Resource and Crop Management
Research Monograph No. 25

# Mucuna — herbaceous cover legume with potential for multiple uses

R.J. Carsky, S.A. Tarawali, M. Becker, D. Chikoye
G. Tian, and N. Sanginga

International Institute of Tropical Agriculture

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# Preface

The Resource and Crop Management Research Monograph series is designed for the wide dissemination of results of research about the resource and crop management problems of smallholder farmers in sub-Saharan Africa, including socioeconomic and policy-related issues. The range of subject matter is intended to contribute to existing knowledge on improved agricultural principles and policies and the effect they have on the sustainability of small-scale food production systems. These monographs summarize results of studies by IITA researchers and their collaborators in the IITA Resource and Crop Management Division (RCMD). They are generally more substantial in content than journal articles.

The monographs are aimed at scientists and researchers within the national agricultural research systems of Africa, the international research community, policy makers, donors, and international development agencies. Prepublication review and editing of each manuscript are conducted within RCMD.

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## Acronyms and Abbreviations

| | |
|---|---|
| CARDER | Centre d'action régional pour le développement rural |
| CATIE | Centro Agronomico Tropical de Investigacion y Ensenanza |
| CIAT | Centro Internacional de Agricultura Tropical |
| CIDICCO | Centro Internacional de Informacion sobre Cultivos de Cobertura |
| CIMMYT | Centro Internacional de Mejoramiento de Maiz y Trigo |
| CIRAD | Centre de coopération international en recherche agronomique pour le développement |
| COMBS | Collaborative Group on Maize-Based Systems Research |
| CPAC | Centro de Pesquisa Agropecuária dos Cerrados |
| FAO | Food and Agriculture Organization of the United Nations |
| LEXSYS | Legume EXpert SYStem |
| IITA | International Institute of Tropical Agriculture |
| ILRI | International Livestock Research Institute |
| NCSU | North Carolina State University |
| PDEBE | Projet de développement de l'elevage dans le Borgou Est |
| RAMR | Recherche appliquée en milieu réel |
| SAA | Sasakawa Association for Africa |
| SSP | single superphosphate |
| WAFSRN | West African Farming Systems Research Network |
| WAP | weeks after planting |
| WARDA | West Africa Rice Development Association |

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# Introduction

There is renewed interest in green manure cover crops in the agricultural research and development community and mucuna (several varieties of *Mucuna pruriens*) is one of the preferred leguminous cover crops in the tropical zone. Scientific interest in mucuna has also increased dramatically in West Africa because of the relatively widespread adoption observed recently in the Benin Republic (Manyong et al. 1996; Galiba et al. in press). Cover crops have the ability to conserve soil and suppress weeds. When plowed under as green manures, they contribute to soil nitrogen supply and possibly nematode reduction. Mucuna herbage may be fed to livestock and the seed may be consumed in limited quantities by people and animals.

This summary of knowledge is targeted to scientists who are developing and testing crop and/or livestock systems using mucuna. Information from many agroecological zones in the tropics is synthesized with special emphasis given to results from Africa and determinants of mucuna adaptation are reviewed. Benefits of mucuna may not be realized in all agroecological zones and under all management systems. Management of mucuna is considered under separate sections for current season management of the mucuna crop and subsequent season management of the residue. A final section lists and prioritizes future research needs for mucuna utilization and management in Africa.

Frequent reference will be made to two databases which provide decision support for integration of herbaceous legumes into farming systems. One database is called LEXSYS — Legume EXpert SYStem (COMBS 1994; Weber et al. 1997). The other is COVERCROPS (Kiff et al. 1996). Detailed data for mucuna (*Mucuna pruriens*) from both databases are presented in Annexes 1, 2, and 3. Sources of mucuna seed from the COVERCROPS database are presented in Annex 4.

Mucuna's importance is shown by the many common vernacular names given to it in different parts of the world. These are listed in Annexes 1–3. In this review we will use the term mucuna when talking in general terms about *Mucuna* spp., but when citing specific results, we will use the Latin binomial or variety name which was given by the authors.

## History

The history of mucuna has been reviewed by Buckles (1995) who traced its movement from its origin in Asia to Africa and the Americas by the late 1800s or early 1900s. Velvet bean was a very important crop in the southeastern USA in the early- to mid-1900s. It was grown in rotations with cotton before nitrogenous fertilizer became widely available, as well as being used as a forage crop. The use of mucuna declined to almost zero by 1960 in the USA but increased in Central America where it was adopted for plantations, animal feed, and soil fertility maintenance in maize cropping systems. Thurston (1997) describes mucuna slash/mulch systems in Guatemala, Honduras, and Mexico which are currently in use by small-scale farmers in those countries.

In West Africa, mucuna was tested extensively in Nigeria for soil fertility maintenance. Experiments on mucuna effects and management were conducted at Moor Plantation in southwestern Nigeria for many years (Faulkner 1934; Vine 1953).

In francophone West Africa, mucuna was recommended for southern Côte d'Ivoire by Botton (1957/58). Mucuna rotation has helped maintain soil productivity and crop yields for 25 years on approximately 50 ha of the IITA experimental farm in southwestern Nigeria and on some 20 ha of the WARDA experimental farm in central Côte d'Ivoire since the early 1990s.

In spite of extensive testing and use on experimental stations, adoption of mucuna-based soil management by farmers has not been reported in Nigeria or Côte d'Ivoire. Recently, however, adoption by farmers has been observed in the Benin Republic. The Recherche Appliquée en Milieu Réel (RAMR) project started demonstrating the use of mucuna for soil fertility improvement in southern Benin in 1986 (Versteeg and Koudokpon 1990). In 1988, the project gave mucuna seed to 20 farmers and 14 of them obtained a dense stand and cover of mucuna and observed suppression of *Imperata cylindrica*, a major weed in the area. In 1989, the research team observed that 103 farmers had planted mucuna (Versteeg and Koudokpon 1990). This spontaneous adoption was based on farmers' observation of project demonstrations in 1986 and 1987 and other farmers' fields in 1988. The number of farmers testing mucuna grew to 500 in 1991 (IITA 1992) and 3000 in 1993, based on estimates by the extension services in Benin (IITA 1994). By 1996, approximately 10,000 farmers were testing mucuna throughout the Benin Republic, based on estimates by Sasakawa Global 2000 who joined in the extension effort (SAA 1996; Galiba et al. in press). Approximate numbers of farmers testing mucuna in the Benin Republic are summarized in figure 1.

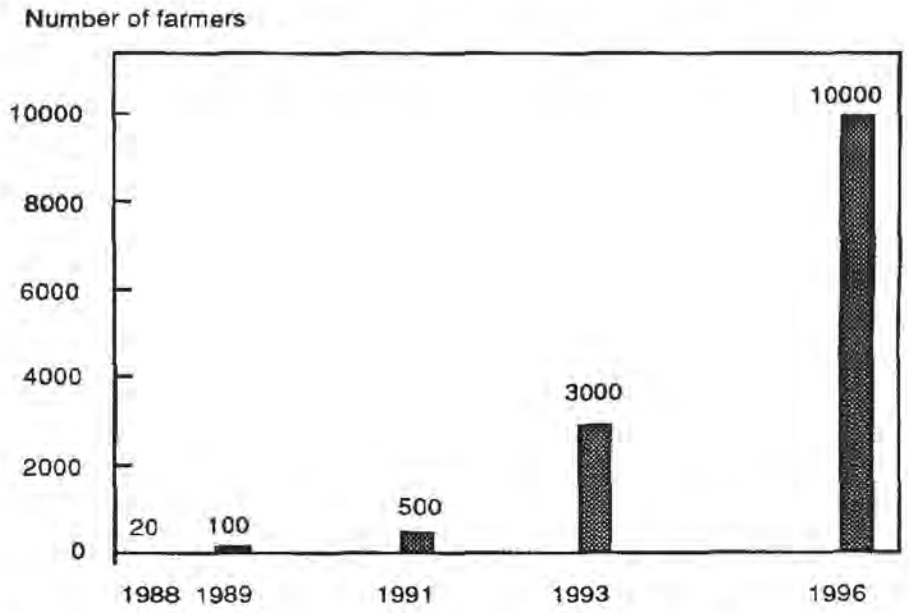



**Figure 1. Approximate number of farmers testing mucuna in the Benin Republic in recent years (from Versteeg and Koudokpon, 1990; IITA 1991; IITA 1993; and Galiba et al. in press)**

Recently it was reported that mucuna has been grown extensively as a minor crop in Ghana for at least a century (Osei-Bonsu et al. 1995). Farmers plant only a few stands, usually near trees so the vines can climb and bear more fruit. The seed is used for human food in limited amounts.

## Description

### *Taxonomy*

*Mucuna* spp. are in the family Fabaceae. Their taxonomy is confused, with several synonyms occurring at the genus and species levels (Duke 1981). Kay (1979) suggests that only two species of mucuna are commonly grown, the true velvet bean *M. pruriens* var. *utilis*, which has medium-sized seeds, and the horse bean *M. sloanei*, which has larger seeds and an extremely hard seed coat. Numerous varieties of *M. pruriens* were formerly treated as separate species (Kay 1979). These "species" are *M. deeringiana*, *M. utilis*, *M. cochinchinensis*, *M. aterrima*, *M. nivea*, and *M. hassjoo*. They are described in table 1 by Kay (1979) who suggested that they should be considered as varieties of *M. pruriens*.

**Table 1. Cultivars of *M. pruriens* which were formerly treated as separate species (from Kay 1979)**

| Variety name | Common name | Latin binomial | Synonym | Main area | Main use |
|---|---|---|---|---|---|
| *Deeringiana* | Deering, Florida, or Georgia velvet bean | *M. deeringiana* | *Stizolobium deeringianum* | USA S. America | cattle fodder |
| *Utilis* | Bengal velvet bean | *M. utilis* | *Stizolobium utile* | India | |
| *Aterrima* | Mauritius velvet bean | *M. aterrima* | *Stizolobium aterrimum* | Mauritius, Australia, Brazil, W. Indies | rotation crop; cover crop |
| *Hassjoo* | Yokohama velvet bean | *M. hassjoo* | *Stizolobium hassjoo* | Japan | |
| *Cochinchinensis* | Lyon bean | *M. cochinchinensis* | *Stizolobium niveum* *Mucuna nivea* | Philippines, SE Asia | vegetable immature pods |

Note
*Mucuna pruriens* var. *utilis* and var. *hassjoo* were probably developed for human consumption in India and Japan, respectively, judging from Buckles (1995).

Wilmot-Dear (1984) also classified *M. aterrimum*, *M. cochinchinensis*, *M. hassjoo*, *M. nivea*, and *M. utilis* as varieties of *M. pruriens* (var. *aterrima*, *cochinchinensis*, *hassjoo*, *nivea*, and *utilis*, respectively) Although we have adopted this classification, we will use the Latin binomial name given by other authors when citing their work. The taxonomic confusion can be seen in the synonyms that are given in the cover crop databases (annexes 1–3).

The main distinguishing features of the mucuna varieties are flower color, seed color, pubescence on the pod, leaf size, and phenology (especially time to flower and maturity). Flower color is purple or white. Mucuna seed colors include black, white, beige, brown, grey, and mottled (Kay 1979; Duke 1981; Calegari et al. 1993; Buckles 1995). There are two major types of pubescence on the pods. One type is long and erect and causes stinging or itching. This type of mucuna is generally not cultivated and is known as *M. pruriens* var. *pruriens* (Skerman et al. 1988). The other type of pubescence is silky and adpressed (lying down) and the variety is hence given the common name of velvet bean. Mature mucuna pods are normally 5 to 15 cm long and slightly ridged (Kay 1979) especially when mature. Seeds are globular and approximately 1 x 1 cm and there are 4 to 12 seeds per pod.

Mucuna varietal characteristics are usually recognized only locally, not universally. For example, the flower color, seed color, pod length, and maturity cycle of cultivated varieties in southern Brazil (table 2) may not correspond to characteristics ascribed to these varieties elsewhere.

**Table 2. Characteristics of mucuna grown by farmers in southern Brazil (from Calegari et al. 1993)**

| Species | Common name | Origin | Flower color | Seed color | Pod length | Maturity cycle in S. Brazil |
|---|---|---|---|---|---|---|
| *M. deeringiana* | Mucuna-anã | SE Asia | Purple | brown/black on white | 5–8 cm | 150 days |
| *M. pruriens* | Mucuna-cinza | Philippines | White | grey | 9–13 cm | 210–240 |
| *M. aterrima* | Mucuna-preta | SE Asia | Purple or White | black | 9–13 cm | 210–260 |

# I

# Adaptation of Mucuna

## Growth habit and life cycle

Mucuna varieties have a spreading/trailing or climbing growth habit except for some erect (bush type) varieties mentioned by Botton (1957/58) and Kay (1979). Mucuna varieties are herbaceous with an annual life cycle which ranges from 100 to 290 days according to Buckles (1995) and Keatinge et al. (1996). Days to maturity range from 100 to 260 days for the varieties which are commonly used in southern Brazil (table 2). Part of the observed variation is genetic. For example, Hairiah et al. (1993) observed in Indonesia that *M. pruriens* var. *utilis* dies after about four months, but *M. deeringiana* has a growth cycle of about nine months. In Brazil, Resck et al. (1982) reported days from planting to flowering of 75 for *M. niveum*, 100 for *M. deeringiana*, and 150 for *M. aterrima*. In screening trials in the Guinea savanna zone of West Africa, *M. pruriens* var. *cochinchinensis* consistently flowered and matured earlier than var. *utilis* and produced more seed (table 3).

