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Lessons for appropriate technology generation: Example of soil management technology at IITA

Key note

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Abstract — There are many legume-based technologies capable of regenerating soil fertility but few are being adopted by farmers in West Africa. At the IITA we found that alley cropping and cover cropping systems are biologically sustainable but have low adoption by farmers in the medium term. Negative reactions by farmers stimulated us to consider grain legume rotations for soil fertility maintenance, a decision that permitted a concentration of effort by several disciplines on the system. The short-term payoff was the generation of a large body of scientific information. Positive reactions of farmers have led to research at the farm level focusing on the increases in maize yield due to the N benefits and the reduction in *Striga hermonthica* parasitism. A preliminary estimate of impact can be calculated for northern Nigeria where gross revenue from soybean-maize rotation is 50 to 70% higher than continuous maize cropping. Several research and development efforts are now underway testing soybean or cowpea rotation with maize.

Résumé — Bilan des recherches sur la mise au point de technologies appropriées : l'exemple de la gestion de la fertilité des sols à l'IITA. L'intégration des légumineuses fixatrices d'azote dans les systèmes techniques de production a donné lieu à de nombreux travaux de recherche destinés à améliorer ou restaurer la fertilité des terres, mais très peu de ces systèmes techniques sont vraiment appropriés par les paysans en Afrique de l'Ouest. A l'IITA, les recherches ont porté d'abord sur les systèmes agro-forestiers et les cultures de couverture. Puis, l'IITA s'est intéressé à un effet positif additionnel des légumineuses : la réduction du parasitisme du *Striga hermonthica*. Une équipe pluridisciplinaire a été constituée pour étudier plusieurs aspects des rotations céréales-légumineuses à graine et générer des recommandations pour les services de recherche finalisée des pays d'Afrique de l'Ouest et d'Afrique centrale. L'impact de cet effort a été très net au nord du Nigeria, où la rotation soja-maïs sur deux ans augmente le revenu brut de 50 à 70 % par rapport à la monoculture du maïs, du fait d'un contexte économique incitatif ; cela conduit beaucoup d'ONG à tester les rotations céréales-légumineuses à graines avec les paysans.

Introduction

The IITA in its research for sustainable soil management has passed through several stages during which the focus of the technological solution has varied. In very general terms the focus of the IITA planted fallows technology has been: i) Alley cropping from 1976 to 1992; ii) Cover crops from 1980 to 1999; iii) Grain legume rotations from 1992 to present.

We have benefited from the experiences of our predecessors and the purpose of this article is to share the lessons learned with the larger community. The current focus on grain legume rotations is a result of the relatively low adoption of alley cropping and cover crops.

Alley cropping

Douthwaite *et al.* (2002) describe the history of alley cropping with some benchmark events. The first major event was the publication by Kang *et al.* (1981) that the technology could maintain maize yields in 1980 after 4 years of cropping while control yields declined. The formation of the Alley Farming Network for Tropical Africa (AFNETA) in 1989 was a recognition that the technology should be tested in many areas. By 1992 there were AFNETA trials in 20 countries and many publications on alley cropping.

Adoption studies by Whittome (1994), Dvorak (1996), Swinkels and Franzel (1997), Adesina *et al.* (1997) show difficulties with alley cropping and little farmer-to-farmer diffusion. An example given by Adesina *et al.* (1997) suggests that farmers did not test alley cropping if they learned about it from farmers (table I).

Table I. Testing of alley farming (number of farmers who tested / number of farmers informed) as influenced by the source of information.

| Source of Information | Nigeria | Benin |
|-----------------------|-----------|----------|
| Researcher | 134 / 164 | 46 / 125 |
| Extension | 0 / 3 | 26 / 74 |
| Farmer | 4 / 40 | 0 / 24 |

Source: Adesina *et al.* (1997).

Meanwhile other agroforestry systems could be observed in West Africa. The traditional agroforestry system in southern Benin was an oil palm fallow (Kang *et al.*, 1991). While improving the soil, it produces some oil and weaving material and after the fallow it produces palm wine and whiskey. These products all serve to generate cash and make the oil palm fallow an investment with direct economic benefits.

Another agroforestry system currently gaining in popularity in southern Benin is the *Acacia auriculiformis* woodlot. The major product of the system besides soil fertility improvement is wood for fuel, construction and furniture, rare commodities in the over populated savanna zone near the coast of Benin. In some parts of southern Benin projects are still involved and subsidizing the system. But in other areas it has continued to expand even after projects pulled out (Douthwaite, Carsky and Floquet, unpublished, 2001).

