Experiences with Mucuna in West Africa

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Abstract

West Africa has large areas with adequate rainfall and solar radiation. However, soils are relatively infertile, fertilizer use is low, and the soil is easily degraded under intensified agriculture. Shifting cultivation, the basis of the traditional agricultural systems, cannot be sustained because of the rapidly growing population. Of the alternative soil-management strategies that have evolved, one of the most promising is the use of *Mucuna* (*Mucuna pruriens*) as a weed-smothering and soil-improving cover crop.

Mucuna adoption first occurred in southwestern Benin, where researchers and extensionists tested the technology with farmers from 1988 to 1992. Because of the promising results, extension services undertook to disseminate *Mucuna* to large numbers of farmers. The possibility that this technology may solve farmers' problems in other areas of West Africa prompted us to examine adoption in Benin to learn the conditions under which it is acceptable. Adoption first occurred in an area of very high rural population density, where land pressure no longer permitted the use of long fallows to restore soil fertility and reduce weed infestation. Suppression of spear grass (*Imperata cylindrica*) was perceived to be a major benefit of *Mucuna* fallowing and therefore provided a window of opportunity for promoting adoption of the technology. Based on farmer and researcher experience, expansion of *Mucuna* fallowing is more likely to occur in areas where soil fertility is declining, inorganic fertilizers are expensive, noxious weeds such as *Imperata* severely affect farmers' production, and development organizations have good contact with farmers. Adoption is likely to be stimulated by new markets for *Mucuna* seeds. Adoption is also most likely to occur in areas with long growing seasons (7 months or more). Other windows of opportunity for *Mucuna* fallows may exist in the need for additional livestock feed or the need to reduce *Striga hermonthica* or nematode buildup in intensified cereal systems.

Résumé

L'Afrique de l'Ouest possède de grandes zones caractérisées par une pluviométrie et un ensoleillement adéquats, mais les sols sont relativement pauvres et l'utilisation des engrais est faible. Une grande partie des ressources du sol se dégrade facilement avec la pratique de l'agriculture intensive. La culture itinérante, qui est la base des systèmes agricoles traditionnels, ne peut se maintenir avec une croissance démographique rapide. Pour cette raison, des stratégies alternatives de gestion des sols ont mises sur pied, parmi lesquelles l'une des plus prometteuses est l'utilisation du pois mascate (*Mucuna pruriens*) comme plante de couverture pour l'amélioration du sol et la lutte contre les adventices.

Le *Mucuna* a été adopté pour la première fois au sud-ouest de la République du Bénin, où les chercheurs et les vulgarisateurs ont testé la technologie avec les paysans de 1988 à 1992. Compte tenu des résultats encourageants, les services de vulgarisation ont commencé à disséminer le *Mucuna* à un grand nombre de paysans. Pensant que cette technologie pourrait résoudre les problèmes des paysans dans d'autres régions d'Afrique de l'Ouest, nous avons décidé d'étudier le problème de l'adoption au Bénin pour connaître les conditions nécessaires à son adoption. Nous avons d'abord introduit le *Mucuna* dans une région ayant une forte densité de population rurale, où la pression foncière ne permettait plus la pratique de longues jachères pour restaurer la fertilité et réduire l'infestation des adventices. L'élimination du chiendent (*Imperata cylindrica*) était vue

comme un avantage principal pour la jachère avec le *Mucuna* et a ainsi créé des possibilités pour l'adoption de la technologie. Sur la base des expériences paysannes et de la recherche, la diffusion de la jachère avec le *Mucuna* ne sera efficace que là où la fertilité des sols baisse, les engrais inorganiques sont chers, les adventices nocives, comme le chiendent, affectent de façon dramatique les productions des paysans et où les organisations de développement ont d'excellents contacts avec les paysans. L'adoption semble être stimulée par les nouveaux débouchés pour les semences du *Mucuna*. Les zones ayant de longues périodes de campagne agricole (7 mois ou plus) pourraient aussi être concernées. D'autres débouchés pour les jachères avec le *Mucuna* pourraient exister, tel que le besoin de fourrage supplémentaire pour le bétail ou le besoin de réduire le *Striga* ou les colonies de nématodes dans les systèmes intensifs de culture de céréales.

Introduction

The farming systems predominant in West Africa are based on shifting cultivation practices. These traditional slash-and-burn systems operated efficiently in the past, when land for cropping was abundant. But today, with a rapidly increasing population, these agricultural practices are under severe pressure. An estimated annual population growth rate of 3% was recorded in the West African countries in the early 1980s; however, food-crop production was increasing at only half of that rate (Steiner 1982).

Consequently, marginal lands were brought into cultivation and small-scale farmers were compelled to change from extensive to intensive use of the land, without knowing the appropriate management practices. Fallow periods, which used to be long enough (10 years or more) to allow the replenishment of soil fertility, were drastically shortened or simply abandoned. As a result, woody species have disappeared. For example, the closed forest area on the coast of West Africa was disappearing at a rate of 5.1% per year during the early 1990s, mainly to accommodate agricultural production (Kang et al. 1991). This deterioration of forest resources has been aggravated by nearly two decades of drought. West Africa is currently witnessing a shift in ecological zones — desertification of the Sahel, sahelization of savannas, and savannization of the forests (Tolba 1993).

Inadequate agricultural practices have led to a dramatic decline in soil fertility, invasion by noxious weeds, and extremely low crop yields. The alarming soil degradation will in the long run threaten food security if appropriate soil-management practices are not developed. The bush-fallow agricultural system practiced by smallholders cannot meet food requirements in densely populated areas; therefore, alternative systems that can ensure high soil productivity, without compromising the environment, have to be developed. According to Lal and Cummings (1979), the adverse effects of the overuse of land may be minimized if, after clearing the soil, farmers sow a cover crop. In an effort to minimize the soil degradation associated with agriculture, extensionists have encouraged the use of cover crops such as *Stylosanthes guianensis, Pueraria phaseoloides, Mucuna pruriens,* and *Centrosema pubescens*.

In the late 1980s and early 1990s, *Mucuna* was first adopted by farmers participating in a research project in Mono province in southwestern Benin (see Versteeg et al., this volume). *Mucuna* was then disseminated throughout the country by government extension services and nongovernmental organizations (NGOs). This paper presents a case study of the use of *Mucuna* cover crops in West Africa, with a view to identifying the potentialities and constraints related to the use of green-manure cover crops (GMCCs). The understanding of the biophysical and socioeconomic conditions under which GMCC technologies are feasible, the adoption behaviour of farmers, and the benefits arising from the adoption of these technologies could allow for extrapolation to similar situations, which would help to address the problem of land degradation in West Africa.

