July/Juillet 1998

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Contributing *to* Sustainable Agriculture

Plantes *de* couverture *en* Afrique *de l'*Ouest
Une contribution *à* *l'*agriculture durable

Edited by/sous la direction de
D. Buckles, A. Etèka, O. Osiname, M. Galiba and/et G. Galiano

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Published jointly by
International Development Research Centre, PO Box 8500, Ottawa, ON, Canada K1G 3H9
International Institute of Tropical Agriculture, Oyo Road, PMB 5320, Ibadan, Nigeria
Sasakawa Global 2000 — Bénin, 04 BP 1091, Cotonou, Benin

Legal deposit: 2nd quarter 1998
National Library of Canada
ISBN 0-88936-852-X

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The catalogue of IDRC Books may be consulted online at http://www.idrc.ca.

This book may be consulted online at http://www.idrc.ca/books/focus.html.

Publié conjointement par
Centre de recherches pour le développement international, BP 8500, Ottawa (Ontario) Canada K1G 3H9
Institut international d'agriculture tropicale, Oyo Road, PMB 5320, Ibadan, Nigeria
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Dépôt légal : 2^e trimestre 1998
Bibliothèque nationale du Canada
ISBN 0-88936-852-X

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Foreword

Widespread depletion and degradation of soil resources contribute to food insecurity, limit efforts to alleviate poverty, and constrain human development in much of sub-Saharan Africa (SSA). This region supports more than 500 million people, and the population continues to increase by about 3% per year. Yet, in contrast to the situation in most other regions of the world, SSA's per capita agricultural production continues to decline, and soil degradation is a leading cause of this decline. The International Soil Reference and Information Center of the United Nations Environment Programme estimated that by 1991, for Africa as a whole, 5×10^6 ha of productive land had been degraded to the point that rehabilitation was not economically feasible. In addition, some 321×10^6 ha of crop land had been moderately to severely degraded. About 174×10^6 ha currently shows signs of falling production.

In 1997, the United Nations Development Programme reported that in 1993 SSA had the highest incidence of poverty in the world, with 38% of the population, or 220 million people, each living on less than 1 United States dollar per day. Given current demographic and population trends, this level of poverty will affect more than half of the population by 2000. The majority of Africa's poor dwell in rural areas and depend on subsistence agriculture. Women carry out most of the small-scale farming. Collectively, they account for most of the food production. However, they suffer disproportionately from poverty and have inadequate access to the financial resources, technologies, and knowledge that would enable them to restore productivity on their farms. The International Development Research Centre (IDRC), many other international development and research organizations, nongovernmental organizations, and national governments greatly emphasize the need to arrest soil degradation, restore soil productivity, and alleviate poverty in SSA.

IDRC's primary channel for addressing land degradation in Africa and the Middle East is its People, Land and Water (PLAW) program initiative. PLAW's goal is to promote equitable, sustainable, and productive use of land and water resources by rural women and men in stressed ecosystems of Africa and the Middle East to enhance their income, food, and water security. This goal is pursued through research that will lead to better management of the systemic and external factors in both the degradation and the improvement of the productive capacity of land and water resources. PLAW supports the development of local and national policies and institutional arrangements to equitably increase access to and availability and quality of land and water resources. Along with other program initiatives within IDRC, PLAW encourages the exchange of information among stakeholders, with the particular intention of fostering participation of local people in their own development. Through IDRC's research activities, the rural poor become familiar with a range of options for better managing their soils, thereby improving their standard of living.

The many technological approaches to improved soil management include methods for erosion control and the use of intercropping and inorganic fertilizers, including locally available rock phosphates. Nutrient capture and N fixation remain important topics for study. Recently, some investigators shifted their focus from the simplistic provision of soil nutrients for crops uptake to a more holistic understanding of the structure and function of the myriad of physical and biotic components of the soil system. Central to this theme is the management of soil organic matter and associated N fixation through technologies such as using compost, crop residues, animal manure, biomass, ramial chipped wood, improved fallows, hedgerow intercropping (or alley farming), and cover crops.

This publication focuses on the potential of cover crops to maintain and improve soil fertility in SSA. Often in isolation, African researchers have experimented with cover cropping, but the results have not been readily accessible to colleagues and farmers. This book documents past experience with cover crops in Africa, and IDRC hopes it will stimulate future research on socioeconomic and biophysical aspects of this important topic. IDRC anticipates that cover cropping, along with an appropriate mix of other relevant technologies and policies, will eventually lead to improved soil productivity in a number of farming systems.