**Table 3. Flowering date and seed production of two varieties of *Mucuna pruriens* in the subhumid zone of Nigeria (Tian and Carsky, unpublished)**

| Site - planting date<br>variety | Flowering | Maturity<br>(days) | Seed Production<br>(kg ha$^{-1}$) |
|---|---|---|---|
| Ilorin (8.5°N) - July 94 | | | |
| *Cochinchinensis* | 93 | 133 | 1430 |
| *Utilis* | 146 | 168 | 210 |
| Ilorin (8.5°N) - 6 August 95 | | | |
| *Cochinchinensis* | 98 | 140 | 1060 |
| *Utilis* | 133 | 161 | 20 |
| Kasuwan-Magani (10.3°N) - July 94 | | | |
| *Cochinchinensis* | 95 | 137 | 1830 |
| *Utilis* | 118 | 149 | 480 |

The other factor in the duration of the life cycle is the planting date. Mucuna is a short-day annual (Duke 1981) so that it flowers in October/November in the northern hemisphere. Thus, for example, *M. pruriens* var. *utilis* should flower 6 months after planting when planted in April/May, at 5 months when planted in June, at 4 months when planted in July, and at 3 months (or not at all) when planted in August.

## Length of growing period requirements

The published databases do not specify the length of growing period (LGP) requirements of mucuna. Rather they give annual rainfall requirements which are somewhat related to the LGP.

Mucuna is a vigorous annual whose primary products are soil fertility maintenance, soil protection, and weed suppression. In order to provide these benefits, mucuna does not need to complete its reproductive cycle. Mucuna can achieve nearly 100% groundcover in two months (see below) if soil fertility is adequate. Thus, the groundcover benefit can be achieved under adequate soil fertility conditions, even in the semi-arid zone. However, soil moisture in October/November may not be adequate for seed production to occur. In the semi-arid zone with less than 120-day growing period, mature seed production of those varieties may not be possible. The semi-arid zone should be considered marginal for the use of the current varieties of mucuna.

The lower end of the optimum annual rainfall range in the published databases is 1000 mm, indicating that at least 5 months of adequate growing conditions are necessary for successful reproduction, if mucuna is planted at the beginning of the rains. As the growing season lengthens, mucuna dry-matter accumulation will increase if soil conditions are adequate and if longer duration mucuna varieties are used. Table 4 presents a synthesis of results from field trials in which mucuna dry-matter accumulation was determined during the rainy season in the tropics. This synthesis of available literature suggests that LGP is a factor in dry-matter accumulation although other factors such as soil fertility (discussed below) and varietal characteristics are important. High biomass accumulation of approximately 10 t $ha^{-1}$ appears more likely in the humid zone and lower biomass accumulation is more likely where the growing season is shorter. Late planting results in lower dry matter in the subhumid monomodal and semi-arid zones.

Dry-matter production and groundcover of mucuna will also depend on the occurrence of drought and waterlogging (see below). Mucuna's reaction to drought is moderately tolerant (annex 1) but it does not survive the dry season in most areas. Drought tolerance was specifically studied in Brazil (Burle et al. 1992) at a site with a 4-month dry season. Legumes were planted at the end of the rainy season and 3 out of 4 *Mucuna* spp. survived the dry season. During the dry season these varieties shed their leaves, but when the rain started, they grew immediately from existing vines. Dry season survival was related to depth of rooting which was found to be greater than 100 cm because of long-term correction of subsoil acidity and P deficiency (Burle et al. 1992).

The maximum annual rainfall limit is approximately 3000 mm (annex 1). This limitation is probably related to secondary problems associated with excess humidity, such as acid soil conditions and disease pressure.

**Table 4. Mucuna dry-matter (t ha$^{-1}$) accumulation during the rainy season reported in literature from different agroecological zones in the tropics**

| Country | Rainfall range (mm) | Dry matter Mean | Dry matter Range | Authors | Comments |
|---|---|---|---|---|---|
| **Humid** | | | | | |
| Honduras | 2500–3000 | 11 | 10–12 | Triomphe (1996) | 3 years x many fields |
| Brazil | 2400 | 8.2 | 7.0–10.7 | Smyth et al. (1991) | 3 years |
| **Subhumid Bimodal** | | | | | |
| Nigeria | 1100–1200 | 7.7 | | Sanginga et al. (1996a) | 1 trial; 12 weeks growth |
| Nigeria | 1100–1200 | 4.1 | 4.0–4.4 | Tian (unpublished) | 3 years |
| Nigeria | 1100–1200 | 4.8 | 3.9–5.8 | Muhr (1997) | 1 trial |
| Brazil | 1500 | 6.7 | 4.9–8.5 | Lathwell (1990) | 3 trials |
| Brazil | 1500 | 6.4 | 6.0–6.8 | Resck et al. (1982) | 1 trial; 3 varieties |
| Uganda | | 5.6 | | Fischler (1996) | 1 trial |
| **Subhumid Monomodal** | | | | | |
| Nigeria | 1200 | 5.5 | 4.9–6.4 | Fadayomi (unpublished) | 2 years |
| Nigeria | 1200 | 7 | 6.0–8.0 | Carsky (unpublished) | 1 year, 2 varieties |
| Burkina Faso | 850–1100 | 8.7 | 8.5–9 | Segda (unpublished) | |
| Cameroon | 1100–1300 | 6.3 | 6.0–6.6 | Klein (1994) | 1 year x 2 sites |
| | 700–1100 | 7.4 | 7.0–7.8 | Klein (1994) | ILCA 15169 x 2 sites |
| **Semi-arid** | | | | | |
| Cameroon | 700–900 | 4.6 | 3.6–6.0 | Carsky and Ndikawa (in press) | 2 years x 3 sites |

## Temperature and photoperiod

Mucuna thrives in warm moist conditions and is sensitive to frost (Duke 1981). Temperature range for mucuna growth is 15 °C to 35 °C with optimum growth from 19 °C to 27 °C. The altitude range for mucuna growth (annexes 1–3) is 0 m to 2100 m above sea level and 0 to 1600 m above sea level is the optimum range. Keatinge et al. (1996) reviewed photothermal effects on the phenology of annual legume cover crops and found very little information on mucuna, except that flowering may be hastened by cool nights (<21 °C). As mentioned above, Duke (1981) classifies mucuna as a short-day plant.

## Soil factors

### *Phosphorus*

It is well known that legumes require P for growth and N fixation (Ae et al. 1990; Giller and Wilson 1991). For example, Becker and Johnson (1998) found soil P to be an important factor in mucuna biomass accumulation during the dry season.

**Table 5. Dry matter accumulation (t $ha^{-1}$) of mucuna (mean of two varieties) established one month before rice harvest and determined at subsequent land preparation in four sites in Côte d'Ivoire with variable climate and soils (Becker and Johnson, in press)**

| Site | Climate/vegetation | Soil description | Dry matter |
|---|---|---|---|
| Gagnoa | Bimodal forest | Sandy loam Ultisol | 5.0 |
| Man | Monomodal forest | Acid, P-fixing Ultisol | 1.3 |
| Bouaké | Derived savanna | Fertile loam Alfisol | 4.6 |
| Boundiali | Guinea savanna | Sandy Alfisol | 2.9 |

A site with acid, P-fixing soil produced 1.3 t DM $ha^{-1}$ while two sites with adequate P and a similar climate produced nearly 5 t DM $ha^{-1}$ (table 5). Small amounts of P can improve mucuna growth on P-deficient soils. For example, the response of *M. pruriens* var. *cochinchinensis* groundcover to small amounts of P fertilizer (75 kg SSP $ha^{-1}$) was substantial on fields with 2 ppm Bray P in the monomodal savanna of Nigeria (figure 2). In another trial, maximum groundcover of *M. pruriens* var. *cochinchinensis* and var. *utilis* was increased from approximately 70% to nearly 100% by the addition of 75 kg SSP $ha^{-1}$ on a field with approximately 1 ppm available P (Carsky, unpublished data).

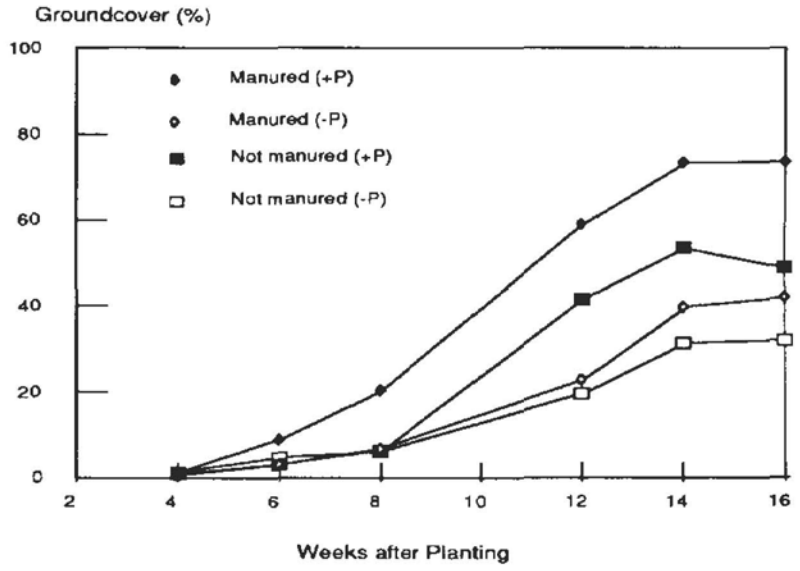



**Figure 2. Response of *M. pruriens* var. *utilis* groundcover to phosphorus fertilization (7 kg P $ha^{-1}$) on two fields with different manure history near Bauchi, 1993. (Carsky, unpublished data)**

It is important to know when to apply P to realize the potential of a mucuna fallow. A summary of eight trials in four West African countries (WARDA 1997) suggests that at least 5 ppm of available soil P are needed if the dry biomass of mucuna is to exceed 2 t $ha^{-1}$ (figure 3). If we compare this with soybean production in the savannas of Brazil, the critical level (the concentration below which a response to fertilization is expected) for Mehlich I extractant was 10 ppm according to Goedert et al. (1986). For soils with P contents of 5 to 10 ppm, the probability of a response to P fertilization is medium and below 5 ppm, the probability is high, making 5 ppm the critical level for soybean in the savannas of Brazil. The critical available soil P level for mucuna is probably also approximately 5 ppm. Taking into account the fact that grain for human consumption is not a primary product of mucuna, P fertilization of mucuna is not economically justified unless plant available P is below 5 ppm.

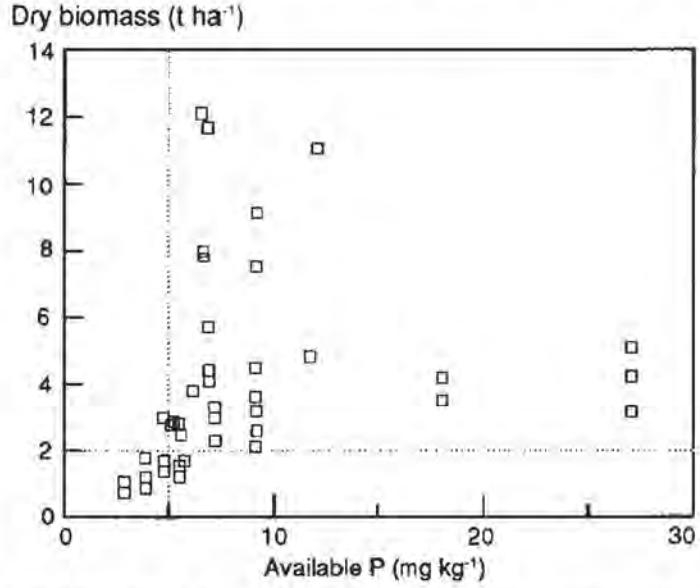



**Figure 3. Relationship between available soil P (various extractants, mostly Bray-1) and mucuna dry biomass accumulation (mostly during the rainy season) at eight sites in West Africa (WARDA 1997)**

Some legumes, such as pigeon pea (Ae et al. 1990) may make sparingly soluble P in the soil more available or may reduce the P fertilizer requirement on such soils. On P-fixing soils in the highlands of Cameroon, Yamoah et al. (1996) suggested that the P fertilizer requirement of maize and bean was reduced through mucuna rotation. Yield of maize grain without P following mucuna was similar to the control (without mucuna) with 150–200 kg P $ha^{-1}$ (figure 4). In P-fixing soils of the Brazilian savanna, the addition of mucuna residue to soil did not increase extractable P but it did increase slightly the amount of P that was chemically exchangeable (LeMare et al. 1987). Similar studies on the effect of mucuna on P availability should be intensified.