Characteristics of the West African farming environment

Climate, soil, and biophysical characteristics

West Africa has several distinct agroecological zones, which are described in Ker (1995) and others. The growing season varies from about 300 d (along the coast from Sierra Leone to Côte d'Ivoire) to about 60 d in the Sahel (Figure 1). The arid zone has 60–120 d, and the semi-arid zone has 120–150 d. Subhumid (150- to 270-d growing season) zones (SHZs) are found in Senegal, The Gambia, Guinea Bissau, Guinea, Mali, Burkina, Côte d'Ivoire, Ghana, Togo, Benin, Gambia, and Nigeria. The SHZ is divided into a drier, monomodal-rainfall area to the north (150–210 d with no dry period) and a more humid, bimodal-rainfall area to the south (210–270 d separated by a short dry period). The former is often referred to as Guinea savanna, and the latter is referred to as the forest–savanna transition zone, or the derived savanna zone.

Figure 1. Major agroecological zones in West Africa, based on length of growing period (LGP). Source: Resource Information System, IITA (Jagtap 1995).

Soil conditions determine the intensity of cropping, the need for fallowing, the varieties of crops that can be grown, and the risk of drought (Mutsaers et al. 1986). Major soils are Alfisols in the savanna areas and Oxisols or Ultisols in the humid areas (Jones and Wild 1975). The Food and Agriculture Organization of the United Nations (see Manyong et al. 1996b) classified the major soil units of Africa as high fertility (very suitable), moderate fertility (suitable), and low fertility (requires major improvements or not suitable) (Figure 2). Manyong et al. (1996b) calculated that soils in the first two categories — that is, those fertile enough to support crops — occupy only 24% of West Africa. The remaining 76% of soils in West Africa can be characterized therefore as poor, requiring judicious use of fertilizers, organic-matter (OM) management, and erosion control. Soil-improvement measures, such as agroforestry, minimum tillage, grass strips, and cover crops with herbaceous legumes, are needed to allow sustainable use of the soil resource.

Figure 2. Soil-fertility classes in West Africa. Source: Adapted from FAO (1978, cited by Manyong et al. 1996b), Resource Information System, IITA (Jagtap 1995).

Weeds are a major constraint to crop growth in the humid zones and SHZs, and weeding requires a major labour input. Although there are many species of weeds (Akobundu and Agyakwa 1987; Weber et al. 1995b) two major ones are spear grass (*Imperata cylindrica*) in the humid zones and witchweed (*Striga* spp.) in the dry zones.

Spear grass is abundant in the humid zones and SHZs where the land is used intensively. The weed is generally found in West Africa in food-crop fields wherever population density is high. Spear grass is one of the most difficult weeds to control in the tropics (Thurston 1997). It causes many farmers in southern Benin to abandon their fields to fallow (Hinvi et al. 1991).

Witchweed is a parasitic flowering plant that, like spear grass, is more serious with land-use intensification (Weber et al. 1995a; Berner et al. 1996). The most serious species is *Striga hermonthica*, which is parasitic to maize, sorghum, and millet. It is very difficult to control because it does much of its damage (direct extraction of plant nutrients) beneath the soil surface.

Socioeconomic conditions of smallholders

More than 70% of the people in West African countries live in rural areas (Ker 1995). Population density decreases from the coastal and humid forests in the south toward the transition zone in the middle of the region and then increases again in pockets of the dry subhumid and semi-arid savannas in the north (Weischet and Caviedes 1993). Population densities in the region are generally at less than 50 people km^{-2}, except along the coast that runs east from Abidjan to Port Harcourt and the savanna pockets mentioned above (Manyong et al. 1996b). Those areas may have in excess of 200 people km^{-2}.

Tropical African agriculture is dominated by smallholding. Steiner (1982) reported that 80–90% of the agricultural farms in Africa are smallholdings. For example, in Nigeria, more than 80% of small-scale farms were found to range from 0.1 to less than 6.0 ha (Olayide 1980). The situation is similar in other West African countries, where most holdings are less than 2 ha and 96% cover less than 10 ha (Harrison 1987, cited by Ker 1995).

In general, road infrastructure is deficient in West Africa. Although the access to markets is fairly good in the south, it gradually deteriorates northward, except in the pockets of high population density mentioned above. The presence of tree cash crops (cocoa, coffee, palm products, rubber) and of major centres in the south has attracted national and international funding for road maintenance (Manyong et al. 1996b). In the north, the poor quality of road infrastructure increases the marketing margins for inputs such as chemical fertilizers, rendering them expensive for small-scale farmers, especially compared to staple food prices.

The literacy rate in West Africa is low. Furthermore, smallholders lack resources and access to credit, which leads to low investment in agricultural activities and, consequently, to low productivity and low income, causing a vicious cycle of poverty. Access to extension services is generally limited, although there are countries and periods in which support for extension services, through loans and NGOs, is strong.

Farming systems of smallholders

Agricultural practices in West Africa are highly diverse and far from static. Farming systems are often a mixture of crop and livestock enterprises. Cattle and sheep dominate livestock holdings in the drier areas; goats and poultry, in the more humid. Fencing is not widespread, and crops and animals commonly compete. Cattle are important as providers of manure and draft power, but these are important elements of the farming systems only in the semi-arid and drier SHZs of Nigeria (von Kaufmann and Blench 1990) and elsewhere in West Africa. In these areas, animal traction is mostly used for land preparation and some weed control. In the rest of the region, manual land preparation dominates.

Major crops are summarized by Ker (1995) as follows: millet, sorghum, and cowpeas in the arid and semi-arid zones; groundnuts and cotton as cash crops in the semi-arid and dry SHZs; maize replacing sorghum in many areas of the Guinea savannas; rice in waterlogged areas; sweet potato and cassava in the moist SHZs; and yam, cocoyam, plantain, and tree crops in the humid zones.

Intercropping is still an important characteristic of smallholder cropping systems. Eighty percent of the cultivated area in West Africa is under mixed cropping (Steiner 1982). Whether an area is under sole crops or is under mixed crops depends on agroecological zone, farm size, labour availability, crop species, and local resources. For example, intercropping is more pronounced in forests than in savannas, as the holdings in the forest are smaller and the number of crop species is greater. Multiple cropping is beneficial because it reduces the risk of crop failure and makes efficient use of available labour. Multiple cropping provides farmers with a balanced diet, and it is a sound soil-conservation strategy (Norman et al. 1982). The dominant crops in the humid and subhumid cropping systems are tree crops (cocoa, coffee, oil palm, and coconut, estimated at 14% of West Africa), cassava (8%), yam (16%), and maize (15%) (Manyong et al. 1996b). In the semi-arid and arid zones, sorghum- and millet-based systems predominate.