Lessons learned from alley cropping

- Direct economic benefits are needed, not just soil improvement.
- Alley cropping must be targeted to high population density areas where firewood is needed and fertilizer is not easily available.
- Farmers need to experiment with the technology and make modifications to it.
- Completely new systems are more difficult to understand and experiment with than simple components.

Cover cropping: case of *Mucuna* fallow

Mucuna had 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) summarized 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 weed 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. The ability to weaken *Imperata* was a major advantage that promoted adoption. But Carsky *et al.* (2001) predict relatively limited adoption in West Africa based on the known benefits of soil improvement and weed suppression. However, other possible benefits for *Mucuna* may be the ability to control *Striga*, consumption of grain and/or forage by humans and/or livestock. One of these additional benefits would increase adoptability beyond the zone predicted by Carsky *et al.* (2001). Globalized markets could provide other opportunities for *Mucuna*. For example, some projects are trying to develop organically produced cotton in Africa for the European market and *Mucuna* fallow may be found to be the best way to provide organic N for cotton.

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

In many systems the niche occupied by *Mucuna* takes land out of production for the major cereal crop or at least for the grain legume grown during the less favorable time of year. In a comparison of grain legumes with *Mucuna* in Kaduna, maize yields after *Mucuna* were higher than after cowpea but the latter system was more economically beneficial (Oyewole *et al.*, 1999). Farmers in the study site eventually abandoned *Mucuna* in favor of cowpea.

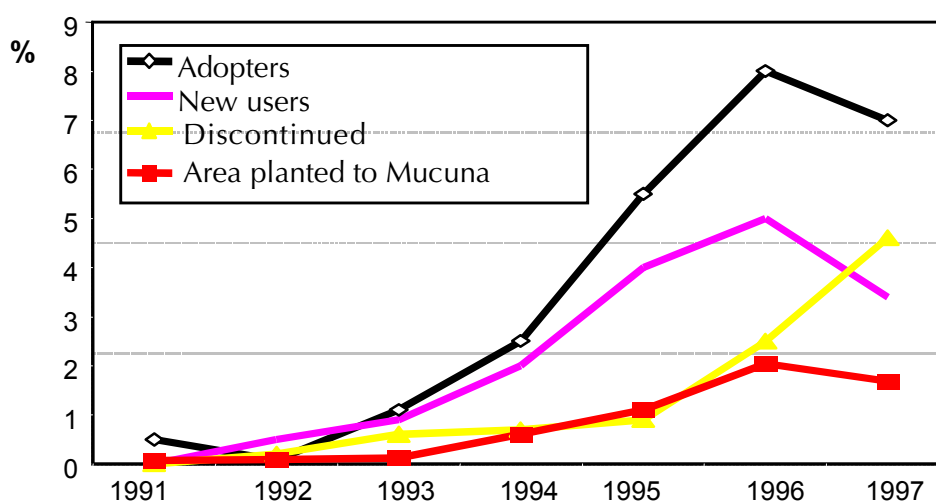


Figure 1. Dynamics of *Mucuna* fallow adoption in southern Benin from 1991 to 1997 (from Honlonkou *et al.*, 1999).

- Lessons learned from the Mucuna fallow system:
 - Legumes with multiple benefits are likely to be adopted;
 - Legume benefits that are solutions to problems perceived by farmers help promote adoption;
 - Direct economic benefit is needed by resource-poor farmers.

Grain legume rotations

While IITA and partners were struggling to find niches for alley cropping and Mucuna fallow, cowpea already had a high level of use in West Africa (Schulz et al. 2001) and soybean adoption was increasing, especially in Nigeria. IITA soybean varieties were adopted in the late 1980s and early 1990s through the efforts of development NGOs and government organizations. In Benue State, a soybean growing area for several decades, Sanginga (1998) observed that more than 50% of randomly selected farmers had adopted new IITA varieties during a 10-year period. In nearby southern Kaduna State another NGO gave seed of improved soybean to farmers. Manyong *et al.* (1998) found that by the third year, 35 farmers had passed seed of the new varieties to 45 additional farmers. Adoption of soybean in Nigeria was stimulated by a large effort to develop food recipes using soybean and incorporating soybean into traditional Nigerian dishes (Osho and Dashiell, 1998). There has been a big increase in the demand for soybean in most of the major cities in Nigeria. An example of this is Ibadan (one of the largest cities in Nigeria) where an urban market survey revealed that soybean was sold in only two markets in 1987 but in 19 markets by 1990. Soybean retailers in those markets expanded from a total of 4 to 419 (Osho and Dashiell, 1998).