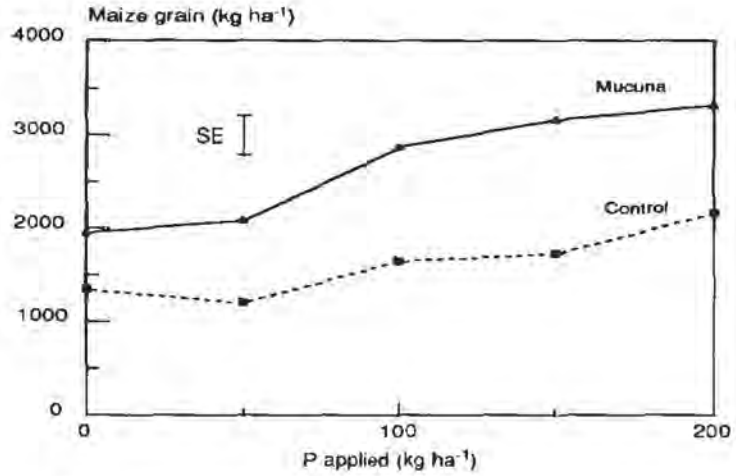



**Figure 4. Maize grain yield as affected by mucuna rotation and P fertilizer application on a P-fixing soil in the highlands of Cameroon (from Yamoah et al. 1996)**

**Soil acidity**

The pH requirement for mucuna growth is quite broad. The optimum range is 5.0 to 7.0 (annexes 1–3). Kay (1979) states that mucuna is fairly tolerant of acid soils but for optimum yields, a pH above 5 is required. The relatively low dry-matter accumulation observed by Becker and Johnson (1998) on an acid soil in southwestern Côte d'Ivoire compared to other sites (table 5) supports the current knowledge. Also Vine (1953) noted that results of green manuring trials in highly acid soils of southeastern Nigeria were disappointing, since the legumes did not grow well enough to improve soil properties. Hairiah and Van Noordwijk (1989) found that although *Mucuna pruriens* var. *utilis* had more shallow root systems than five other legumes, it was best in suppressing weeds in a 4-month period on acid soils (pH 4.5 in water) in southeastern Nigeria. Dry-matter accumulation by 14 weeks after planting (WAP) was only 3.2 t $ha^{-1}$. At the same site, Hamadina et al. (1996) estimated that 93 % of mucuna roots were located in the top 10 cm of soil after 5 months of growth, a finding apparently related to subsoil acidity.

**Response to N fertilizer**

Mucuna can absorb inorganic N effectively from the soil so it can respond to applied N just like any nonleguminous plant. For example, the yield of mucuna with N fertilization was similar to the yield with inoculation on soils in the Guinea savannas of Nigeria and derived savannas of Benin (Sanginga et al. 1996a; 1996b). Also Akobundu and Udensi (1995) applied N fertilizer to *Mucuna pruriens* var. *utilis* and var. *cochinchinensis* in a field study near Ibadan in an attempt to generate more groundcover to smother weeds. Both varieties responded to N application (table 6).

Available soil N can reduce nodulation and effective N fixation in legumes. The proportion of N fixed from the air will be reduced on fertile soils and when N is applied. Therefore, N fertilization of mucuna is not recommended.

**Table 6. Effect of N application on dry matter accumulation (kg ha$^{-1}$) of two varieties of *Mucuna pruriens* in southwestern Nigeria (I.O. Akobundu, unpublished data)**

| Mucuna variety | N rate | Mucuna dry matter | |
|---|---|---|---|
| | | 19 WAP | 30 WAP |
| *Utilis* | 0 | 2680 | 2340 |
| | 30 | 4080 | 3300 |
| | 90 | 3860 | 4200 |
| *Cochinchinensis* | 0 | 3650 | 5270 |
| | 30 | 4150 | 6080 |
| | 90 | 4730 | 6130 |

**Response to inoculation with rhizobium**

Kay (1979) reports that inoculation is not usually necessary if mucuna is grown in areas where cowpea has been cultivated. Otherwise, inoculation with a commercial cowpea inoculum may be necessary. Although cowpea is commonly grown in West Africa, there is substantial variability in the nodulation of mucuna. In a survey of 34 mucuna fields in southern Benin, Sanginga et al. (1996a) observed 0 to 135 nodules quadrat$^{-1}$ (measuring 0.25 m$^2$). No nodules were observed in seven fields (21%). In a pot trial conducted with soils from five sites in the Nigerian savanna (Sanginga et al. 1996b) nodules were found on mucuna in only one out of the five soils at 4 WAP. At 8 WAP, mucuna nodule numbers were still low but nodule mass on mucuna was the highest (almost 300 mg nodule$^{-1}$) of the 12 legumes studied. In related field experiments at four savanna sites, nodule number at 16 WAP ranged from 3 to 27 plant$^{-1}$ and nodule mass ranged from 40 to 3700 mg plant$^{-1}$ (Sanginga et al. 1996b).

**Soil texture and hydrology**

Botton (1957/58) stated that mucuna varieties grow in all soil conditions, even poor sandy soils. Preferred soil texture is sandy to sandy clay. Growth in clay soils may be hindered by waterlogged conditions. Mucuna is susceptible to waterlogging (annex 1; Kay 1979). Becker et al. (in press) grew *M. pruriens* var. *cochinchinensis* along a valley toposequence in central Côte d'Ivoire. Biomass in the periodically waterlogged lowland was severely reduced compared to the valley slope with mean water table depth at 32 cm (table 7).

**Table 7. Biomass (g plant$^{-1}$) of *Mucuna pruriens* var. *cochinchinensis* as a function of water table depth (cm) in the early rainy season at Bouaké, 1995 (from Becker et al. in press)**

| Average water table depth | Age of plants | | |
|---|---|---|---|
| | 1 month | 2 months | 3 months |
| 128 | 41 | 386 | 936 |
| 32 | 47 | 724 | 1514 |
| 8 | 23 | 286 | 555 |

## Pests and diseases

Mucuna is often thought to be immune to any pests and diseases (Botton 1957/58). However, there are many reports of disease, insect, and nematode susceptibility (Duke 1981; annex 1). As mucuna use increases, additional insect and disease problems can be expected to become important. This has already happened in areas of Central and South America (Thurstan 1997). A disease or pest problem could represent a threat to the use of mucuna as a soil improving, weed suppressing cover crop. For example, after many years of mucuna rotation, a fungal disease problem occurred in 1991 at the IITA farm in southwestern Nigeria which was identified as *Macrophomina phaseolina* by Berner et al. (1992). More than 75% of the crop was lost to the disease which causes stunting, necrotic crowns, and necrotic lesions along roots and runners. Clearly, it is necessary to maintain some biodiversity so as to avoid relying on only one species or variety. It is also necessary to carry out assessments of disease and pest susceptibility, not only because of detrimental effects on the cover crop species themselves, but also because of the potential of these newly introduced species to act as intermediate hosts for crop plant diseases or pests. For example, it was recently observed that mucuna species are susceptible to sunn hemp mosaic tobamovirus (J. Hughes and S. Tarawali, IITA, unpublished data).

# II

# Crop Establishment and Management

## Crop establishment

### Seeding rates and spacing

Kay (1979) gave the weight of 1000 seeds as approximately 1.1 kg. This is greater than the range of 1000 seed weight of 0.5 to 0.9 kg given by Calegari et al. (1993) and 0.62 to 0.96 kg reported by Kolawole and Kang (1997). Germination rate of mucuna seed is generally high, usually between 90 and 95% according to Kay (1979). Seed quality is generally good because the seed are not usually damaged in the field or in storage by insects. This may be because of toxic chemicals in the seed such as L-DOPA (L-3, 4-dihydroxyphenylalanine) (Kay 1979). As with all seed, drying may be necessary to prevent fungal infection.

Unlike many herbaceous legumes, mucuna does not require scarification. Mucuna emergence, even through crusted soil, is usually rapid because of large seed size and nutrient content (Kolawole and Kang 1997). Therefore mucuna is an easy species to establish. A minor problem is the weight of seed needed which can be a constraint for the rapid spread of its use as a cover crop.

Kay (1979) and Botton (1957/58) report seeding rates of 11 to 22 kg $ha^{-1}$ for row planting and 45 to 90 kg $ha^{-1}$ when broadcast. At 90% germination, this gives 10,000 to 20,000 plants $ha^{-1}$ for rows planted 1 m apart. According to Kay (1979), inter-row spacing of mucuna grown for seed should be 1 to 2 m. But when grown for green manure, rows should be 0.5 to 1 m apart.

Versteeg and Koudokpon (1990) found 80 x 80 cm spacing with one seed per hole to give acceptable groundcover. The resulting density is 15,000 to 16,000 plants $ha^{-1}$ and requires about 10 to 15 kg $ha^{-1}$ of mucuna seed. This is the density which is recommended by Sasakawa Global 2000 project for sole crop and relay intercropping (annex 5). The seeding rate for mucuna intercropping should be reduced, compared to sole cropping, thus reducing competition with the companion crop and economizing on seed (further discussion on intercropping below). The livestock development project in northeastern Benin Republic recommends 11 kg $ha^{-1}$ of mucuna seed for intercropping (Yai, in press).

Mechanized planting can be done with a 4-row no-till planter on 75 cm rows with an in-row spacing of around 30 cm, after spraying weeds with a nonselective herbicide and mowing with a rotary mower (Couper and Olayode 1990), a system which is clearly not appropriate for small-scale farmers in West and Central Africa.

### Seeding depth

Because of large seed size (Kolawole and Kang 1997) and great vigor of early seedling growth (Botton 1957/58), mucuna can be placed relatively deep (5 to 7 cm) at planting. Deep planting may help the seed to avoid periodic drought at the soil surface.

## Crop management

### Weeding requirements

When spaced properly and growing normally, mucuna hardly needs to be weeded. Indeed, farmers may not adopt mucuna cover cropping if the cover crop must be weeded. Fischler (1996) reported that it was not necessary to weed mucuna in on-farm trials in Uganda. For establishment in fields severely infested with *Imperata cylindrica*, Versteeg and Koudokpon (1990) recommended slashing the field at planting and again when mucuna is at the 3- to 4-leaf growth stage.

### Fertilization

Kay (1979) reports that application of superphosphate at a rate of 112 to 225 kg $ha^{-1}$ has been recommended in the USA. If fertilizer is available, and if soil test P is below 5 ppm, then P fertilization can recommended at similar rates in Africa, knowing that the applied P will remain in the soil and mucuna residue for subsequent crops. Single superphosphate application rates as low as 75 kg $ha^{-1}$ can be used, based on results summarized above.

## Mucuna seed production

Kay (1979) summarized mucuna seed yields as ranging from 700 to 1100 kg $ha^{-1}$ in India and 1700 to 2200 kg $ha^{-1}$ in the USA, with the lowest report of 600 kg $ha^{-1}$ in Australia. Carsky and Ndikawa (unpublished) recorded an average seed yield of about 200 kg $ha^{-1}$ in several environments in semi-arid northern Cameroon. Seed yields in the Nigerian savanna zone are generally around 250 kg $ha^{-1}$ for *utilis* and 1400 kg $ha^{-1}$ for *cochinchinensis* (table 3) when growth is good.

Support of some kind is generally recommended for improving quantity and quality of legume seed production (Humphreys and Riveros 1986). For climbing legumes, seed yields can be increased at least five times by trellising (Kachelriess and Tarawali 1994). Calegari et al. (1993) recommend trellising (with maize stalks or wooden stakes) to increase seed production of mucuna. Farmers in Ghana traditionally provide support to their mucuna by planting it next to trees (Osei-Bonsu et al. 1995).

# III

## Utilization and Benefits

### Weed control

Botton (1957/58) and Thurston (1997) reviewed the literature on the effects of mucuna on weeds and found several reports of mucuna being able to control both nut grass (*Cyperus rotundus*) and spear grass or cogon grass (*Imperata cylindrica*), two of the most difficult weeds to control in the tropics. Weed control may, under many conditions, be the major reason for farmer adoption of mucuna cover cropping. This was the case in southern Benin where *Imperata cylindrica* has become a major problem (Manyong et al. 1996). Many researchers have used mucuna for weed management, either planted as a sole crop or intercropped with food and plantation crops. It is generally assumed that mucuna suppresses weeds through its physical presence on the soil surface. However, mucuna may also release toxins which have allelopathic effects on the growth of neighboring plants.

#### Physical suppression

Weeds require light to germinate and carry out photosynthesis. The presence of a dense cover reduces light availability and thus prevents weed seedling germination and growth. Typical of the literature encountered is the report by Muhr (1997) that 75 to 80% groundcover was achieved in only 6 WAP in the moist savanna of southwestern Nigeria. In Costa Rica, Valverde et al. (1995) found that mucuna sown at densities of 50,000 and 80,000 plants $ha^{-1}$ reduced the biomass of itchgrass (*Rottboellia cochinchinensis*) by 75 to 95% compared to plots without mucuna. Triomphe (1996) also reported on mucuna's ability to control *Rottboellia*.

The suppressive effect of mucuna on weeds is related to its growth rate and dry-matter productivity. *M. pruriens* var. *cochinchinensis* had higher growth rates and biomass production compared to *M. pruriens* var. *utilis* (table 7) which resulted in better control of weeds (figure 5). Becker and Johnson (1998) showed that mucuna grown as a dry season fallow in upland rice-based systems at four sites in Côte d'Ivoire reduced weed biomass to about 20% of that in the natural fallow. In the same study, mucuna completely controlled *Imperata cylindrica* at a derived savanna site and *Chromolaena odorata* at a forest site.

Mucuna was the most effective *I. cylindrica* control method in a comparison with herbicides, tillage, and other cover crops by 19 weeks after treatment (Akobundu and Poku 1984) and 67 weeks (Poku and Akobundu 1985). *I. cylindrica* suppression appears to be the major reason for the adoption of mucuna short fallows by farmers in Benin (Versteeg and Koudokpon 1990; SAA 1996).