The major fertility-management practice is fallowing. In addition to this, household wastes (including food-processing, human, and animal wastes) are applied to fields near the homestead. Crop residues and weeds are recycled in more distant fields, and fertilizer is more likely to be applied on those fields. Availability of fertilizer depends on countries' importation and subsidy policies, as well as on road access to sources of supply. For example, fertilizers were highly subsidized for many years in Nigeria. These subsidies are presently being lifted, and fertilizer use among resource-poor farmers is decreasing. Farmers in cotton-growing areas in the former French colonies have very good access to fertilizer through the cotton companies.

Some properties of *Mucuna*

According to the Food and Agriculture Organization of the United Nations (FAO 1982), Weber et a6l. (1997), and Kiff et al. (1996), *Mucuna* is adapted to a broad range of precipitation (optimum range of 1 000–2 500 mm a^{-1}) and elevation (0–1 600 m asl). It tolerates a relatively narrow range of temperatures (19–27°C) but is still adapted to most of the humid zones and SHZs of West Africa. Osei-Bonsu and Buckles (1993) reported that *Mucuna* performs well in the forest and the forest–savanna transition zones of Ghana (bimodal precipitation pattern). In Benin, as in Côte d'Ivoire, Ghana, Nigeria, and Togo, *Mucuna* grows better in areas with a bimodal rainfall regime.

In the semi-arid zones, *Mucuna* grows well but accumulates less biomass (Carsky and Ndikawa, this volume), and many of the varieties may not complete their reproductive cycle, making seed multiplication difficult. For seed production, *Mucuna* should be seeded as early as possible at the beginning of the rainy season. According to Buckles (1995), the life cycle of *Mucuna* varieties varies from 100 to 290 d. Thus, some varieties may be more appropriate for the semi-arid zone. Varieties tested with farmers and disseminated in Benin and elsewhere are *M. pruriens* var. *utilis* and *M. pruriens* var. *cochinchinensis*. They are distinguished by their seed colour, *utilis* being black and *cochinchinensis* being white.

The established databases (Kiff et al. 1996; Weber et al. 1997) state that *Mucuna* is adapted to soil with sandy to sandy-clay texture, pH of 5.0–7.0, and low fertility. *Mucuna* is susceptible to waterlogging and somewhat tolerant to drought. Waterlogged and very infertile, acid soils, with a pH of 4.5 or less, are unsuitable for *Mucuna* (Hairiah et al. 1993).

Mucuna usually produces substantial amounts of seed. Not all the seeds may be harvested by farmers, but at the onset of the next rainy season, the uncollected seeds germinate before the maize is sown. These *Mucuna* seedlings are easily weeded out. Alternatively, farmers can cut the *Mucuna* vines without killing the plant, allowing it to regrow after maize harvest.

Mucuna-management systems in Benin

Two management systems have been developed in Benin for integration of *Mucuna* into cropping systems. One is a sole-cover-crop fallow for severely degraded fields. The other is a maize–*Mucuna* relay crop for fields requiring less rehabilitation. Other possible management systems can be used depending on the length of growing season and the benefits required by farmers. For example, farmers in the bimodal-rainfall zone can grow sole food crops during the first season and a sole crop of *Mucuna* during the second season.

Sole-crop short fallow

For severely degraded and *Imperata*-infested fields, *Mucuna* should be planted in a pure stand at the start of the rainy season. The plot is slashed with a cutlass or sickle before the *Mucuna* is sown. The spacing is 0.8 m x 0.4 m, with two seeds per hole; about 30 kg seed ha^{-1} is required. Three or four weeks after the planting of *Mucuna*, a second slashing may be needed to allow *Mucuna* seedlings to overcome spear grass, as it is a fast-growing weed. However, we observed that if *Mucuna* starts vining, a second slashing may cause damage to *Mucuna* seedlings. In the bimodal-rainfall zone, *Mucuna* is usually planted in March and April to maximize biomass accumulation and ground cover. But the sowing date can be extended to May if the rains are not well established.

Mucuna usually produces substantial biomass, which covers the soil and strangles all the weeds or climbs as high as its support (weeds, trees, associated crops) allows. Production of 7–9 t of dry matter (DM) ha^{-1} is commonly observed in the bimodal-rainfall zone (Carsky et al. 1998). In the dry season, usually in December, at the end of its life cycle, *Mucuna* leaves a thick mulch free of weeds. This allows for a subsequent maize crop during the major rainy season with little or no land preparation or weeding. Maize can be seeded directly through the mulch with a stick, hoe, or cutlass.

Intercrop with maize

Mucuna can be intercropped with maize when *Imperata* infestation is not severe. Maize is planted at a normal spacing of 0.8 m x 0.4 m, with 2 seeds per hole. Then 40–45 d after planting (DAP) the maize (just after second weeding), the farmer sows the *Mucuna*, either between or within the rows. Sowing *Mucuna* too early (before 45 DAP maize) can result in reduced maize yields (Osei-Bonsu and Buckles 1993). *Mucuna* spacing is 0.8 m x 0.8 m, with two seeds per hole, and about 30 kg seed ha^{-1} is required. After maize harvest, the land is left to *Mucuna* fallow, which prevents farmers from cropping the land during the second (minor) rainy season.

Adoption of *Mucuna* in southwestern Benin

Characteristics of the zone and the country

The Mono province of southwestern Benin has a bimodal rainfall pattern, resulting in a first growing season from April to July and a second one from September to November. Going north, the short dry season becomes increasingly shorter, until it is no longer observed at 9 or 10°N. Thus, the bimodal-rainfall system blends into a monomodal one. Parallel to this, the rains establish later and end earlier, resulting in an increasingly shorter growing season as latitude increases. This north–south gradient in the rainfall pattern is also observed in Côte d'Ivoire, Ghana, Nigeria, and Togo.

Overall, population densities in southern Benin are 100–200 people km^{-2} (Manyong et al. 1996b). Throughout the rest of Benin, rural population densities are 25–50 people km^{-2} in the middle portion and fewer than 25 people km^{-2} in the north (Manyong et al. 1996b). Some pockets of higher population pressure are found, for example, in southern Benin where, in a series of low-rising plateaus, soils are old and stable. The soils on these plateaus have supported high population densities (220–350 people km^{-2}) for a long time. The soils are locally called *terres de barre* (Raunet 1977). They are Acrisols (low base saturation) or Lixisols (moderate base saturation) in the FAO classification (Stahr et al. 1996), with sandy topsoil and clayey subsoil. Thus, they are physically stable (not prone to erosion) but chemically very poor. Farmers have developed a fallow system based on a dense stand of oil palm (Kang et al. 1991).