Don Peden
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Préface

La dégradation générale des sols et leur épuisement contribuent à l'insécurité alimentaire, limitent les efforts de réduction de la pauvreté et restreignent le développement humain dans la majeure partie de l'Afrique sub=saharienne. La région compte plus de 500 millions d'habitants, et la population continue d'y augmenter d'environ 3 % par année. Pourtant, contrairement aux autres régions du monde, la production agricole par habitant continue de baisser, et la dégradation du sol en est une des principales raisons. Le Centre international de référence et d'information pédologique du Programme des Nations Unies pour l'environnement estime que depuis 1991, 5×10^6 ha des terres productives de toute l'Afrique se sont dégradés à un point tel que la réhabilitation n'est plus économiquement faisable. En outre, quelque 321×10^6 ha de terres cultivables ont subi une dégradation de modérée à grave et 174×10^6 ha montrent actuellement des signes de baisse de production.

En 1997, le Programme des Nations Unies pour le développement a signalé qu'en 1993, l'Afrique sub=saharienne affichait le plus haut taux de pauvreté au monde, 38 % de sa population, soit 220 millions d'habitants, comptant sur moins d'un dollar américain par jour pour assurer leur subsistance. En raison des tendances démographiques actuelles et des mouvements de la population, ce niveau de pauvreté touchera plus de la moitié de la population d'ici l'an 2000. La majorité des Africains pauvres habitent des secteurs ruraux et vivent d'une agriculture de subsistance. Les femmes s'occupent de pratiquement toutes les tâches liées à cette agriculture de petite échelle. Ensemble, elles sont responsables de la presque totalité de la production agricole. Elles souffrent toutefois de façon disproportionnée de la pauvreté et n'ont pas l'accès voulu aux ressources financières, à la technologie ou au savoir qui leur permettraient d'améliorer la productivité de leur ferme. Le Centre de recherches pour le développement international (CRDI), et un bon nombre d'autres organismes de recherche et de développement, d'organisations non gouvernementales et d'administrations gouvernementales nationales se préoccupent grandement de la nécessité de mettre fin à la dégradation des sols, de les rendre productifs à nouveau et d'alléger la pauvreté en Afrique sub=saharienne.

Le CRDI compte principalement sur l'initiative de programme Des gens, des terres et de l'eau (GTE) pour contrer la dégradation des sols en Afrique et au Moyen-Orient. Cette initiative vise à promouvoir l'exploitation équitable, durable et productive des ressources en sols et en eaux par les femmes et les hommes des secteurs ruraux dans les écosystèmes perturbés de l'Afrique et du Moyen-Orient, et ainsi améliorer leur sécurité en eau, en aliments et en revenus. On cherche à atteindre cet objectif au moyen d'une recherche qui permettra une meilleure gestion des facteurs systémiques et externes touchant à la dégradation et à l'amélioration de la capacité de production des ressources en eaux et en sols. L'initiative GTE favorise l'élaboration de politiques locales et nationales, de même que des ententes avec des institutions pour accroître l'accès équitable et la disponibilité des ressources en terres et en eaux de bonne qualité. Au même titre que d'autres initiatives de programmes du CRDI, l'initiative GTE veut contribuer à l'échange d'information entre les intervenants, et tout particulièrement encourager la participation des gens du milieu rural à leur propre développement. Grâce aux activités de recherche du CRDI, les pauvres gens du milieu rural s'initient à une variété de moyens qui leur permettent de mieux gérer leurs sols, et améliorent ainsi leur mode de vie.

Les nombreuses solutions technologiques à l'amélioration de la gestion des sols comprennent des méthodes de contrôle de l'érosion ainsi que l'utilisation de cultures intercalaires et de fertilisants inorganiques, dont les phosphates naturels que l'on trouve sur place. La saisie d'éléments nutritifs et la fixation du niveau d'azote demeurent d'importants sujets d'étude. Récemment, l'attention de certains enquêteurs s'est déplacée du simple approvisionnement en éléments nutritifs du sol à des fins de récolte vers une compréhension plus globale de la structure et de la fonction d'une multitude d'éléments physiques et biotiques du système des sols. Ce thème a pour élément central la gestion de la matière organique du sol et la fixation du niveau d'azote associé par le truchement de technologies telles que l'utilisation de compost, de residus de récoltes, d'engrais organiques, de la biomasse, de bois raméal fragmenté, de meilleures jachères, de cultures intercalaires en couloirs (ou cultures en bande) et de plantes de couverture.