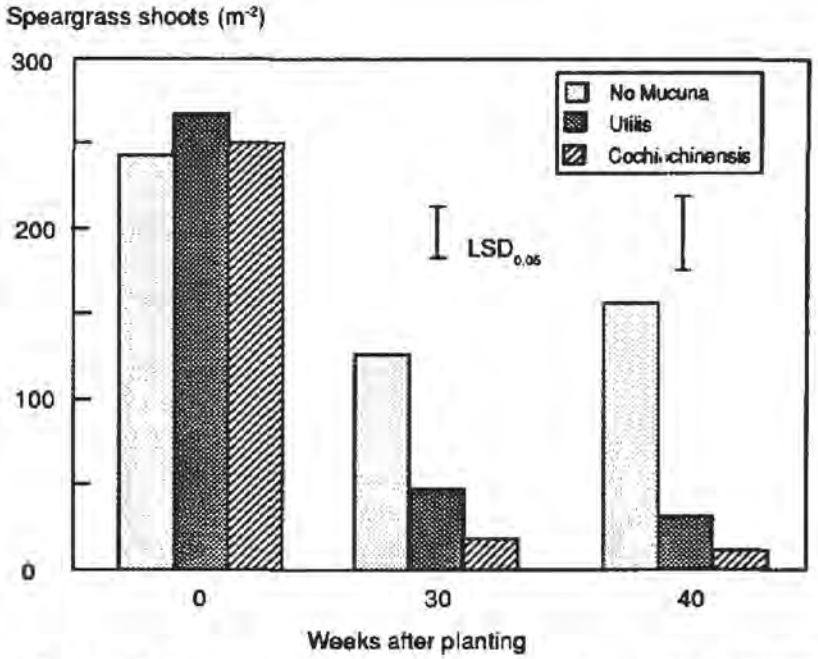



**Figure 5. Effect of mucuna on weed density (Akobundu and Udensi 1995). Differences at 0 WAP were not statistically significant**

**Allelopathy**

Allelopathy may be defined as the production of chemical substances by one plant that are released into the environment and affect the growth of neighboring plants positively or negatively (Fujii et al. 1992). The chemical substances may be released through root exudation and/or residue decomposition. Sahid et al. (1993) evaluated the allelopathic effects of several leguminous cover crops including *Mucuna pruriens* var. *cochinchinensis* on the germination and growth of two weeds, *Asystasia intrusa* and *Paspalum conjugatum*. They observed that weed germination was reduced by 23 to 27% when grown in 67 g $l^{-1}$ of aqueous extract of leaves and stems of mucuna. Fujii et al. (1992) found that kidney bean *(Phaseolus vulgaris)* growth was reduced by 30% when grown in soil mixed with mucuna residue. They identified the harmful substance as L-3, 4-dihydroxyphenylalanine (L-DOPA) which is present in leaves and roots of *Mucuna pruriens*. L-DOPA has been found to have suppressive effects on broad-leaved weeds but little effect on grass weeds (Fujii et al. 1992). These observations were consistent

with those of Hepperly et al. (1992) who found that *M. pruriens* var. *deeringiana* effectively controlled broad-leaved weeds but not grass weeds. After continuously cropping *Mucuna pruriens* for 5 years, Fujii et al. (1991) found that it reduced the weed population by 75% compared to fallow and plots continuously sown to upland rice. In another experiment designed to eliminate competition for growth-determining resources, Fujii et al. (1992) found that root exudates of mucuna inhibited the growth of cucumbers and lettuce but not of dry bean and stimulated the growth of grass weeds (*Phleum pratense, Agrostis alba,* and *Cynodon dactylon*). These findings may have implications when rotations include crops which are susceptible to mucuna toxins. It is also important to note that allelopathic effects have been demonstrated in greenhouse and laboratory experiments under artificial conditions. Toxicity is inferred from the response of target plants to the presence of extracts or ground tissue of mucuna. These results may have little relevance for field conditions where toxins from root exudates or decomposing plant tissue may be adsorbed or modified through soil biological action, and diluted and leached by rain water.

**Table 8. In vitro germination of seed of *Striga hermonthica* by mucuna varieties expressed as % of germination caused by GR-24 (unpublished data from Carsky, Ng, and Berner, IITA)**

| Variety | Preliminary trial | Full trial root age | | |
|---|---|---|---|---|
| | | 4 | 6 | 8 |
| Planting date | 17/4/95 | 18/3/96 | 19/2/96 | 5/2/96 |
| Assay date | 17/5/95 | 17/4/96 | 17/4/96 | 17/4/96 |
| GR-24 value | 252 | 230 | 230 | 230 |
| | % of GR-24 | | | |
| *Utilis* | 50.1 | 16.1 | 6.7 | 29.1 |
| *Cochinchinensis* | 10.4 | 5.3 | 3.0 | 6.1 |

**Note**
Method described and explained by IITA *Striga* Research Group (1997)

### Control of parasitic weeds

There are anecdotal reports that mucuna may reduce parasitic weed problems, especially *Striga hermonthica*, a parasitic weed of cereals. This is a complicated issue to discuss, especially since there are very few data upon which to base such a discussion. If it is true that the problem is reduced through the use of mucuna, then there may be several mechanisms (see Sallé and Raynal-Roques 1989; Berner et al. 1996 for background on *Striga* spp.). One mechanism may be "suicidal germination" in which *Striga* seed are germinated by mucuna root exudates but the *Striga* plants subsequently die as they fail to find an appropriate host. The data in favor of this hypothesized mechanism are not very strong as *M. pruriens* varieties rarely stimulated more than 20% of *Striga* seed in laboratory assays (table 8).

## Soil improvement

Rapid groundcover by mucuna can help to physically protect the soil from raindrop impact and prevent the crusting of surface soil, thereby reducing runoff of rainwater and soil erosion. This helps to maintain soil physical and chemical properties. In addition, mucuna leaf litter fall helps to protect the soil and return organic matter to the soil.

Although there are several reports of complete mucuna groundcover and substantial biomass accumulation, there are few reports of its influence on soil physical properties and no reliable reports of erosion control by mucuna in West Africa. Mucuna cover cropping can be expected to decrease the bulk density of the soil, although no cases were found in the West African literature. When the bulk density decreases, soil porosity concurrently increases and soil resistance decreases.

Improved soil physical properties are often related to increasing soil organic matter. However, differences in soil organic matter are generally observed only after several years of differential soil management. Becker (unpublished) observed a 3 to 9% increase in soil organic matter after a short mucuna fallow compared with a weedy fallow, although the difference was not statistically significant. After one season of mucuna, Carsky and Tian (unpublished) recorded 12% higher total N compared to natural fallow at one site but no difference at another site.

Rates of decomposition of organic residues increase with increasing N concentration and decreasing concentration of lignin and polyphenols (Tian et al. 1995). Becker (unpublished) found 4-month-old mucuna to contain 8.6 to 16.3% lignin, 0.6% water soluble polyphenols, and C/N ranging from 12 to 21 – all low values. Tian et al. (1992) found 6% N, 4.0% polyphenols, and 16.8% lignin in mucuna leaves and petioles. They observed mucuna decomposition rate to be among the highest in a group of ten herbaceous and woody species' leaves and petioles. Mucuna residue is therefore likely to decompose rapidly if temperature and moisture conditions are favorable for microbial activity and it would generally not be expected to contribute substantially to increasing soil organic-matter content. Vine (1953) reported that the changes in total soil N during 12 years with yearly mucuna green manure were negligible. As shown in figure 6, there was no increase in total N when mucuna residues were incorporated and a very slight decrease when mucuna residues were burnt.

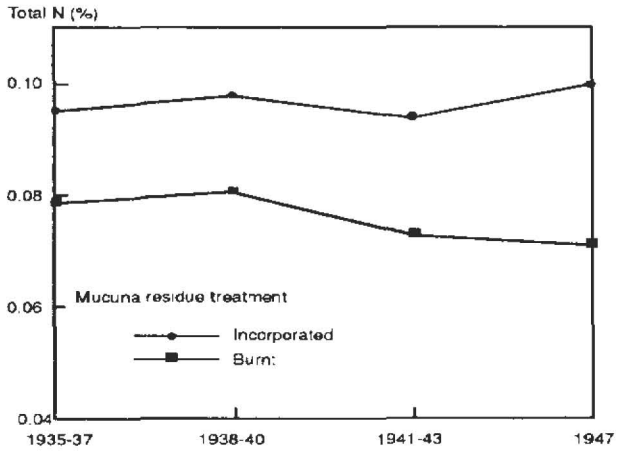



**Figure 6. Effect on soil total N (%) of incorporating green mucuna vs. slashing and burning the mucuna and incorporating the ashes (from Vine 1953)**

The amounts of N derived from the atmosphere (Ndfa) by mucuna are variable. Published estimates range from less than 20 to more than 200 kg $ha^{-1}$ (table 9). Most of these estimates come from researcher-managed trials. On farmers' fields there have been observations in the Republic of Benin of very poor growth of mucuna with very little nodulation and consequently very little N fixation (Sanginga et al. 1996a). There have also been reports of poor mucuna growth when the topsoil is removed (Hairiah et al. 1993) and on an acid, P-fixing soil in southwestern Côte d'Ivoire (Becker and Johnson 1998). In these cases Ndfa will undoubtedly be very low as well.

**Table 9. Amounts of N fixed by *Mucuna pruriens* sole crop during the rainy season (except where indicated) in the tropics**

| Country | Months of growth | Amount (kg $ha^{-1}$) | Method | Authors |
|---|---|---|---|---|
| Indonesia | 6 | 69 | Difference | van Noordwijk et al (1995) |
| Brazil | 5 | 95 | Difference | Carsky (1989) |
| Nigeria | 4 | 106 | Difference | Tian (unpublished) |
| Nigeria | 3 | 205 | $^{15}N$ dilution | Sanginga et al. (1996a) |
| Côte d'Ivoire | 6 | 18–213* | $\delta^{15}N$ dilution | Becker and Johnson (1998) |

Note

* Dry season fallow

Because of its rapid decomposition, mucuna is a good source of N to subsequent crops in a rotation. Van Noordwijk et al. (1995) estimated that 83% of mucuna N was available to a subsequent maize crop. In some studies, the yield of a non-legume test crop after mucuna was compared with the yield of the test crop after a control (a non-legume crop or a fallow). If the test crop after the control receives a range of levels of N fertilizer, then the fertilizer replacement value of the mucuna can be estimated. This is a rough estimate of the quantity of N fertilizer which is saved by using the mucuna fallow. It is valid when N nutrition is the major benefit of the mucuna fallow. Some of the more dependable fertilizer replacement values (with complete N fertilizer response curves) reported in the literature are summarized in table 10. The fertilizer replacement values range from 10 to 150 kg N $ha^{-1}$ depending on growth of mucuna, control treatment, and management of residues.

Soil improvement is a major factor in increasing cereal yields after mucuna fallows. These increases are highly variable but generally positive (table 11). The effects depend on the control treatment, treatment of the residues, and the amount of mucuna biomass produced (Lathwell 1990; Burle et al. 1992). Generally the estimate of mucuna benefit is greatest when compared to continuous maize, intermediate when compared to weedy fallow, and least when compared to bare fallow.

**Table 10. Estimates of N fertilizer replacement values (kg ha$^{-1}$) from rotations of *M. pruriens* followed by maize in the tropics**

| Country | Zone | Season | Estimate | Residue Mgt. | Authors |
|---|---|---|---|---|---|
| Brazil | Humid | Rainy | 39–109 | incorporated | Smyth et al. (1991) |
| Brazil | Humid | Dry | 30 | mulch | Burle et al. (1992) |
| Brazil | Subhumid | Rainy | 150 | incorporated | Carsky (1989) |
| Brazil | Subhumid | Dry | 10–20 | mulch | Burle et al. (1992) |
| Malawi | Subhumid | Rainy | 55 | incorporated | MacColl (1990) |
| Nigeria | Subhumid | Rainy | 58 | removed | Muhr (1997) |

Note
Fallow duration was one year or less except for MacColl (1990) which was three years with periodic cutting of fodder

Most of the available results are from researcher-managed trials, but Versteeg and Koudokpon (1990; 1993) reported mean maize grain yield gains of 500 kg ha$^{-1}$ (local maize variety) and 800 kg ha$^{-1}$ (improved variety) following a rainy season fallow of mucuna in many farmer-managed trials in southern Benin. This corresponds to at least 20 kg ha$^{-1}$ of additional N in the maize crop which might be made possible by the application of about 50 kg N ha$^{-1}$ as urea. This is slightly higher than the fertilizer N replacement values observed in Brazil when the mucuna residues are left on the soil surface as mulch (table 10).

Almost all of the results in table 11 are from maize-based systems, but results from rice-based systems are similar. In researcher-managed trials at four sites in Côte d'Ivoire, use of mucuna as dry season fallow increased upland rice grain yields by 100 to 590 kg ha$^{-1}$, averaging 310 kg ha$^{-1}$ (Becker and Johnson 1998). This increase also corresponds to a mineral fertilizer substitution of about 50 kg N ha$^{-1}$ from urea.

## Animal feed

There have been reports that mucuna is avoided by ruminants (Skerman et al. 1988) but this was probably the variety with stinging hairs on the pods which was mentioned above. Kay (1979) and Buckles (1995) cited cattle grazing as an important use of mucuna in the southern USA in the early 1900s. Bolton (1957/58) states that the cultivated varieties have good forage quality but that rather than fresh forage, animals prefer dry fodder made from mucuna and maize stalks. Muhr et al. (in press) observed *in sacco* digestibility of 43% in mucuna hay with 2% N and 12% crude protein. Yai (in press) notes that in a livestock development project in northeastern Benin Republic, mucuna is adopted by farmers more than other legumes which were tested (including *Stylosanthes*, *Lablab*, *Cajanus*, and *Leucaena*). It is grown with maize and harvested for dry season feed. In many studies in the semi-arid or subhumid zones, such as Carsky and Ndikawa (in press), cattle are observed to eat most available mucuna vegetation early in the dry season. In spite of the existing reports, mucuna is not mentioned in the most recent review of tropical legumes in animal nutrition (D'Mello and Devendra 1995).