Three major cropping systems are found in Benin (VMM, unpublished data):

- Oil-palm–maize-based systems, found in the south, have oil palm, maize, cassava, cowpea, and groundnut as the major crops. Fire is used to clear land, and hoeing is common. Little or no fertilizer is used, and traditional crop varieties are grown. Major field problems are weeds (*I. cylindrica*), insects, and soil fertility. Oil palm is used for fallow between food-crop cycles and for the production of economic goods, such as firewood, animal feed, palm oil, palm wine, and whiskey (Kang et al. 1991). A typical farm size is less than 1 ha, and the cropping intensity is very high (67–80%). Trading is very important as a source of cash.
- Maize–cassava- and maize–yam-based systems are found in the moist SHZ in the middle of Benin. The major crops are maize, cassava, yam, cotton, and cowpea. Fire is used to clear land, and hoeing is common, although animal traction is increasingly used in places where cotton is important. Fertilizer and improved crop varieties are more commonly used because of support from cotton-development companies. A typical farm size is 1–3 ha, and the cropping intensity is low to moderate (23–50%).
- Yam-, cotton-, and sorghum–millet-based cropping systems dominate in the dry SHZ and semi-arid zones to the north. Cattle are important there and are used as a source of traction and manure in mixed farming, but conflicts arise when the cattle of nomadic herders damage crops. Fertilizer is available to cotton farmers. Because of lower population density, farm sizes are larger and cropping intensity is low, unless farmers use fertilizers or animal manure.

Introduction of *Mucuna* and its adoption

According to Buckles (1995), in the 1920s several experimental stations in Nigeria grew *Mucuna* spp. as improved fallow and as relay crops with maize and cassava, with a view to intensifying small-scale shifting agricultural systems. Vine (1953) and others reported the results of long-term trials. However, Agboola (1975) reported that the use of *M. pruriens* var. *utilis* in rotation failed to gain any wide acceptance, despite the wide publicity given it by the Ministry of Agriculture in Nigeria. This is probably typical of several places in West Africa, for example, in Francophone West Africa when Botton (1957/58) recommended *Mucuna* for southern Côte d'Ivoire.

In 1986/87, *Mucuna* was introduced in Mono province within the framework of Recherche appliquée en milieu réel (RAMR; applied research in practice), a development-oriented research project of the Ministry of Rural Development (MRD) of Benin, the International Institute of Tropical Agriculture (IITA), and the Royal Tropical Institute of the Netherlands. A small number of demonstration plots of *Mucuna* fallows were established (often on local school grounds), and farmer visits were encouraged (Versteeg and Koudokpon 1990). In 1988, the project tested *Mucuna* fallow, fertilizer-N, pigeon-pea hedgerows, and alley cropping with many farmers in an effort to explore ways to maintain or improve soil fertility and produce food crops (the project's priority issue). Twenty farmers chose to test the *Mucuna*-fallow system. Fourteen obtained a dense stand and cover of *Mucuna* and observed reduced *I. cylindrica* infestation. The farmer collaborators identified the reduced need for manual weeding or herbicide use in the subsequent maize crop as an unexpected benefit, which resulted in some spontaneous adoption. In 1989, the research team observed that 103 farmers in the neighbourhood had planted *Mucuna* (Versteeg and Koudokpon 1990). This spontaneous adoption was based on what farmers had seen in project demonstrations in 1986 and 1987 and on other farmers' fields in 1988.

The government extension services — which included each Regional Action Centre for Rural Development (RACRD) of MRD — became interested in this success and started testing the system with farmers. In 1990, the RACRD for Mono province tested the system with 180 farmers in 12 more villages (Versteeg, personal communication, 1991[(2)]). These efforts were extended to other southern provinces in 1991, and the number of farmers testing *Mucuna* grew to about 500 (IITA 1991). Large NGOs got involved, and the estimated number of farmers testing *Mucuna* was 3 000 in 1993 (IITA

1993) and nearly 10 000 throughout Benin in 1996 (Figure 3).

Figure 3. Estimated number of farmers testing *Mucuna* in Benin in recent years. Source: Versteeg and Koudokpon (1990), IITA (1991, 1993), and Galiba et al. (this volume).

Determinants of adoption in southwestern Benin

In 1994, econometric models and a sample of about 280 farmers from Mono province were used to investigate the determinants of adoption in southwestern Benin (Manyong et al. 1996a; Houndékon et al., this volume). The researchers evaluated the influence of farmer and field characteristics and farmers' perceptions of the technology.

Field characteristics had the most influence on adoption. The most important determinant (positively related to adoption) was the number of weeding operations farmers had needed before they began the *Mucuna* testing. If fewer than three weeding operations were required, then *Imperata* was not felt to be a serious problem, as farmers normally weeded twice anyway. But three, four, or five weeding operations were often needed to reduce damage from *Imperata*. If more than five weedings were required, then *Imperata* was left in the field, cut off, and sold in the market as roofing material.

The second determinant (negatively related to adoption) was the presence of young palm trees in the field. This is because oil palm is used for long-term fallow and several valuable products, and *Mucuna* would smother the young trees. The third determinant (positive) was the farmers' perception of poor soil fertility.

Other determinants related to the farmer and farm were secure land tenure (positive); the amount of fallow land owned by the farmer (negative); and access to external research or extension institutions (positive). Determinants related to the farmers' perception of the technology were the fact that wild *Mucuna* causes itching, thereby discouraging trespassing by strangers (positive); the loss of the opportunity to grow a second-season food crop on the field (negative); and the possibility of a market for *Mucuna* seeds (positive).

Dissemination of *Mucuna* in Benin

In addition to the RACRDs, some major NGOs involved in the diffusion of *Mucuna* were Sasakawa Global 2000 (SG 2000), the Regional Centre for Development of Health, and the Projet de développement de l'élevage dans le Borgou Est (development project for animal husbandry in east Borgou). SG 2000's effort started in 1992, when it purchased about 4 t of *Mucuna* seeds from farmers who had been exposed to *Mucuna* technology through RAMR in Mono province. These *Mucuna* seeds were distributed free of charge to 128 targeted farmers in provinces where spear-grass invasion and soil depletion were problems. A technical bulletin on the establishment of *Mucuna* fallow was developed to guide extension agents. Village extension agents were trained to give technical assistance to farmers, and close supervision was provided by both MRD's and SG 2000's officers.

Thus, many farmers throughout the country were given the opportunity to try, evaluate, and decide whether to adopt the technology. Good contact between farmers and extensionists (a hands-on approach) was the key dissemination strategy (Galiba 1994). A spontaneous-diffusion ratio of seven new farmers for every farmer reached by SG 2000 was observed in Benin (Galiba et al., this volume), indicating that early adopters are regarded as models in their communities and play an important role in the diffusion process.

