the studies to date. Inclusion at < 10% of poultry ration seems feasible. Roasted *Mucuna* beans can be included at such low levels in the poultry feeds without resulting in many of the negative impacts seen in the blood chemistry and anatomy of the birds fed with raw beans (Carew *et al.*, 2003). The most promising results were obtained with boiled beans, but the appropriateness of this technique to feed processing needs to be assessed (Nyirenda *et al.*, 2003). Future work should focus on determining the impact of processing on protein quality of the feeds and on exploring the shelf life of the feeds.

Impact of Mucuna's secondary compounds on human health

Two limited studies on the topic were conducted, and results from them were encouraging for the future utilization of *Mucuna* as a food and feed. First, using the Ames test, Burgess *et al.* (2003) found no evidence of mutagens in ground samples from raw and gently roasted *Mucuna* seeds. Also, Szabo (2003) found toxic alkaloids at 0.0001%. These very low levels, together with their poor gastro-intestinal absorption means they are not expected to cause harm to humans consuming *Mucuna* foods. Future work should continue on a limited scale, testing the processed products for mutagenic effects and for other potentially harmful substances.

Characterization and improvement of Mucuna germplasm

A major finding of the germplasm efforts of the past years is that all evaluated accessions (many of which are commonly utilized) can be considered as mere varieties of the species *Mucuna pruriens* (Capo-chichi *et al.*, 2001). The work on molecular markers (Capo-chichi *et al.*, 2003a) yielded further information on the relatedness among *Mucuna* accessions, indicating that maturity is an important trait in differentiating them. A study has greatly increased understanding of the contribution of genotype and environment to L-Dopa production of *Mucuna*, indicating the greater improtance of genetic factors (Capo-chichi *et al.*, 2003b). Together, the results of these studies have provided novel insights into the potential of genetic improvement to reduce *Mucuna*'s antinutritional factors. Future work should continue on both the evaluation of current *Mucuna* materials and the initiation of breeding, whether through conventional or newer methods.

Conclusion

Knowledge is now available to allow promotion of utilisation of *Mucuna* beans, especially for ruminant feeding. The project resulted in a great deal of new knowledge on the food and feed potential of the crop on which future research efforts can be based. An important lesson highlighted by this experience is that research to alleviate bottlenecks to delivering BNF to farmers may necessitate inclusion of expertise outside of the fields of Agronomy and Soil Sciences. Similarly, with soybean in Nigeria, it was food scientists who helped to create a market for soybean, and with grain legumes in cereal systems in West Africa, it was the Striga biologists who helped to identify additional benefits of grain legumes (Carsky *et al.*, 2003). In the case of the *Mucuna* fallow system it was researchers in animal science, food science, toxicology and analytical chemistry. A project to deliver BNF to farmers needs to decide how it will encourage other useful disciplines to contribute.

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