**Table 11. Cereal grain yield improvement from *M. pruriens* fallows in the tropics**

| Control treatment | Residue management | Grain yield (t ha$^{-1}$) Mucuna | Control | Authors |
|---|---|---|---|---|
| Bare Fallow | Incorporated | 2.6 | 1.4 | Smyth et al. (1991) |
| | | 2.6 | 0.8 | |
| | | 2.2 | 0.3 | |
| Grass Fallow | Mulch | 3.3 | 3.0 | van Noordwijk et al (1995) |
| Maize | Mulch | 4.0 | 2.8 | Fischler (1996) |
| | | 4.2 | 2.7 (1st) | |
| | | 3.4 | 2.3 (2nd) | |
| Bare Fallow | Incorporated | 5.6 | 4.9 | Lathwell (1990) |
| | | 6.8 | 4.6 | |
| Weedy Fallow | Incorporated | 6.3 | 3.7 (1st) | Lathwell (1990) |
| | | 6.1 | 1.8 (2nd) | |
| Maize | Incorporated | 6.3 | 3.3 (1st) | Lathwell (1990) |
| | | 3.0 | 3.1 (2nd) | |
| Maize[a] | Incorporated | 1.4 | 0.3 | Sanginga et al. (1996a) |
| Maize | Mulch | 2.2 | 1.2 | Burle et al. (1992) |
| Bare Fallow | Mulch | 5.0 | 4.2 | Burle et al. (1992) |
| | | 2.0 | 1.3 | |
| | | 4.0 | 3.4 | |
| Maize | Mulch | 1.8 | 1.0 | Versteeg and Koudokpon (1993) |
| Weedy Fallow | Incorporated | 1.1 | 0.5 | Becker and Johnson (in press) |
| | Incorporated | 1.6 | 1.5 | |
| | Burnt | 0.8 | 0.3 | |
| | Burnt | 0.3 | 0.2 | |
| Weedy Fallow | Part removed | 3.6 | 2.0 | Muhr et al. (in press) |
| Weedy Fallow | Mulch? | 3.2 | 1.9 | Dogbe (1997) |
| Maize[b] | Incorporated | 3.1 | 0.9 | MacColl (1990) |
| | | 3.2 | 2.1 | |
| | | 4.0 | 2.9 | |
| Weedy Fallow | | 0.32 | 0.18 | Hamadina et al. (1996) |
| Weedy Fallow | Mulch | 3.3 | 3.0 | Utomo et al. (1992) |
| Grass Fallow | Mulch | 1.0 | 0.6 | Tian (unpublished) |

**Notes**

[a] After three cycles of maize-maize control or mucuna-maize

[b] Fallow duration was three years

Mucuna grain also has feeding potential. According to Kay (1979) and Buckles (1995), an important use of mucuna grain in the USA in the early part of this century was animal feed. It was milled and integrated into feed for cattle and horses (Buckles 1995). According to Kay (1979) mucuna grain is best used for cattle and sheep and can only be fed to pigs if the mucuna makes up less than 25 % of the diet. Mucuna grain is unsuitable as poultry feed according to Kay (1979).

## Human food

*Mucuna pruriens* var. *utilis* is considered as a food legume by Kay (1979) although she notes that mucuna beans require considerable care in their preparation, because of toxins. The toxic principle can be removed by boiling and soaking the seeds in several changes of water. The major toxic principle, L-DOPA, is used in the treatment of Parkinson's disease and mucuna seed may be a commercial source since it contains about 1.5% in whole untreated seed. Versteeg et al. (in press), however, reports that the L-DOPA content of mucuna grown locally was 4.7 to 6.4 %. The concentration can be lowered by processing as mentioned above and also by diluting with other foodstuffs. Therefore, a possible solution, tested recently by Versteeg et al. (in press) and found acceptable by panel members, is to make mucuna flour and mix it with maize or cassava flour.

Small amounts of mucuna are traditionally consumed in the forest zone of Ghana in the daily soup (Osei-Bonsu et al. 1995). In fact, mucuna has been grown in Ghana as a minor crop for at least a century. An informal survey of 60 farmers in the forest and forest-savanna transition zones revealed that about 90% of respondants in the forest zone and 50% in the transition zone knew that mucuna or canavalia are used for food (Osei-Bonsu et al. 1995). Respondants knew that boiling the mucuna bean for 40 minutes and discarding the water renders it safe for limited human consumption. Interviews with Ghanaian women indicated that between 10 and 15 mucuna beans are consumed per person per meal. The seed coat is discarded with the water used for boiling because it does not grind easily. The remaining endosperm is ground into a fine paste along with other ingredients. Respondants prefer the immature beans because the cooking time is reduced. To reduce cooking time, mature beans can be cracked, soaked overnight, or briefly toasted on a fire.

## Nematode suppression

Mucuna is reported to suppress some nematodes while multiplying others (Thurstan 1997). Reddy et al. (1986) reported that although *M. pruriens* var. *deeringiana* supported large nematode populations, it was effective in reducing soil populations of root-knot nematodes in naturally infested soil in Florida. Resck et al. (1982) reported that root-knot nematodes were reduced by *aterrima*, *deeringiana*, and *cochinchinensis* varieties. Attempts to use *M. pruriens* to improve soil fertility for banana plantations in Martinique indicated that while soil fertility was improved, the populations of the nematode *Radophilus similis* were maintained (Ternisien 1989; Ternisien and Melin 1989).

In West Africa, Caveness (1992) reported on the evolution of nematode densities under mucuna fallow, mucuna mulch, and mucuna "live mulch". Screenhouse pot tests showed that the root-knot nematode was maintained on mucuna at a very low level (50 eggs $pot^{-1}$) but at high levels on cowpea (12,500 eggs $pot^{-1}$) and weeds (16,400 eggs $pot^{-1}$). In six fields under mucuna mulch from July to November, the average density of root lesion nematodes (*Pratylenchus* spp) decreased from 85 to 26 individuals $l^{-1}$ of soil while spiral nematodes increased from 20 to 318 $l^{-1}$. The effect on subsequent food crops was not reported.

# IV

## Cropping Systems Design Considerations

### Mucuna residue management

It is generally recognized that incorporation of mucuna results in higher inorganic N availability than mulching or burning. A synthesis of some research results shows that the N fertilizer replacement value (table 10) and cereal grain yield increase (table 11) are higher when mucuna residues are incorporated than when they are left on the soil surface as mulch. N recovery from mucuna was higher when incorporated than when placed on the surface of an Oxisol with pH 5.5 (Costa et al. 1990). They estimated that 45% of the mucuna N was lost (presumably by volatilization) when fresh chopped leaves were applied as mulch. Maize yields following mucuna incorporation were 26% higher than yields following a mulch treatment over three years in the Brazilian Amazon (Smyth et al. 1991). Loss from volatilization is probably much lower if the mucuna dries in situ without chopping. At three sites in the savanna zone of Côte d'Ivoire, the effect of mucuna fallow (compared to weedy fallow) on subsequent rice grain yield was significant if incorporated (0.5 t $ha^{-1}$) or mulched (0.4 t $ha^{-1}$) and not significant if removed (0.3 t $ha^{-1}$) or burned (0.2 t $ha^{-1}$) (table 12).

**Table 12. Effect of fallow vegetation (weeds or *Mucuna cochinchinensis)* and residue management on yield of upland rice (mean of three sites in the savanna zone of Côte d'Ivoire, 1995/96) (from WARDA 1997)**

| Fallow vegetation | N content (kg $ha^{-1}$) | Rice grain yield (t $ha^{-1}$) | | | |
|---|---|---|---|---|---|
| | | removed | burnt | mulched | incorporated |
| Weedy | 19 | 0.52 | 0.58 | 0.53 | 0.56 |
| Mucuna | 42 | 0.81 | 0.79 | 0.91 | 1.12 |
| $LSD_{0.05}$ | 13.7 | n.s. | n.s. | 0.38 | 0.43 |

Although burying residues helps retain more N in the soil, incorporation of fresh mucuna vines into the soil requires substantial labor. Vine (1953) recounted that research on mucuna in southwestern Nigeria was influenced by the need to reduce the labor requirement to an acceptable level while maintaining the benefits from mucuna planted fallows. He reported on several long-term trials to compare incorporation of fresh mucuna (in November) with slashing, drying, and burning the bulk of the mucuna

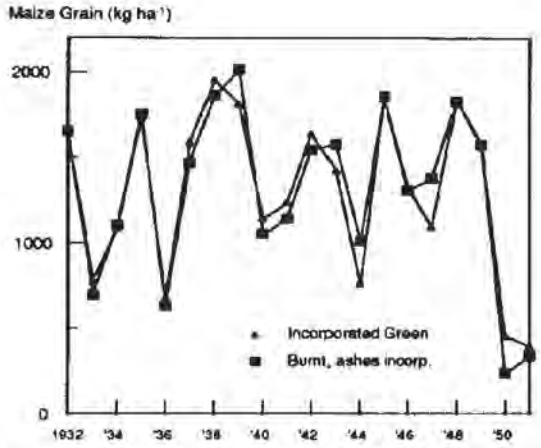



**Figure 7. Labor-intensive incorporation of green mucuna biomass into the soil did not have a substantially better effect on early season maize performance than burning the residue and incorporating the ashes (from Vine 1953)**

biomass and incorporating the ashes in November. A short duration maize crop was grown every year in the first cropping season and mucuna was relayed into the maize and grown in the second season. Grain yields of maize were maintained for at least 17 years (figure 7) and there was no substantial difference between the two mucuna residue management practices (burning vs. burying). Analysis of surface soil samples at the time of maize planting showed that there was more nitrate in the plots where mucuna was incorporated (figure 8) but apparently there was enough nitrate, even from the burning treatment, to support the short duration maize crop. It was difficult to detect a change in total N content of the surface soil under the two treatments (figure 8) although there was a slight decrease under burning.

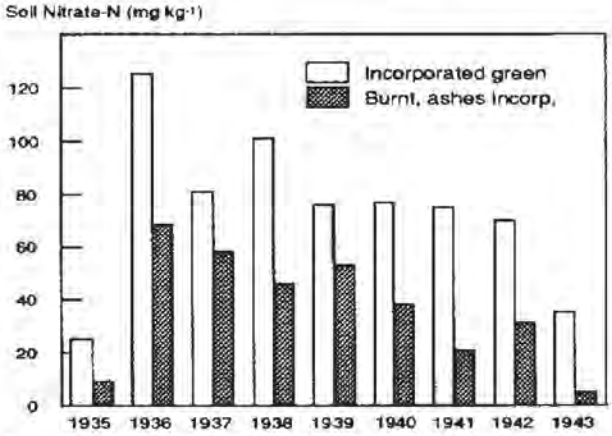



**Figure 8. Soil nitrate in surface soil at maize planting was increased by mucuna residue incorporation in southwestern Nigeria (Vine 1953)**

Burning of crop residues is attractive because it requires no extra equipment and is relatively easy to manage. It has little influence on subsequent non-legume management and can be followed by any crop. Burning usually results in a temporary increase in soil pH which may be of benefit in acid soils of the humid zones. This may be why Webster and Wilson (1986) found that burning mucuna residues and incorporating the ashes improved the yield of the subsequent maize as much as incorporating green mucuna into the soil.

Mulching mucuna residues requires virtually no additional labor. The major consideration is planting the subsequent crop and this is highly crop-specific. Planting of most seeds through the mulch can be done by hand, using a traditional planting tool or a jab planter. Another consideration is the formation of ridges or mounds for the subsequent crop. For example, ridges are often formed for maize and sorghum in the savanna zone and mounds are often made for cassava and yam. Formation of ridges or mounds will break up the mulch and partially incorporate it. This may reduce the weed suppression and soil protection effects but increase the N supply effect. If ridges or mounds are clearly needed, then the solution might be to form these structures before mucuna cropping. However, it remains to be studied whether these structures are still necessary if a good mulch is covering the soil.

Excess residue is not really a concern when the dry season exceeds three or four months. In the subhumid zone, fire, browsing animals, wind, and sometimes termites may eliminate a large proportion of mucuna biomass. Management of large quantities of residue may be a consideration in the humid zone because a substantial amount of mulch will persist throughout the dry season.

Mechanized mucuna fallow systems are possible. At IITA in the subhumid zone of southwestern Nigeria, mucuna is mowed, leaving a thick, uniform mulch (IITA 1986). Maize and some other grain crops can be planted through the mulch using a tractor-drawn drill. For incorporation of mucuna residue, it is usually necessary to slash and allow the green residue to dry briefly before incorporating. In Brazil, mucuna is chopped before incorporation with a heavy disc plow, moldboard plow or rototiller (Guia Rural Abril 1986). If mucuna is incorporated after seed maturity and seed are not collected, then regrowth of mucuna in the subsequent rainy season may be substantial. For mechanized systems, Akobundu (1990) identified several herbicides which effectively controlled mucuna volunteers. Rotary slashing or paraquat also kill the mucuna effectively (IITA 1986).

## Mucuna volunteers

Mucuna can be an aggressive weed so volunteer mucuna in a subsequent crop will need to be managed. Akobundu (1990) reported subsequent maize stalk lodging of 65% and grain yield reduction of 35% (compared to a weed-free treatment) if mucuna volunteers were not controlled. But on the other hand, farmers find mucuna easier to control than the weeds it is meant to suppress, *Imperata cylindrica* in maize-based systems of southern Benin (Versteeg and Koudokpon 1990) and *Chromolaena odorata* in rice-based systems of the humid zone of Côte d'Ivoire (Becker, unpublished).

## Maintaining mulch cover during the dry season

Mulch cover helps to moderate soil temperatures, favoring soil biological activity and maintaining good soil physical conditions. A mulch cover at the onset of the rains protects the soil from raindrop impact, surface crusting, runoff, and erosion. The probability that mulch will persist through the dry season depends on the biomass accumulated, the length of the dry season, and pressure from fire and grazing.