Despite the many possibilities for *Mucuna* use, two simple but effective approaches were recommended: *Mucuna* in pure stands or improved fallow and *Mucuna* in relay with maize, both described above. Pure stands were recommended to improve degraded soil and to reduce spear-grass infestation when it was serious enough to cause farmers to abandon the field to fallow.

From 1992 to 1994, the demonstration-plot size was 5 000 m^2. These plots were also used for *Mucuna*-seed production, but the fact that relatively few farmers were involved was perceived to be a major constraint for the diffusion of the technology. In 1995, the demonstration plot was reduced to 500 m^2 to multiply by 10 the number of farmers reached by the technology. Therefore, 10 000 plots of 500 m^2 each were planted, rather than 1 000 plots of 5 000 m^2 each. *Mucuna* seeds (15 t) were distributed free of charge to farmers, who were supposed to give back the same quantity. To avoid duplication of effort, SG 2000 disseminated the *Mucuna*-fallow technology through the RACRDs (Figure 4). Thus, rather than competing, the government extension services and the NGO complemented each other's efforts. The RACRDs already had many village extension agents in contact with farmers. SG 2000 had found from field surveys conducted in Benin that the government extension agents play an important role as sources of information and hence exert considerable influence on the adoption of recommended agricultural practices (Vissoh 1994).

Figure 4. Organizational chart showing how Sasakawa Global 2000 disseminated *Mucuna* technology in Benin through the government's extension services. Source: Galiba et al. (this volume). Note: CG, contact group or other farmers; SG 2000, Sasakawa Global 2000; VEW, village extension worker; ZEO, zone extension worker.

SG 2000 has repeatedly purchased *Mucuna* seeds from collaborating producers to expand the diffusion of the technology. This also constitutes an incentive for small-scale farmers to adopt *Mucuna*, as a market for seeds adds value to the crop. It may turn out to be an artificial incentive if the market for *Mucuna* seeds becomes saturated, but this strategy was clearly justified at the outset.

According to SG 2000, the current rate of adoption of *Mucuna* is promising, especially in the south, where farmers very much need to eradicate spear grass and enhance soil fertility. A survey of 142 farmers exposed to the technology over 5 years was conducted during the 1996 growing season. The results indicated that 63% of the participating farmers used the technology for at least 3 consecutive years (Galiba et al., this volume). The remaining participating farmers either used *Mucuna* discontinuously or abandoned it. Rogers (1983) pointed out that initial rejection and abandonment frequently occur during the diffusion of an innovation and that such behaviour may be rational and appropriate from the individual's point of view. Later on, farmers may try the technology again, when their conditions or perceptions change.

The discontinued use of *Mucuna* implies that some farmers make use of the technology only when their plot is exhausted, invaded by spear grass, or both. This may be expected, given the result of the adoption study of Manyong et al. (1996a), in which field characteristics (especially spear-grass infestation and low soil fertility) determined the use of the technology. Another research project in southern Benin gave an estimated 50% adoption rate for its six research villages (Floquet et al. 1996).

Regional differences in the adoption rate were noticed: in the south, it was 71%; in the north, 41% (Galiba et al., this volume). The reason for low adoption in the north could be any of the following:

- Cropping land is abundant in the northern provinces, where the population density is quite low (<25 people km^{-2}). *Imperata* is not much of a problem in the drier zones.
- Farmers in the north specialize in cotton production, and they have access to chemical fertilizers from the cotton companies.
- The north has a single rainy season of 4–6 months. Late relay planting does not allow

Mucuna to accumulate much DM or to produce seed.

In the south, where the population density is much higher, there is more pressure on the land. Resource-poor farmers are more likely to use *Mucuna* to reduce the weed infestation or to add OM and N to the soil. Osei-Bonsu et al. (1995) observed in Ghana that a long growing season or a bimodal-rainfall regime could allow farmers to plant *Mucuna* at a time that does not coincide with the planting of food crops, thus reducing pressure on labour and land. In the north, conflicting demands for labour or land for planting both *Mucuna* and food crops are more likely because of the shorter growing season. Adoption in the north may in future be more related to a need for livestock feed. Yaï (this volume), in a livestock-development project in northern Benin, noted that farmers adopted *Mucuna* more than they adopted other legumes (including *Stylosanthes*, lablab *Dolichos lablab*, pigeon pea, and *Leucaena*) because cattle systematically graze all the biomass produced by *Mucuna*.

The SG 2000 survey found that the system of integration preferred by farmers tended to be a sole crop in the north and an intercrop with maize in southern Benin (Galiba et al., this volume).

Agronomic benefits of *Mucuna* use

Mucuna's ability to suppress spear grass was the major reason for its adoption in the bimodal-rainfall zone. In Mono province, Versteeg and Koudokpon (1990) indicated that *Mucuna* reduced *Imperata* to less than 10% of its initial density on farmers' fields. Dovonou (1994) also reported that *Mucuna* brought down spear-grass density from 270 shoots m^{-2} to 32 shoots m^{-2}. However, farmers working with SG 2000 reported a complete elimination of spear grass only after two to three consecutive *Mucuna* crops (Galiba et al., this volume). In researcher-managed trials in the bimodal-rainfall zone of Nigeria (Akobundu and Poku 1984; Akobundu and Udensi 1995), the effectiveness of *Mucuna* was compared with that of other methods of *Imperata* control. *Mucuna* was the most efficient (Table 1). However, the spear grass is not completely eradicated, and rhizomes under the ground should be eliminated by weeding or herbicide before they can put up new shoots. Reinfestation under food crops, especially maize, can occur rapidly.

Table 1. Effectiveness of various *Imperata*-control methods.

	After 4 months		After 15 months	
Treatment	*Imperata* (shoots m^{-2})	Rhizome viability (%)	*Imperata* (shoots m^{-2})	Fresh weight of rhizomes (kg)
Periodic slashings	147	100	98	7
Tillage + ridging	93	78	116	7
Glyphosate™ 1.8 kg	30	79	41	6
Glyphosate™ 3.6 kg	7	70	24	5
Glyphosate™ 1.8 kg + weeding after 1 week	8	50	20	5
Psophocarpus cover	80	?	58	6
Centrosema cover	98	?	36	5
Mucuna cover	0	50	1	2

Source: Adapted from Akobundu and Poku (1984); Akobundu and Udensi (1995).

Note: Initial density, 100 shoots m^{-2}.