With this in mind IITA made a change in focus in the mid-90s with an emphasis on grain legumes, especially those that are being bred at IITA. We did this realizing that the potential benefit of grain legumes to the soil is relatively low but they are infinitely more adoptable than other legume-based technologies. We started to think of grain legume rotations as “improved fallow” systems, although a fallow with a direct economic product.

Table II. Potential soil improvement and farmer adoption of leguminous fallows.

| Legume type | Soil improvement | Adoptability |
|-------------|------------------|--------------|
| Woody | high | very low |
| Forage | high | very low |
| Cover | high | low |
| Grain | low to mod | high |

Furthermore we found that soybean and maybe cowpea could be false hosts for *Striga hermonthica*. This was first discovered by screening a large number of soybean lines using an in vitro technique and subsequently validating the results in the field (Berner *et al.*, 1996). This gave grain legumes another potential benefit in addition to grain for human nutrition and soil improvement. Therefore substantial resources in IITA have been put into the grain legume – cereal rotation system. Research has focused on traits that will improve the benefits of grain legumes to the farming system (biological N fixation, P use efficiency, fodder production, and *Striga hermonthica* seed germination). At the same time maize was crossed and screened for *Striga* resistance and N use efficiency. Also systems studies were carried out on:

- Response of soybean to inoculation as a function of plot history and Rhizobium density;
- Ability of soybean and cowpea to stimulate *Striga hermonthica* germination and reduce the *Striga* seed bank;
- Effect of soybean and P fertilizer on root growth and *Striga hermonthica* reduction;
- Nitrogen contribution of soybean as a function of soybean varieties differing in maturity cycle, N fixation and P fertilizer application;
- Residual effects of soybean as a function of soybean residue management and agro-ecological suitability of soybean;
- Integration of *Striga hermonthica* resistant maize and maize tolerant of low soil N;
- Effects of combining N fertilizer with grain legume residues on maize yield.

Results of these studies have lead to recommendations for maximizing benefits of cowpea to maize in rotation (Carsky *et al.*, 2002).

Payoff from focus on right system

Although the soil fertility benefit of soybean or cowpea is low to moderate, farmers benefit from the production of pulses, reduced *Striga hermonthica* where it is a problem and some fodder production where needed. Thus soybean and cowpea rotation with maize were tested intensively with farmers in the northern Nigeria benchmark area starting in 1999. Testing the grain legume rotation systems poses essentially no risk to farmers compared to alley cropping and cover cropping. The latter systems required substantial investment in labor for eventual increase in yield. If abiotic or biotic stresses occurred unrelated to soil fertility, then maize yields did not compensate the investment.

In one study conducted in several villages by Schulz *et al.*, (2003) soybean and cowpea were used to reduce *Striga hermonthica* seed density in the soil. After one year of soybean (14 fields) or cowpea (5 fields) *Striga hermonthica* seed density was significantly reduced (Table III). *Striga* resistant maize was grown after soybean or cowpea rotation and compared with the farmers' current variety. Subsequent density of emerged *Striga* plants on maize was significantly reduced and maize yield was significantly higher in this integrated control package (Table IV).

Table III. Initial *S. hermonthica* (Sh) seed densities in the soil prior to (1999) and after one year of soybean or cowpea rotation (2000) on 19 farmers' fields in Kaduna State.

| Treatment | 1999 (Sh seed m ⁻²) | 2000 (Sh seed m ⁻²) |
|----------------------------|------------------------------------|------------------------------------|
| Farmer Practice | 16,594 | 26,042 |
| Soybean or cowpea rotation | 30,081 | 15,390 |
| Probability | 0.8891 | 0.0560 |

Table IV. Effect of integrated control consisting of soybean or cowpea rotation and resistant maize variety on emerged *S. hermonthica* plants on subsequent maize and grain yield

| Treatment | Sh plants maize stand ⁻¹) | Maize grain (Mg ha ⁻¹) |
|--------------------|---------------------------------------|------------------------------------|
| Farmer Practice | 0.47 | 0.87 |
| Integrated Control | 0.12 | 1.41 |
| Probability | <0.0001 | <0.0001 |