In the semi-arid zone with a growing period of 150 days or less (7-month dry season), mucuna mulch is not likely to persist, even if it is protected from fire and grazing ruminants. In the semi-arid zone of Cameroon, mucuna senesced very soon after the end of the rains, resulting in a substantial dry mulch in the moderately fertile sites (approximately 5 t $ha^{-1}$) which was substantially reduced during the dry season (Carsky and Ndikawa in press). In a degraded site where less than 4 t $ha^{-1}$ were produced, the mulch disappeared completely during the long dry season.

On the other hand, in the humid zone with a growing period of 210 days or more, mucuna mulch is likely to persist if protected from fire. Yield of *M. pruriens* at Ibadan in January was approximately 6 t $ha^{-1}$, comprising 2 t $ha^{-1}$ of green plants and 4 t $ha^{-1}$ of legume litter (Muhr 1997).

In the intermediate zone with between 150 and 210 days growing period (5- to 7-month dry season), persistance of a mucuna mulch will depend on the quantity of biomass produced and protection of the mulch. The disappearance of mucuna mulch was quantified from January to April on a field site in northern Nigeria (approximately 160 day growing season). Disappearance of mulch dry matter was approximately 4 t $ha^{-1}$ (50% of the mulch residue) during the 3-month period although the site was protected from fire and grazing animals (figure 9). It can be assumed that rates of disappearance of mucuna mulch will be similar in other zones (i.e., approximately 1 t $ha^{-1}$ per month of dry season).

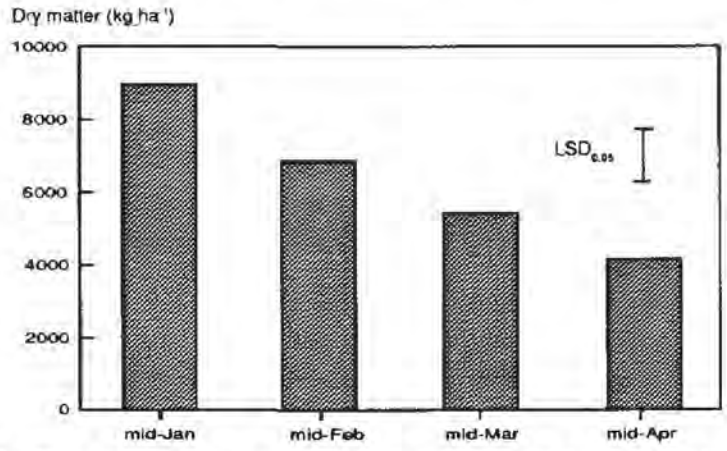



**Figure 9. Dry matter of mucuna mulch left on the soil surface during the dry season on a field in northern Nigeria, 1996 (Tian and Carsky, unpublished data)**

The above estimates of rates of disappearance of mucuna mulch are low compared with the disappearance caused by fire and animal grazing. Cooperation will be needed among entire communities on the use of fire and movement of livestock or else appropriate fire breaks and fencing options will need to be considered.

## Cropping systems niches

A major constraint to the use of planted herbaceous fallows is that they take land out of food crop production, reducing the potential for short-term food supply that many smallholder farmers need. Thus it is necessary to search for temporal or spatial niches in which mucuna can be grown without reducing short-term food production. Intercropped mucuna occupies a spatial niche and several considerations will be discussed below. The most obvious temporal niche is a short-term planted fallow. Most results on the benefits of mucuna-based soil improvement have come from sole cropped rainy season fallows to replace the traditional bush fallow system. The fallow species occupies the land when a food crop might otherwise be grown and therefore may only be acceptable when farmers have few options. Other temporal niches may be identified in which the land might not normally be used for crop production. They mostly consist of dry season mucuna fallow in combination with the early and/or late rainy season.

### Intercropping

*General considerations*

Higher mucuna biomass and better soil cover are obtained by sole cropping compared with intercropping. Intercropping, especially with a tall crop, such as sorghum, millet, maize, or cassava, results in mucuna growing upward as it climbs on the companion crop. Therefore, it has less contact with the ground and exerts a less positive effect as a cover crop and may even have a negative effect on associated cereal yields.

The major management issue for mucuna intercropping is the need to avoid interspecific competition. This includes competition for soil moisture and nutrients and solar radiation. The aggressive climbing habit of mucuna may result in the smothering of the companion crop, resulting in reduced crop yield through competition for solar radiation, possibly increased disease incidence, and difficulty in harvest. It is commonly observed that maize yield is reduced by simultaneous sowing of mucuna. Osei-Bonsu and Buckles (1993) observed that simultaneous sowing of mucuna and maize resulted in a crop yield reduction of 1 t $ha^{-1}$ in Ghana. If the mucuna is planted at the same time as a companion crop, then it must be slashed one to three times to prevent the mucuna from twining around cereal stems. However, the problems related to intercropping can be avoided through manipulation of relative planting dates and densities. These need to be defined for each crop and each agroecological zone.

Most studies of mucuna intercropping use maize as the associated crop because of the high N requirement of maize and its relatively short duration and stature, allowing relay intercropping with a cover crop. There have been very few studies on mucuna

intercropping with other crops, although intercropping should be possible, especially with widely spaced crops such as tree crops. Cover crops are often used in plantations, such as rubber, oil palm, and coffee. It may be possible to use mucuna in those or in other plantations such as cashew and mango, especially if heavily infested with *Imperata cylindrica* as is often observed in the savanna zone.

*Maize/mucuna relay intercropping*

Generally maize should be planted from 4 to 6 weeks before mucuna. It is probably better to err toward later planting of mucuna to avoid competition with the maize crop. The planting time might be a bit earlier if an early maize variety is used and it also depends on the spatial arrangement of mucuna with respect to the associated crop. Most intercropping studies use alternate rows of maize and mucuna. Osei-Bonsu and Buckles (1993) recommended sowing of maize in narrow double rows of 40 cm separated by mucuna in wide rows spaced at 160 cm.

It is debatable whether mucuna intercropping can contribute sufficiently to soil fertility maintenance to be attractive to farmers. The amount of mucuna biomass is decreased in the intercrop so the effect on soil is reduced. In a one-year trial conducted was 5.6 t $ha^{-1}$ in a sole crop and reduced to 1.8 t $ha^{-1}$ when planted 3 weeks after maize (table 13).

**Table 13. Mucuna biomass and maize grain yields in the first season followed by second season maize in the bimodal rainfall zone of Uganda (Fischler 1996)**

| Cropping system | Mucuna DM (t $ha^{-1}$) | Maize grain yield (t $ha^{-1}$) | |
|---|---|---|---|
| | | First season | Second season |
| Sole maize | – | 4.83 a | 2.76 a |
| Maize/mucuna | 1.85 | 3.53 b | 2.90 a |
| Sole mucuna | 5.65 | – | 3.95 a |

**Note**

Means in a column followed by the same letter are not significantly different at $P < 0.05$

Maize grain yield was reduced from 4.8 to 3.5 t $ha^{-1}$ by association with mucuna compared with sole maize. In the second season, maize yield was only slightly higher after the maize/mucuna intercrop (2.9 t $ha^{-1}$) compared with sole maize (2.8 t $ha^{-1}$). Therefore, the residual effect of the mucuna intercrop did not compensate for the loss of maize yield in the first season. Total maize grain yield over the rotation cycle was 7.6 t $ha^{-1}$ for maize followed by maize and 6.4 t $ha^{-1}$ for maize/mucuna followed by maize. The high maize yields suggest a moderate-to-high level of soil fertility (no N was applied) in which maize dominated mucuna planted 3 weeks later. The mucuna intercrop may help to maintain soil

fertility over time, but a farmer may not be likely to use mucuna to maintain soil fertility in this situation because of lower total yields. In another trial conducted on six farmers' fields (Fischler and Wortmann 1997), similar results were observed. However, in this case an additional season was used to generate high mucuna biomass after relaying mucuna into maize. After three seasons, continuous maize gave a total of 8.1 t $ha^{-1}$ while the maize/mucuna relay system gave 6.1 t $ha^{-1}$ (table 14).

**Table 14. First season maize grain yields in a comparison of sole maize, sole mucuna, and maize/mucuna intercrop followed by second season maize (bimodal rainfall zone in Uganda) and subsequent year (third season) maize (Fischler and Wortmann 1997)**

| Cropping system | Maize grain yield (t $ha^{-1}$) | | |
|---|---|---|---|
| | First season | Second season | Third season |
| Sole maize | 3.18 a | 2.66 b | 2.28 b |
| Maize/mucuna | 2.40 b | – | 3.71 a |
| Sole mucuna | – | 4.24 b | 3.42 a |

Note
Means in a column followed by the same letter are not significantly different at $P < 0.05$

Another intercropping study was reported from three sites in the forest-savanna transition zone of Ghana (two growing seasons per year). In this case, mucuna planted 45 days after maize did not reduce maize yield and increased subsequent maize yield in the second season well above a continuous maize control (table 15). Total maize grain yield from the maize/mucuna relay system was 6.1 t $ha^{-1}$ compared with 4.2 t $ha^{-1}$ for continuous maize. Sole mucuna rotation also gave 4.2 t $ha^{-1}$. Comparing this result with that of Fischler (1996), it appears that the benefit of mucuna is relatively greater when soil fertility is reduced

**Table 15. Yield of maize (t $ha^{-1}$) as a function of maize/mucuna cropping systems in three trials in the forest/savanna transition zone of Ghana (unpublished data of Osei-Bonsu and Asibuo, Crops Research Institute, Kumasi, Ghana)**

| | Maize yield | |
|---|---|---|
| | First year | Second year |
| Sole maize | 3.07 | 1.17 |
| Maize/mucuna (0 DAP) | 1.91 | 2.99 |
| Maize/mucuna (45 DAP) | 3.13 | 2.99 |
| Sole mucuna | – | 4.18 |

In summary, mucuna intercropping is difficult to manage, resulting in possibly high current season yield reduction of companion crops and smaller benefits than from sole mucuna rotations. Minimizing the first season yield loss while maximizing the subsequent benefit requires solutions such as changes in spatial arrangements (Osei-Bonsu and Buckles 1993).

**Temporal niches for mucuna planted fallow**

*Fallow period in bush fallow system*

Bush fallow is the traditional method of soil productivity maintenance which functions well where land is abundant. Where land is scarce, farmers develop other solutions which are not necessarily based on native bush regrowth. For example, in southern Benin, farmers have developed a long oil-palm fallow (Kang et al. 1991) among other methods (Hinvi et al. 1991). In these cases, a planted mucuna fallow may shorten the fallow period and allow cropping intensity (number of cropping years/total years) to increase. The mucuna short fallow system was adopted by farmers in some areas of southern Benin where *Imperata cylindrica* infestation was very high (Manyong et al. 1996).

A mucuna fallow is not likely to have a long-term effect. If it is true that 80% of mucuna N is available to a subsequent crop (van Noordwijk et al. 1995) then very little is left for a second crop. The summary of literature is equivocal on this point. For example, Lathwell (1990) reported two very contrasting cases (table 11) in which yields of second crops of maize were no greater than the control (3.0 vs 3.1 t $ha^{-1}$) in the first case and much greater than the control (6.1 vs 1.8 t $ha^{-1}$) in the second case. Fischler (1996) reported an intermediate case (3.4 vs 2.3 t $ha^{-1}$).

*One season in bimodal rainfall zone*

In the bimodal rainfall area, it may be possible to use one of the two rainy seasons for a short mucuna fallow. Either season may be used for mucuna fallow, depending on the preferred season for cropping and the length of the subsequent dry season. For example, in southwestern Nigeria and southern Benin, the second season is short and maize yields are generally low due to drought and stem borers (Mutsaers 1991). Thus, the second season might be best for the mucuna fallow. This was the system used in colonial Nigeria (Faulkner 1934; Vine 1953) to maintain soil productivity for many years.

A similar system was tested by Fischler (1996) in Uganda where the two dry seasons are both short (1 to 2 months). In one researcher-managed trial, maize yield following sole mucuna was high but did not compensate for loss of the crop during the first season (table 14). In a farmer-managed trial (Fischler and Wortmann 1997), a sole mucuna fallow followed by two crops of maize gave the same total yield as three crops of maize (table 15) and therefore gives the impression of being biologically sustainable because of the high maize yields. Its economic sustainability will depend on input costs and product prices.

*Dry season*

Successful use of the dry season for mucuna planted fallows depends on the length of the dry season and the ability of the fallow crop to regrow with the return of the rains. There are two approaches for taking advantage of mucuna during a dry season. One strategy is to allow the mucuna to die and cover the soil surface during the dry season. The key to this strategy, as seen above, is a large amount of biomass in combination with some protection from fire and grazing animals.

A strategy for areas where the dry season is not too severe is to plant the mucuna late in the rainy season so that it will survive the dry season and regrow rapidly in the early rainy season before cereal cropping. This was tested in the savannas of Brazil by Burle et al. (1992). By the beginning of the subsequent rainy season, the dry matter of mucuna varieties ranged from 2.2 to 4.7 t $ha^{-1}$ on a dark red soil and from 0.8 to 2.9 t $ha^{-1}$ on a red-yellow soil. N content of the best mucuna variety (*M. aterrima*) was 94 and 66 kg $ha^{-1}$ on the two soil types. It must, however, be noted that rooting depth in those trials was more than 100 cm.

The strategy was extended to Côte d'Ivoire by Becker and Johnson (1998). Dry matter of mucuna depends on variety, climate, and soil type (table 5). The amounts of mucuna dry matter and N accumulation observed can be expected to have some effect on a subsequent cereal crop. A dry season mucuna fallow was also tested for 3 years in the forest zone of Togo by Dogbe (in press). In spite of higher labor input and higher cost of production (table 16), the mucuna fallow system gave substantially higher net returns (193 \$ $ha^{-1}$) compared with weedy fallow (2 \$ $ha^{-1}$).