Agronomic benefits from *Mucuna* use have not often been extensively measured, but Versteeg and Koudokpon (1990, 1993) reported maize-grain yield increases on farmers' fields of about 500 kg ha^{-1} for a local maize variety and about 800 kg ha^{-1} for an improved variety, following 1 year of fallow with *Mucuna*. In researcher-managed trials on farmers' fields in central Ghana (bimodal rainfall), Osei-Bonsu and Buckles (1993) observed that average maize-grain yields on fields that previously had *Mucuna* were 3–4 kg ha^{-1}, without application of fertilizer-N, which is similar to yields normally obtained with recommended levels of fertilization (130 kg N ha^{-1}). Grain yield on plots previously planted with maize and cowpea was 1.3 t ha^{-1}. Osei-Bonsu and Buckles estimated that *Mucuna* as an intercrop or as a sole crop provided an equivalent of more than 100 kg N ha^{-1} to the following maize. This is similar to an amount Sanginga et al. (1996) estimated for the bimodal-rainfall zone of southwestern Nigeria. Codjia (1996) observed 98% higher maize yields after a *Mucuna* short fallow without chemical-fertilizer application and a 179% increase with 51 kg N, 46 kg P, and 28 kg K ha^{-1}. Thus, for high maize yields, *Mucuna* residue should be supplemented with moderate amounts of inorganic fertilizer.

Mucuna fallowing has additional benefits, such as erosion control and the maintenance or improvement of the soil's physical, chemical, and biological properties. These benefits have not yet been studied within the farmer-adopted systems, but they have been demonstrated on research stations or in researcher-controlled trials on farmers fields. Hulugalle et al. (1986) studied changes in the soil's physical properties after mechanical land clearing at the IITA station in Ibadan. Porosity and infiltration rates increased and penetrometer resistance decreased with the amount of *Mucuna* biomass produced (Table 2). Azontondé (1993) studied soil erosion under a maize–*Mucuna*-relay intercropping system in southern Benin. Losses of 3–7.5 t soil ha^{-1} were observed in the maize–*Mucuna* plot, compared with 30 t soil ha^{-1} in the flat sole-maize plot and 10 t soil ha^{-1} when maize was planted on contour ridges.

Table 2. *Mucuna* biomass produced in the first cropping year after several land-clearing methods and the effect of *Mucuna* on porosity, penetrometer resistance, and infiltration.

Clearing method	*Mucuna* DM (Mg ha^{-1})	Effect of *Mucuna* cover crop (%) [a]			
		Porosity	Penetrometer resistance	Infiltration	
				Rate	Cumulative[b]
Manual	8.5	+7	-4	+41	+134
Shearblade	6.3	+6	-2	+32	+55
Treepusher	5.1	+4	-9	+106	+15
Treepusher–root rake	3.8	-2	-2	+25	+188

Source: Hulugalle et al. (1986).
Note: DM, dry matter.

[a] Compared with maize–cowpea; effects are expressed as percentage differences compared with cropped control. Porosity was measured at 0- to 10-cm depth; penetrometer resistance, at 5- to 7-cm depth.

[b] After 3 h.

Osei-Bonsu (unpublished data) found that 13.8 t ha^{-1} of dry mulch, with a thickness of 12.6 cm, was accumulated by *Mucuna* after a fallow of two seasons in the bimodal-rainfall zone of central Ghana. He estimated 4.1 million earthworm casts ha^{-1}, weighing 21.6 t ha^{-1}, under the mulch and only 1.3 million casts ha^{-1}, weighing 3.6 t ha^{-1}, for plots planted with cowpea.

Relaying *Mucuna* into maize may be expected to have fewer benefits than planting *Mucuna* as a sole crop. The benefits depend on the DM accumulation and ground cover achieved, which in turn depend on soil fertility, growing season, and management.

Agronomic aspects of seed production

Mucuna-seed production has recently been a topic of research because seed supply has been perceived as a major bottleneck in the dissemination and adoption process. In Togo, Agounke et al. (1996) compared two different systems of *Mucuna*-seed production — the staking method and the nonstaking method — using *M. pruriens* var. *utilis* and *M. pruriens* var. *cochinchinensis*. The authors found that staking *Mucuna* plants provided higher yields in both of these varieties. This result agrees with that of Lusembo (1995), who observed that providing support significantly increased the number of inflorescence per plant, flowers per inflorescence and seeds per pod and the total seed yield of *C. pubescens* in Uganda. Staking also significantly improved the germination rate of the harvested seed.

Mucuna-residue-management systems

Mucuna-residue management has been the subject of some research because labour input is very much affected by management of the often voluminous residue. The residue may be burned, left as mulch, or incorporated into the soil. Vine (1953) compared burning with incorporation in southwestern Nigeria for many years. A short-duration maize crop was grown every year in the first cropping season. Grain yields of the maize crop were maintained with both systems for at least 17 years. Topsoil samples at maize-seeding time showed that there was more nitrate in the plots with green *Mucuna* than in the plots with only *Mucuna* ashes incorporated into the soil (Figure 5).

Figure 5. Effect of *Mucuna*-residue management on levels of nitrate in surface soil at Moor Plantation at the time of maize planting. Source: Vine (1953).

Incorporation of *Mucuna* biomass into the soil requires substantial labour for seedbed preparation. If no significant difference in yields is found between incorporation of *Mucuna* mulch and seeding directly into the mulch, then it is advisable to plant maize directly into the *Mucuna* mulch. Osei-Bonsu (this volume) observed in Ghana that *Mucuna* mulch was so effective in weed suppression that no weeding was needed in maize following the cover crop for up to 6 weeks after planting. In contrast, the plots without *Mucuna* as cover crop were severely infested with weeds by the third week. Even when two hand-weedings were done in the non-*Mucuna* plots, more weed pressure was observed in these than in the *Mucuna* plots by the sixth week.

Economic evaluation of *Mucuna* use

An economic analysis was conducted using some of the yield and adoption data mentioned above (Manyong et al. 1998). These data indicated that high returns are achieved at both farmer and regional levels 3 years after *Mucuna* is adopted. If *Mucuna* seed can be sold, then the system is economically beneficial from the first year of introduction. An *ex ante* benefit–cost analysis over 8 years indicated a ratio of 1.24 when *Mucuna* was included in the system and 0.62 for the system without *Mucuna*. The ratio was as high as 3.56 if *Mucuna* seeds were sold (Table 3). However, yearly analysis of the benefit–cost ratio indicated a declining trend over time for all systems, suggesting that addition of external inputs (probably fertilizer-P and fertilizer-K) is required to achieve full sustainability (Figure 6). Adoption of *Mucuna* throughout Mono province would result in annual savings of about 6.5 million kg of N, or about 1.85 million United States dollars (Manyong et al. 1998).

Table 3. Average future cost and returns over 8 years of systems with and without *Mucuna* fallows in Mono province, Benin.

	With *Mucuna*		
	Scenario 1 [a]	Scenario 2 [b]	Without *Mucuna*
Gross returns (USD ha^{-1})	354	836	110
Variable costs (USD ha^{-1})			
Seed	9	9	4
Labour	276	276	172
Net revenue (USD ha^{-1})	69	620	-66
Benefit–cost ratio	1.24	3.56	0.62
MRR (%)	124	629	

Source: Manyong et al. (in preparation).
Note: MRR, marginal rate of return; USD, United States dollars.