Another study focused on the soil fertility and economic benefit of soybean rotation in northern Kaduna State (Kaya) with TGx-1448-2E or Samsoy2 compared with Lablab purpureus or maize. After TGx-1448-2E succeeding maize and/or sorghum crops gave good yields with less nitrogen fertilizer than they would normally apply. Farmers in Nigeria are excited about TGx 1448-2E because it is high yielding, resistant to Frog Eye Leaf Spot, resistant to pod shattering, has high % Ndfa and stimulates *Striga* germination. The highest net benefits for the two seasons (1450 US\$/ha) were obtained with the rotation of TGx 1448-2E followed by the local variety Samsoy 2 (1000 US\$/ha). The lowest net benefits (600 US\$/ha) were obtained with *lablab* (Sanginga *et al.*, 2001). Economic analysis of these systems shows already an increase in the gross income of farmers of 50-70% compared to those following the current practices of mainly continuous maize cultivation.

In subsequent seasons all the farmers opted to grow TGx 1448-2E instead of their own varieties or lablab that were compared in the on-farm demonstrations. Through farmer-to-farmer seed diffusion, more farmers in the villages around the benchmark site had abandoned their old varieties and grew TGx 1448-2E in 2000 (Sanginga *et al.*, 2001). The farmers commented that the IITA variety yields more and produces more biomass than their own varieties. Sasakawa Global 2000 and other NGOs have started testing grain legume - maize rotation with large numbers of farmers in northern Nigeria.

A rough estimate of impact assumes an increase in grain legume cultivation area of 10% in the northern Guinea savanna in Nigeria (about 30,000 ha) with yield increases of 20%. This would lead to additional fixed N and P acquisition from sparingly soluble P sources valued annually at \$44 million (Sanginga *et al.*, 2003).

Production of soybean in Nigeria has been estimated at 405,000 tons in 1999 compared to less than 60,000 tons in 1984 (FAO, 2000). We expect that this estimate will increase dramatically in the next five years.

Limits to technological interventions

While it is clear that the right technology in the right conditions can make a big difference we must not forget the importance of the economic environment and the availability of information. There are several forces that limit the cultivation of grain legumes including low yields, difficult processing and anti-nutritive factors and societies tend to reduce legume production as they develop (Smil, 1997). For now the demand for soybean and cowpea in Africa seem far from saturated but clearly the market is not infinite. The world market price for soybean is much lower than the current domestic Nigerian market, making new systems vulnerable and less competitive in the world market. Market information will be crucial in the future to decisions by farmers about what to produce and therefore they should be important determinants of research to develop viable food production systems. The payoff from focus on right system at local levels is likely to be modified by new rules from international markets, which in the future will be dictating the competitiveness of all production systems at local, domestic, regional and international levels. Therefore there is the need to integrate parameters from market globalization into the development process of soil management technologies so that production systems remain viable in the long run.

Government policies can have a major influence on what is commercially beneficial to farmers (Keatinge *et al.* 2001). For example Adesina and Coulibaly (1998) calculated that the comparative advantage for alley farming in Cameroon increased after the removal of subsidies and the devaluation of the FCFA. Policies could be put in place to favor or disfavor the cultivation of grain legumes and all potential scenarios should be studied carefully.

An important part of the grain legume – maize rotation system is adequate soil nutrients because grain legumes do not fix all of the N needed by subsequent maize and because both crops need other nutrients, especially P. Government policies can influence tremendously the use of fertilizers and sustainable land stewardship in general (Keatinge *et al.*, 2001).

Summary of lessons learned

From the work on alley cropping and Mucuna fallow, Douthwaite *et al.* (2001) made several generalizations to guide participatory technology development. Some of the most important have guided the work on grain legume rotation systems in northern Nigeria:

- Choose trial sites where the adoption potential is high because this will provide motivation to farmers to participate, learn, adapt, select and promulgate.
- Provide farmers technologies that are easily understood, are easy to modify, and motivate farmers by offering a promise of real short-term benefit.
- Ensure that farmers adopt because of a promise of benefit rather than because of other incentives such as free seed or fertilizer.
- Carry out separate trials to assess adoptability and biological performance.
- Allow farmers flexibility in management of the technology.
- Identify modifications that farmers make to the technology because these are: indicators of interest; source of potential improvements; and give insights into farmers' perceptions.
- Keep in mind the policy environment and how it influences the farmers' motivation to adopt the technology.

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