**Table 16. Effect of mucuna dry season fallow on productivity of rainfed lowland rice (mean of 3 years in the forest zone of Togo). From Dogbe (1997)**

| | Weedy fallow-rice | Mucuna-rice |
|---|---|---|
| Grain yields (t $ha^{-1}$) | 1.85 | 3.22 |
| Cumulative weed biomass (t $ha^{-1}$) | 1.32 | 0.81 |
| Labor input (man-days $ha^{-1}$) | 180 | 250 |
| Cost of production (\$ $ha^{-1}$) | 385 | 460 |
| Gross return (\$ $ha^{-1}$) | 383 | 653 |
| Net return (\$ $ha^{-1}$) | 2 | 193 |

This system was used by Muhr et al. (in press) to provide animal feed and still fertilize a subsequent maize crop. Although 33 kg N $ha^{-1}$ was removed in the hay cut in the middle of the dry season, there was a further 44 kg N $ha^{-1}$ in the green manure that was cut and incorporated before maize planting. Subsequent maize grain yield was 1.5 t $ha^{-1}$ higher following mucuna than the natural fallow control.

*Early rainy season*

Lowland rice is often planted late in the season when the soil is saturated. Pre-rice green manuring is possible because of the substantial amount of time between the onset of the rains and rice planting.

In some areas there is a long rainy season (170 to 200 days) without a drought period (monomodal rainfall pattern). Mucuna can be grown in the first part of the long rainy season followed by a short duration maize variety, transplanted millet, or other crop. Preliminary results from an area with a growing season of 180 days in northern Nigeria (table 17) indicate that early season mucuna plus a small amount of N (such as 30kg N $ha^{-1}$) to the subsequent maize crop resulted in maize yields which were high enough to compensate for the loss of the early season cowpea crop (the farmers' traditional practice in the zone).

**Table 17. Yield of maize and cowpea in farmer-managed trials and partial budget analysis comparing mucuna with cowpea (the traditional practice) as early season crop (Carsky, unpublished)**

| | Mucuna/maize | Cowpea/maize+30N | Mucuna/maize+30N |
|---|---|---|---|
| Cowpea yield (t $ha^{-1}$) | – | 0.40 | – |
| Maize yield (t $ha^{-1}$) | 1.39 | 1.15 | 1.83 |
| Gross revenue ($ $ha^{-1}$) | 201 | 249 | 265 |
| C = Total cost ($ $ha^{-1}$) | 92 | 111 | 114 |
| B = Net revenue ($ $ha^{-1}$) | 109 | 138 | 151 |
| B/C | 1.18 | 1.24 | 1.32 |

## Adoption of mucuna in West Africa

Mucuna adoption first occurred in southwestern Benin Republic where researchers and extension workers tested the technology with farmers from 1988 to 1992. Because of the promising results, the dissemination of mucuna to large numbers of farmers was then undertaken by extension services. The systems most often adopted were a sole mucuna fallow during the entire rainy season (in the case of severe *Imperata cylindrica* infestation) or a second season sole mucuna fallow (Versteeg and Koudokpon 1993). In 1994, the determinants for the adoption of mucuna were investigated from a sample of about 280 farmers in the Mono Province, using econometric models (Manyong et al. 1996). Relationships between adoption of the technology and farmer characteristics, field characteristics, and farmers' perceptions of the technology were evaluated.

Field characteristics were the most important group of determinants of adoption. The most important factor, which was positively related to adoption, was the number of times the farmer needed to weed *Imperata cylindrica* previous to testing mucuna. The second determinant, negatively related to adoption, was the presence of young palm

trees in the field. This is because oil palm is a long-term fallow with several valuable products and mucuna would smother the young trees. The third determinant of adoption was poor soil fertility as perceived by the farmer. This characteristic was positively related to adoption. Other determinants related to the farmer and farm were (1) secure land tenure (positive), (2) the amount of fallow land owned by the farmer (negative), (3) access to external research and/or extension institutions (positive). Determinants related to the farmer's perception of the technology were (1) the fact that wild mucuna causes itching, thereby discouraging entry of strangers into the field (positive), (2) the loss of the second season food crop on the field (negative), and (3) the possibility of the existence of a market for mucuna seeds (positive).

Mucuna fallowing may solve farmers' problems in other areas of West Africa which has prompted Vissoh et al. (in press) to examine adoption in Benin to learn where it will and will not be acceptable. Based on farmer and research experience, expansion of mucuna fallowing is more likely to occur where soil fertility is declining, inorganic fertilizers are expensive, noxious weeds such as *I. cylindrica* severely affect farmers' production, and development organizations have good contact with farmers. Adoption is likely to be stimulated by new markets for mucuna seeds. It may also be most likely in areas with long growing seasons (7 months or more). Other windows of opportunity for mucuna fallows may exist, such as the need for additional livestock feed or the need to reduce nematode buildup in intensified cereal systems.

# V

# Future Research Needs and Summary

## Future research needs

### Encourage biodiversity

The number of varieties of mucuna that have been tested in West Africa has been limited. Recent results from research in West Africa have been almost uniquely for *M. pruriens* var. *utilis* and var. *cochinchinensis*. Thus, there has recently been an attempt to increase the diversity in the mucuna germplasm used in West Africa (table 18).

**Table 18. Characteristics of *Mucuna pruriens* cultivars in IITA collection from one season of observation in southwestern Nigeria 7.4 °N (Tarawali, unpublished)**

| Name | Flower color | Seed color | 1000 seed weight (kg) | Seed shape | Days to flower |
|---|---|---|---|---|---|
| Cochinchinensis | Purple | White | 0.84 | Flat; short hilium | |
| Utilis | Purple | Black | 0.61 | Varied | |
| IRZ | White / purple | 50% white / 50% mottle | 0.72 | Elliptic; short hilium | |
| Deeringiana | Purple | 70% bright mottle/30% white | 0.74 | Elliptic; short hilium | 195 |
| Preta | Purple | Black | 0.40 | Varied | poor flowering |
| Jaspadea | Purple | White | 0.64 | Elliptic; short hilium | 135 |
| Rajada | Purple | Mottle | 0.38 | Round | 96 |
| Georgia | Purple | Black | 0.46 | Varied | 177 |
| VeraCruz-mottle | White | Approx. 50% mottle/50% white | 0.64 | Elliptic; short hilium | 146 |
| VeraCruz-black | Purple | Black | 0.46 | Varied | 158 |
| VeraCruz-white | Purple | 50% bright mottle/50% white | 0.59 | Elliptic; short hilium | 143 |
| Ghana | Purple | Dark mottle | 0.74 | Round; Short hilium | 92 |

For use of mucuna for soil improvement, there is a need for:

- Additional information on critical levels of soil available P. The possibility of using cheap sources of P (African rock phosphates) should be pursued as well as identification of species or varieties which utilize sparingly soluble P most effectively.
- Knowledge about rooting in different soils and their contribution to improved physical properties and improved subsequent crop yields. This information can guide crop management or selection of mucuna varieties.
- More complete knowledge about the persistance of mucuna mulch during the dry season as a function of management in different zones.
- Identification of species mixtures such as fast growing mucuna to give early soil cover and a slower growing but drought resistant, decomposition resistant, or persistent species (such as *Desmodium*, *Centrosema*, or *Stylosanthes* spp.)

Characterization and screening should be continued in several sites, and the varieties should be selected for uniform characteristics so that a diverse set of distinct varieties is available for different cropping systems niches and different uses. Botanical expertise should be employed to characterize the different types so that a commonly understood taxonomy can be utilized to allow extrapolation to different environments.

**Optimize benefits**

Mucuna has potential benefits other than soil improvement and weed suppression, including human food, animal feed, and the suppression of parasitic weeds and nematodes. If these benefits are well known, then farmers themselves will develop appropriate cropping systems, finding niches for mucuna. Research needs related to these benefits are:

- Thorough study on how to prepare the seed for human consumption should be carried out with subsequent analysis of toxins. The preparations need to be tailored to local tastes but the analyses could be centralized.
- Measurements of digestibility for ruminants and toxicity of leaves.
- Field studies of the ability of mucuna to suppress *Striga* spp. which have not been rigorously conducted and therefore are needed to confirm existing anecdotal reports.
- More systematic study of effects of cover crops including mucuna on parasitic nematodes in various cropping systems.
- Identification of species for live fencing to protect cover crops from livestock.
- Identification of practices to protect cover crop mulch from fire during the dry season.

**Identify cropping systems niches**

There should be further work on the identification of spatial and temporal niches for mucuna in cropping systems. This includes:

- *Ex ante* matching of target environments with management systems based on the potential benefits of mucuna.
- Identification of optimal establishment dates to maximize groundcover of the cover crop while minimizing competition with the companion crop. Potential companion crops include yam, cotton, coffee, and various tree crops.
- Identification of crops which can best take advantage of the improved soil and vegetation conditions of the short mucuna fallow.
- Appropriate tillage techniques to take advantage of the fallow. For example, would it be better to make mounds for yam after mucuna or to leave the mucuna as a mulch and forgo mounding?

**Determine adoption of mucuna use by farmers**

Development of improved systems should have certain targets in mind. These should be based on what farmers are likely to adopt. *Ex post* analysis of biophysical and socioeconomic conditions under which mucuna fallows have been adopted (Vissoh et al. in press) should be used to help with *ex ante* studies of where to pursue development and testing of mucuna fallows.

## Summary

Mucuna is one of the most promising fallow species for soil improvement and weed suppression. Research on mucuna has been scattered throughout the tropics and over a long time period. Thus, this review attempts to synthesize the available information for those contemplating the use of mucuna or already using it to improve farming systems. An important outcome of this review is to point out that mucuna does not grow well under all conditions, and therefore can not contribute to farming systems in all environments. For example, mucuna does not grow well in acid, waterlogged, or low-P soils, and in zones with a short growing season zone. Mucuna is adapted to the humid and subhumid zones but only marginally to the semi-arid zone.

There are many cropping system niches (temporal and spatial) in which mucuna can be grown to provide the desired benefits. Temporal niches (sole mucuna fallows) appear most promising because mucuna's aggressive nature results in substantial competition when intercropped with many crops. Mucuna fallow systems must be tested locally with farmers as was done in southern Benin where the most successful adoption has taken place. Benefits in addition to soil improvement and weed suppression, include animal feed, human food, and possibly others. These additional benefits will influence farmers' perception and adoption of mucuna and therefore should be explored.

Another important outcome of this review is that there are several distinct varieties of mucuna and therefore information on adaptability, crop management, benefits, and cropping systems niches must be extrapolated with some caution. *M. pruriens* var. *utilis* and *var. cochinchinensis* are best known and can be tested under a range of biophysical conditions and systems niches. At the same time research is needed to encourage the biodiversity of mucuna, identify and optimize its benefits in farming systems, and identify determinants of adoption in order to better target mucuna fallow technology to farming systems.

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**Annex 1 LEXSYS version 2.0 database record for *Mucuna pruriens***

| | |
|---|---|
| IITA/WAFSRN: | Lexsys 2.0 |
| Detailed Information on Specific Species: | |
| COMBS: | Date: 20-11-6 |

**BOTANICAL INFORMATION**

Species/variety : *Mucuna pruriens* (L.) DC.
Vernacular names: velvet bean, mucuna, pica-pica, bengal bean, pois noir, pois mascate, pois du bengale, ojo de buey, ojo de venado, fava café, olhos de burro
Synonyms: *Stizolobium deeringianum, Stizolobium aterrimum, Styzolobium niveum, Mucuna utilis, Mucuna velutina, Mucuna cochinchinensis, Mucuna nivea*
Taxonomy: Papilionoideae, Phaseoleae
Distribution: South Asia (Indian Subcontinent) South-East Asia

**ECOLOGICAL ADAPTATION**

| Pytochoria | Vegetation |
|---|---|
| Guinea-Congolian Reg. Cent. of Endemism | Forest |
| Guinea-Congolian Reg. Cent. of Endemism | Anthropic landscape |
| Zambezian Reg. Cent. of Endemism | Forest |
| Zambezian Reg. Cent. of Endemism | Bushland and thicket |
| Zambezian Reg. Cent. of Endemism | Wooded grassland |
| Sudanian Reg. Cent. of Endemism | Bushland and thicket |
| Sudanian Reg. Cent. of Endemism | Wooded grassland |
| Somalia-Masai Reg. Cent. of Endemism | Bushland and thicket |
| Somalia-Masai Reg. Cent. of Endemism | Wooded grassland |
| Guinea-Congolian/Sudanian Reg. Trans. Zone | Forest |
| Guinea-Congolian/Sudanian Reg. Trans. Zone | Anthropic landscape |
| Lake Victoria Regional Mosaic | Forest |
| Lake Victoria Regional Mosaic | Bushland and thicket |
| Lake Victoria Regional Mosaic | Wooded grassland |
| Lake Victoria Regional Mosaic | Anthropic landscape |

| | | |
|---|---|---|
| Precipitation range (mm/year) | : 650–3000 | Prec. opt.: 1000–2500 |
| Altitude range (m ab. sea lev.) | : 0000–2100 | Alt. Opt. : 0000–1600 |
| Temperature range (degr. cent.) | : 15–35 | Temp. opt.: 19–27 |
| Shade | : Highly tolerant | |
| Fire | : Susceptible | |
| Soil-pH range | : 04.5–07.7 | |
| pH optimum | : 05.0–07.0 | |
| Soil fertility requirement | : Low | |
| Soil-phosphorus requirement | : Low | |

Adapted to a wide range of soils of low fertility; P application stimulates growth and N fixation on P-deficient soils.

| | |
|---|---|
| Soil depth adaptation | : No data |
| Soil texture adaptation | : Sand to sandy clay |
| Tolerance to waterlogging | : Susceptible |
| Tolerance to drought | : Moderately tolerant |

## PLANT MORPHOLOGY

Growth type : Herb; Spreading/trailing or climbing

Spreading and vigorously climbing herb with twines up to 6m length; variety *utilis* is less hairy than many other accessions.

| | |
|---|---|
| Plant height (m) | : 0.30–0.80 |
| Root system | : No data |
| Nodal roots | : None |
| Seed size (g/1000 seed) | : 900.0–1100.0 |

## PLANT PHYSIOLOGY

| | |
|---|---|
| Life cycle | : Annual |
| Photosensitivity | : No data |

Growth cycle depends on variety; black seeded varieties require 5–6 months to maturity, white seeded varieties 4–5 months.

| | |
|---|---|
| Initial growth rate | : Moderate |
| Productive growth rate | : High nodulation |

Seed yields 250-1100 kg/ha; white and black seeded varieties available; seeds available from IITA.