[a] Only maize seeds are sold.

[b] Both maize and *Mucuna* seeds are sold.

Figure 6. Trend in the benefit–cost ratio for systems without (system 0) and with *Mucuna* (*Mucuna* 1 and *Mucuna* 2), in Mono province, Benin. Note: system 0, existing system; *Mucuna* 1, only maize grain is sold; *Mucuna* 2, both *Mucuna* and maize grain are sold.

Major biophysical and socioeconomic constraints to the use of *Mucuna* by smallholders

Although the current rate of adoption of *Mucuna* fallowing by smallholders in Benin is promising, its acceptance as a profitable agricultural practice faces many constraints. Knowledge of these can be helpful to agricultural researchers trying to develop improved systems and local adaptations with farmers, as well as to extension efforts in other countries.

Land scarcity

Intensive use of the land is the cause of its degradation, but farmers with very little land will still plant their exhausted plots in the hope of harvesting something. These farmers are therefore reluctant to plant *Mucuna* because of the land, labour, and rainfall dedicated to a crop with no direct economic use. This may appear to contradict the finding of Manyong et al. (1996a), in which the amount of fallow land owned by the farmer was negatively correlated with adoption. But there are probably two forces at play. With increasing landholding, above a certain moderate level, there is decreasing land pressure and less need for labour-intensive soil management. With decreasing availability below the threshold, the farmer is barely surviving and cannot reduce food output in the short term. Thus, it appears that farmers with small to moderate landholdings are most likely to adopt *Mucuna* fallowing, rather than farmers with very small or large landholdings. A market for *Mucuna* seed would make the system more attractive, as shown by the economic analysis above.

Land-tenure system

Control of land seems to influence investment in sustainable soil-management practices. When property rights are lacking, farmers cannot be sure they will benefit from their efforts, and therefore they have little or no incentive for adopting sustainable land-use practices (Wachter and North 1996). In an adoption study in Mono province, Houndékon et al. (1996) found that insecure land possession bore a negative relationship to the adoption of *Mucuna* fallowing. Tenant farmers are unlikely to adopt the system, as they cannot know when the landowners will take back their land.

Toxicity of grain for human and animal consumption

Mucuna contains substantial quantities of 3-(3,4-dihydroxyphenyl)-L-alanine, known as L-Dopa. Human consumption of unprocessed beans can cause intoxication, but the toxins can be removed by boiling and soaking the seeds in several changes of water (Kay 1979). According to Versteeg et al. (this volume), the L-Dopa content of *Mucuna* ranges from 4.7 to 6.4%. Nevertheless, *Mucuna* has been grown extensively as a minor food crop in Ghana for at least a century (Osei-Bonsu et al. 1995). However, only small quantities of the beans are consumed, after processing, in stews or soups. The beans are boiled for 40 min with other ingredients, and the water used for boiling the seed, together with the seed coat, are discarded. Versteeg et al. (this volume) recently tested a recipe in which *Mucuna* was mixed with maize flour to make *pâte* (the main staple food in southern Benin). Popularizing consumption of *Mucuna* grain would increase the market for *Mucuna* seed and stimulate adoption of the cover crop. This is therefore a useful avenue of research. Consumption of *Mucuna* hay by animals poses none of the problem associated with human consumption of the seed.

Fire

Burning, especially during the dry season, is very common in the West African savannas. Bush fires destroy accumulated *Mucuna* mulch in the dry season. A violent wind or a heavy rain can export the ashes, which contain valuable nutrients. Hoefsloot et al. (1993) estimated that 85% of the fixed N is found in the aboveground vegetation, mostly in the leaves and seeds, and that the remaining 15% is stocked in the roots. Vine (1953) observed that if the legume biomass is burnt or removed from the field in one way or another, the stock of N will not increase.

Burning of *Mucuna*-fallow biomass can be prevented by firebreaks around plots. However, constructing these demands a lot of labour, and farmers might not find it worthwhile. Eventually, there will be behavioural changes related to sustainable agriculture, and community control of bush burning will be one of those changes.

Limited range of associated crops

It is impossible to intercrop an aggressive cover crop like *Mucuna* with short-stature crops such as tomato, cowpea, and groundnuts or with long-duration crops such as cassava and plantain. Appropriate management of such systems requires additional labour, which increases costs. Thus, intercropping of *Mucuna* is confined to maize, sorghum, and millet.

Disease incidence

Although *Mucuna* has generally been free from pests and diseases in West Africa, outbreaks may occur with repeated use of the cover crop. For example, after many years of *Mucuna* rotation at the IITA farm in southwestern Nigeria, a disease outbreak occurred that was identified as *Macrophomina phaseolina* by Berner et al. (1992). It reduced ground cover and biomass drastically. Similarly, it was reported that after repeated *Mucuna* fallows, a buildup of knot nematodes is possible (Wilson and Lal 1986).

Therefore, a large number of varieties of *Mucuna* and other cover crops should be collected and maintained. Although many species of *Mucuna* are known (Wilmot-Dear 1992), only *M. pruriens* var. *utilis* and *M. pruriens* var. *cochinchinensis* have been tested in Benin, Nigeria, Togo, etc. IITA, the West African Rice Development Association, the International Institute for Land Reclamation and Improvement, and various national agricultural research systems maintain several varieties of *Mucuna* and small quantities of many other cover-crop and fallow species.

Perspectives for adoption of *Mucuna* elsewhere in West Africa

Mucuna and other cover crops are being tested in other countries by farming-systems researchers, and *Mucuna* fallows are being tested by extension services in most of West Africa. These efforts are new, compared with the activity in Benin. A look at the Benin experience and at conditions in other areas may allow us to predict where *Mucuna* fallows will be adopted. From the adoption study of Manyong et al. (1996a), it is clear that land scarcity is a major factor. This translates into severe spear-grass infestation at the field level, which provides an impetus for adoption. Elsewhere in Africa, innovative soil-conservation practices are often observed in places where population densities are high, making land relatively scarce and labour relatively cheap (Scoones et al. 1996). Other modifying factors are access to capital, markets, and infrastructure; land tenure; and access to information (Scoones et al. 1996). In another review, Weber et al. (1996) noted that innovative techniques for cattle confinement, manure collection and application, compost application, and improved fallow are most likely to emerge as land-use intensifies to the point at which soil and vegetation are significantly degraded. This kind of degradation is occurring in places where population density is high relative to the carrying capacity of the land. Broadly speaking, carrying capacity decreases with decreasing length of growing season, with soil characteristics and management characteristics (such as use of fertilizer) as modifying factors.