## REPORTED PESTS

Foliage feeding insects : *Anticarsia gemnatalis*

Foliage pathogens : *Phytophthora drechsleri, Cercospora stizolobii, Mycosphaerella cruenta, Phyllosticta mucunae, Xanthomonas stizolobiicola*

Stem and root pathogens : *Rhizoctonia solani, Sclerotium rolfsii, Macrophomina phaseoli*

Pathogens reproductive parts: *Pseudomonas stizolobii*

Parasitic nematodes : *Meloidogyne hapla, Meloidogyne incognita, Meloidogyne javanica, Meloidogyne thamesi, Pratylenchus brachyurus, Rotylenchus reniformis*

## MANAGEMENT REQUIREMENTS

Legume planting : Rough seedbed preparation. Broadcasted on soil and incorporated. Seeds planted at row spacing of 90-180cm and intrarow spacing of 15-90 cm.

| | |
|---|---|
| Legume establishment | : Minor weeding |
| Productive phase | : None or minor |
| Legume maintenance | : Self-seeding<br>Slashing |

## PLANT PRODUCTS

| | |
|---|---|
| Vegetable for human nutrition | : Not used - Not used |
| Grain for nutrition (kg/ha) | : 0–500 |
| Grain protein content (%) | : 23–24 |
| Grain carbohydrate (%) | : 59–60 |
| Grain fat (%) | : 5–6 |
| Grain toxicity | : Moderate toxicity; Processing required |

Seeds of white seeded varieties can be used for human nutrition after lengthy boiling, roasting or fermentation to destroy toxic ingredient.

| | |
|---|---|
| Green fodder for livestock | : Low potential - Not useful |
| Hay for livestock (kg/ha) | : 0–2000 |

Green plant has low palatability and is rarely eaten by animals; provides hay; varieties with a reduced hairiness should be used for fodder and hay production in order to increase palatability to animals and to make handling easier; white seeded varieties tend to be less hairy and provide better fodder.

| | |
|---|---|
| Above ground biomass (kg/ha) | : 5000–7000 |

## CONTRIBUTION TO SOIL

| | |
|---|---|
| Increase of soil-N content | : High potential–Moderate potential |
| Control of soil erosion | : High potential–Moderate potential |
| Suppression of common weeds | : High potential–Moderate potential |

Highly contributing plant to soil fertility and pest control; it is used as a relay crop in maize by farmers in Benin Republic for the reduction of *Imperata cylindrica* in highly infested fields.

| | |
|---|---|
| Suppression of parasitic weed | : Trap crop for *Striga gesnerioides* |

Moderate stimulation of germination of *Striga gesnerioides* reported.

| | |
|---|---|
| Nematode suppression | : Trap crop for *Meloidogyne* root-knot |

Trap crop for *Pratylenchus* on cereals. General nematode suppression reported. Used as a rotation crop for the control of nematodes in maize in Brazil; reports on its reaction to *Meloidogyne* spp. are contradictory; resistance to *Meloidogyne incognita, M. javanica, M. arenaria* and *M. hapla* has been reported from Georgia, USA, for varieties Early Jumbo and Victor.

## SYSTEM INTEGRATION

| | |
|---|---|
| Planted in rotation with | : Cereals |
| Planted as a relay crop into | : Cereals |
| Simultaneous intercropping in | : Pastures |
| Short-cycled intercropping in | : No data |
| Extended intercropping with | : No data |

Used as improved fallow in rotation and relay with many other crops

**Annex 2 COVERCROPS (Kiff et al. 1996) database record for *Mucuna pruriens***

Species No:032
Species Scientific Name: MUCUNA PRURIENS
Alternate Names:

| | |
|---|---|
| MUCUNA PRURIENS VAR. DEERINGIANA | DOLICHOS PRURIENS |
| STIZOLOBIUM DEERINGIANUM | MUCUNA ESQUIROLII |
| MUCUNA COCHINCHINENSIS | MUCUNA PRURITA |
| STIZOLOBIUM PRURITUM | MUCUNA NIVEUM |

Common Names:

| | | |
|---|---|---|
| FLORIDA VELVET BEAN | DEERING VELVET BEAN | TERCIOPELO |
| FRIJOL DE ABONO | FRIJOL NESCAFE | CHINAPOPO |
| HARICOT DE VELOURS | QUENK MULA | FRIJOL DE MULA |
| VELVET BEAN | BUFFALO BEAN | COWITCH |
| FOGARATE | PICA-PICA | POIS VELU |

Purpose:

| | | |
|---|---|---|
| ANIMAL FEED | COVER CROP | GREEN MANURE |
| HUMAN FOOD | EROSION CONTROL | WEED SUPPRESSANT |

Human Food Potential:

| | | |
|---|---|---|
| PULSE | COFFEE | MEDICINE |

Livestock Feed Potential:

| | | |
|---|---|---|
| FORAGE | HAY | SILAGE |
| CONCENTRATE | | |

Origin:
Distribution: AFRICA, ASIA, AMERICAS, CARIBBEAN
Zone: SUB-TROPICS, SUB-HUMID TROPICS, HUMID TROPICS

| | | |
|---|---|---|
| Rain Lower: 650 | Rain Upper: | |
| Alt Lower: 0 | Alt Upper: 2100 | |
| Frost: SENSITIVE | Water: | Drought: |
| PH Range Lower: 4.5 | PH Range Upper: 7.0 | |
| Legume: Y | Rhizobium: NON-SPECIFIC | |
| Perennial/Annual: A | Inter Crop Suit: N | |
| Form: CLIMBING | | |

Seed Source:

| | | | |
|---|---|---|---|
| Col 1 | Indo 1 | USA 1 | Aust 1 |
| Eth 2 | C.Rica 1 | Hond 1 | Sing 1 |

Comments:
Seeds used as human food only in time of famine. Require long cooking time with many changes of water. Will grow on a wide range of soils, tolerant of some acidity. Suited to cooler climates than *Mucuna pruriens* var. *utilis*. Used to maintain soil moisture, restore degraded land (including land compacted by machinery) and to intensify the cropping system (long-fallow substitution). Elimination or suppression of noxious weeds, e.g., *Imperata, Rottboellia, Cyperus, Cynodon* spp.

**Annex 3 COVERCROPS (Kiff et al. 1996) database record for *Mucuna pruriens*.var. utilis**

---

Species No:033
Species Scientific Name: MUCUNA PRURIENS VAR. UTILIS
Alternate Names:

| | |
|---|---|
| MUCUNA PRURIENS | STIZOLOBIUM ATERRIMUM |
| MUCUNA ATERRIMA | MUCUNA CAPITATA |
| STIZOLOBIUM PRURIENS | STIZOLOBIUM HASSJOO |

Common Names:

| | | |
|---|---|---|
| BENGAL BEAN | MUCUNA | MUCUNE |
| TERCIOPELO | FRIJOL NESCAFE | CHINAPOPO |
| HARICOT DE VELOURS | QUENK MULA | FRIJOL DE MULA |
| KAFE GO BOUWO | MAURITIUS BEAN | PORTUGUESE COFFEE |
| VELVET BEAN | | |

Purpose:

| | | |
|---|---|---|
| ANIMAL FEED | COVER CROP | WEED SUPPRESSANT |
| EROSION CONTROL | GREEN MANURE | HUMAN FOOD |

Human Food Potential:
PULSE COFFEE

Livestock Feed Potential:

| | | |
|---|---|---|
| FORAGE | SILAGE | HAY |
| PASTURE | CONCENTRATE | |

Origin: SOUTHERN ASIA, MALAYSIA
Distribution: AFRICA, AUSTRALIA, N. AMERICA
Zone: SUB-HUMID TROPICS, HUMID TROPICS

| | | |
|---|---|---|
| Rain Lower: 650 | Rain Upper: 2500 | |
| Alt Lower: 0 | Alt Upper: 2100 | |
| Frost: SENSITIVE | Water: | Drought: |
| PH Range Lower: 4.5 | PH Range Upper: 7.0 | |
| Legume: Y | Rhizobium: NON-SPECIFIC | |
| Perennial/Annual: A | Inter Crop Suit: N | |
| Form: CLIMBING | | |

Seed Source:

| | | | |
|---|---|---|---|
| Col 1 | Ghan 2 | Indo 1 | Italy 1 |
| USA 1 | Eth 2 | RSA 1 | Hond 1 |

Comments:
Used as human food only in time of famine. Seeds require long cooking with repeated changes of water. Will grow on a wide range of soils. Tolerant of some acidity. Doesn't intercrop well as it tends to climb and strangle other plants. Used to maintain soil moisture, restore degraded land (including land compacted by machinery), intensify the cropping system (long-fallow substitution), suppression of noxious weeds, e.g., *Imperata*, *Rottboellia*, *Cyperus*, *Cynodon* spp.

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**Annex 4 Sources of mucuna seed, extracted from COVERCROPS (Kiff et al. 1996) database**

| Mailing Address | Telephone/Fax | Seed Availability |
|---|---|---|
| Germplasm Curator, CIAT, A.A. 6713, Cali, Columbia | 572 4450000/ 572 4450273 | Small samples Free |
| Dr. S.O. Bennett-Lartey, Head, Plant Genetic Resources Centre, CSIR, PO Box 7, Bunso, East Region, Ghana | | Small quantities Free |
| Seed Improvement and Production Group, Plant Genetic Information and Exchange Department, FAO, Via delle Terme di Caracalla, 00100 Rome, Italy | 39 6 52253783/ 39 6 52256347 | Small quantities Free |
| Mr. Stephen Kresovich, USDA-ARS, Regional Genetic Resources Conservation Unit, University of Georgia, 1109 Experiment Street, Griffin, GA 30223-1797, USA | 404 2287207/ 4042293323 | Small quantities Free |
| Dr. Jean Hanson, Head, Forage Genetic Resources Unit, ILRI, P.O. Box 5689 Addis Ababa, Ethiopia | 251 1 613215/ 251 1 611892 | Small quantities Free |
| Centre for Research and Development in Biology, Jalan Raya Bogor, Km 46, Cibinong, Indonesia | 021 8754587/ 021 8754588 | Unspecified quantities, Free |
| Grassland Research Centre, Department of Agricultural Development, Private Bag X05, Lynne East, 0039 Pretoria, South Africa | 012 8080805/ 012 8082155 | Unspecified quantities, Free |
| Dr. Milton Flores, CIDICCO, A.P. 4443, Tegucigalpa MDC, Honduras | 504 32 7471/ 504 32 741 | Large quantities Seed and freight charged |
| Dr. J.B. Hacker, Project Leader, Australian Tropical Forages Genetic Resources Centre, CSIRO, GPO Box 1600, Canberra City, ACT 2061 | 07 377 0209/ 07 371 3946 | Small quantities Free |
| Phytogenetic Resources Unit, CATIE 7170, Turrialba | 556 64 31/ 556 15 33 | Unspecified quantities, Free except for mailing |
| Mr. Samuel Ratman, Director, Inland and Foreign Trading Co., Block 79A, Indus Road 04-418/420, 0316 Singapore | 2722711/ 2716118 | Any quantity, Commercial |

**Annex 5 Technical guide on establishment of mucuna fallow from Sasakawa Global 2000 project in Benin and Togo (translated from French)**

1. **For Weed Control**

1.1 *Field partially infested by* imperata

If a maize crop is possible, then sow mucuna 45 days after sowing maize at a mucuna density of 0.8 m by 0.8 m (1 seed per planting hole). [Note: This should be at second weeding so the mucuna seed is planted in rows between the maize rows in a clean seedbed.]

1.2 *Field highly infested by* imperata *or sedges*

- Slash vegetation at the beginning of the rainy season
- Sow mucuna at a spacing of 0.8 m by 0.8 m (1 seed per planting hole)
- After one month, slash again if necessary. If the mucuna has started to spread and to twine around the *imperata*, then slashing will damage the mucuna and should not be done.
- During the dry season, make a fire break around the plot. It is advisable to burn the vegetation in surrounding plots early in the dry season.
- If mucuna seed is needed for future work, then harvest the pods after drying and before shattering.

2. **For soil fertility improvement**

- Sow mucuna in rows between maize rows 45 days after sowing maize as above.
- If the field is needed for a second season maize crop, then incorporate the mucuna biomass during ridging.
- To avoid burning the mucuna biomass, make a fire break around the plot at the end of the rainy season.
- Harvest the mucuna pods after drying and before shattering.

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| 2. | Cropping Systems and Agroeconomic Performance of Improved Cassava in a Humid Forest Ecosystem. Felix I. Nweke, Humphrey C. Ezumah, and Dunstan S. C. Spencer | June 1988 |
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|---|---|---|
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