If fertilizer and herbicide are readily available at prices lower than those for food, then cover-crop technology is unlikely to be adopted. For example, farmers in the cotton-growing areas have easy access to fertilizer and may be less likely to feel a need for a cover crop, unless degradation of the soil's physical properties occurs. Adoption is also unlikely to occur on fertile soils, unless weed pressure is very high. Infestation of a particularly noxious weed in southern Benin provided a window of opportunity for cover-crop adoption. Weed infestation is often a more visible problem than inadequate soil nutrients.

Another visible window of opportunity might be *S. hermonthica* parasitism or the need for dry-season livestock feed in the dry savanna. Yaï (this volume) reported successful adoption in a livestock-feeding project in northeastern Benin. In addition, the L-Dopa content might be a market opportunity, rather than a constraint, as L-Dopa has a use in the treatment of Parkinson's disease. Nematode infestation prompted Mr Hirofumi Kage to try *Mucuna* green manuring in the Brazilian savannas (Guia Rural Abril 1986). After this worked, he never stopped using *Mucuna* to maintain the productivity of his soils.

Another factor in adoption that became evident in Benin is the need for close contact among researchers, extensionists, and farmers. RAMR introduced the technology to address the soil-fertility issue. However, farmers were most interested in its ability to suppress weeds. Researchers had to listen with an open mind to farmers, rather than ignoring this feedback, which did not correspond to their expectations (Versteeg et al., this volume). Dissemination of the technology was fairly easy because of the good relationships between the researchers and extensionists. Both services are under the same ministry in Benin. Furthermore, the extension services were supported by strong NGOs, such as SG 2000, which made an effort to work with the existing system.

The adoption rate of *Mucuna* cover cropping was lower in the drier zones of northern Benin was lower than in the more humid southern region. This may be partly because of the technology's more recent introduction to the dry zones, but it may also be related to the loss of the entire growing season in the north, resulting from the *Mucuna*-fallow system. Farming-systems teams will need to work with farmers to develop locally acceptable modifications, keeping in mind the windows of opportunity mentioned above.

Key issues requiring policy intervention, promotional strategies, or further research

Impact studies are needed to document the social profitability of cover crops. This information can help policymakers decide whether and how to promote cover cropping. The major policies hindering or promoting adoption of cover-crop technology are probably related to availability and pricing of fertilizer, availability of land, and access to information. Farmers will have no incentive to adopt a legume-based soil-management technology if the (subsidized) price of N from fertilizer is less than the cost of growing GMCCs for N. The major land-tenure issue may be absentee ownership of large tracts of land by individuals or government agencies in some areas of West Africa. Access to extension information is an important policy issue that will influence adoption of any new agricultural technology. Whenever extension messages are lacking, the adoption of GMCC technology will be slow or nil.

Indiscriminate burning of bush vegetation, especially during the dry season, could be prevented by law, but a law such as this needs to be enforced by local populations. Likewise, control of cattle movement needs to be addressed locally. Establishment of firebreaks could be encouraged, but fire-control techniques need to be less labour intensive and more profitable. Planting a crop such as soybean around the plot could provide a firebreak with an economic product.

Promotional strategies can take many forms. Contests are often used to promote improved cropping practices. A farmer may receive an award for most mulch produced, most *Mucuna* seed produced, etc. Promotional activities should identify the appropriate medium of communication. Radio is most appropriate in the rural areas of West Africa, where television is confined to the cities or movement of people is hindered by poor roads. The seed-scarcity problem should be addressed by involving NGOs, private companies, and farmer organizations in seed production and distribution. Also needed is a mechanism to disseminate information on cover crops to interested workers in the region.

Researchers and extensionists should not promise too much when it comes to cover-crop technology but should clearly identify the probable benefits to farmers of adopting cover cropping in their areas. These highly visible windows of opportunity will not be the same over very broad areas. They must be identified locally by farming-systems teams, in collaboration with farmers. An example of what might result from this is the observation that *Mucuna* can control *Striga* in the Guinea savanna (Versteeg, personal communication, 1996**(3)**). This claim should be confirmed with rigorous research. If it is found to be true, then management systems should be developed to optimize the effect of *Mucuna* on *Striga*.

As discussed above, the cover-crop strategy for West Africa cannot rely on one species. Other species, as well as a range of *Mucuna* varieties, are needed. For the semi-arid zones, researchers need to identify and test short-duration and drought-resistant *Mucuna* cultivars and species. *Mucuna* may not be at all appropriate for the zone, and other species should be tested, keeping farmers' needs in mind. Short-duration and erect-species accessions should be identified for various niches, which will be fairly location specific. Erect species may be more appropriate for intercropping with food crops. This could be a solution in places where farmers cannot afford to give up scarce land just to grow a soil amendment. However, seasonally waterlogged areas will require quite different species of legumes.

Whenever many choices are available, information about those choices becomes important. The Legume Expert System, LEXSYS, developed at IITA for integrating herbaceous legumes into farming systems, is a good start in that direction (Weber et al. 1997). Better communication is also needed to enable researchers and extensionists in various parts of West Africa to benefit from each others' experiences, including the positive experience with *Mucuna* in Benin.

Some additional research is still required on

- The effect of P and rhizobial inoculation on the efficiency with which *Mucuna* fixes atmospheric N;
- Integrated *Imperata* management (cover crops, herbicide, and tillage); and
- Persistence of *Mucuna* mulch during the dry season in different zones.

Processing *Mucuna* seeds to eliminate L-Dopa is likely to lead to a breakthrough in the promotion of *Mucuna* technology. Toxicologists should focus on the antinutritional aspects of *Mucuna* grain. If this major constraint is solved, *Mucuna* is likely to be widely adopted as a staple legume.

Conclusion

Cover-crop technologies can improve soil productivity and reclaim weed-infested lands; therefore, their use as an alternative to shifting cultivation has to be encouraged and promoted. The application of GMCCs as short fallow, either in rotation or in relay intercrop, would help to stabilize the short-fallow systems that farmers are currently forced to develop. A short fallow of *Mucuna* may reduce by half the amount of fertilizer-N required to grow a subsequent cereal crop, and this would have a large economic impact for the region.

Currently, a large gap exists between potential benefits of cover crops as conceived by researchers and real adoption by farm households (Weber 1996). Researchers need to make many candidate legumes available to farmers to experiment with, in collaboration with farming-systems researchers and extensionists with good farmer contact. The suppression of *I. cylindrica* acted as a window or entry point for farmers' acceptance of the *Mucuna* technology in the humid savannas. Other benefits of cover crops should be identified, in collaboration with farmers, to increase potential adoption.

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[2] M. Versteeg, IITA, Ibadan, Nigeria, personal communication, 1991.

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