Cette publication porte en particulier sur les possibilités des plantes de couverture en vue de maintenir et d'améliorer la fertilité des sols en Afrique sub=saharienne. Souvent de façon isolée, des chercheurs africains ont expérimenté des plantes de couverture, mais les résultats n'ont pas été communiqués à des collègues ou aux agriculteurs. Cet ouvrage documente les expériences passées en matière de plantes de couverture en Afrique. Le CRDI espère qu'il encouragera de nouvelles recherches sur les aspects socio-économiques et biophysiques de cet important sujet. Le CRDI prévoit que les plantes de couverture, assorties d'une combinaison appropriée d'autres techniques et politiques, permettront d'en venir à une productivité accrue des sols dans un certain nombre de systèmes agricoles.

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Introduction

Agricultural productivity in sub-Saharan Africa (SSA) must be increased substantially in the next decade to avert a serious food crisis. Since the 1970s food production across much of the region has not kept pace with population growth. This has led to increased pressure on the land, a decline in soil fertility, and accelerated desertification on marginal soils.

Efforts to revive agricultural productivity in SSA must deal with the degraded soils in many parts of Africa. Decades of cropping without fallow have decreased soil fertility, reduced levels of soil organic matter (OM), and acidified soils. In southern Benin, for example, where the red Ultisols of the Allada Plateau have been intensively farmed, OM content has dropped in 23 years from 2.6% to 0.8%; pH has fallen from 5.8 to 4.8; and maize yields have plummeted from an average of 1 500 kg ha^{-1} to 400 kg ha^{-1}. Weeds have invaded the land, which is now so hard to farm that some people refer to it as comatose.

Soil degradation and weed infestation are so severe in many areas that fast recovery will almost certainly rely on some external inputs, such as chemical fertilizers. Where external inputs are expensive or their availability is limited, green-manure cover crops (GMCCs), grown on site, can help to maximize the benefits of external inputs. GMCCs are efficient, low-cost sources of N. They improve soil structure, increase the soil's biological activity, and help to control pests. A major advantage of GMCCs is their capacity to control noxious weeds such as *Imperata cylindrica* that are choking out crops in many regions. The biomass generated by GMCCs can also be used as feed for animals, helping to create incentives to control wild fires that damage cropland. Evidence from West Africa presented in this collection suggests that GMCCs help to revive degraded land and to sustain intensive agricultural practices.

Much of the recent experimentation with GMCCs has been by developing-world farmers in nonmechanized farming systems. Of note is the experience of Central American farmers with *Mucuna* spp., an aggressive Asian legume now widespread in the humid tropics. In Guatemala, northern Honduras, and southern Mexico, more than 30 000 small-scale farmers have been using *Mucuna* spp. as a GMCC for decades, a practice only recently documented (Bunch 1993; Buckles 1995; Arteaga et al. 1997; Flores 1997; Buckles et al. 1998). In the southern

Brazilian states of Paraná, Rio Grande do Sul, and Santa Catarina, more than 125 000 small- and medium-scale farmers use several different GMCCs to improve soil fertility, control weeds, and grow forage and feed for animals (Calegari et al. 1997). Traditional and innovative improved fallow systems, sometimes involving GMCCs, are appearing in many Southeast Asian countries (Cairns 1997). The success of these systems is motivating scientists to initiate cover-crop research and disseminate practical, farmer-tested information to other parts of the world.

In the West African Republic of Benin, thousands of farmers are now using *Mucuna* spp. to rehabilitate fields formally abandoned because of degraded soils or excessive *I. cylindrica* infestation. Other legumes have also been used successfully by farmers in drier regions of Africa, such as Mali. They include *Dolichos lablab* and *Stylosanthes hamata*, used to improve pasture, and *Aeschynomene histrix*, used as a rotational crop to combat *Striga* and improve pasture.

Farmer experience with GMCCs shows that local people are not passive in the face of resource problems — no matter how poor they are, they are by necessity engaged in seeking solutions. Latin American, Southeast Asian, and West African farmers have been remarkably creative with GMCCs, developing and circulating a wide range of cropping practices. A lesson to be learned from this experience is that researchers should closely examine local strategies for improving land management and, if appropriate, build on them through action research.

The papers presented in this collection provide the elements needed to develop a strategy for research and promotion of GMCCs in West Africa. At the initiative of Canada's International Development Research Centre (IDRC), a regional workshop was organized jointly by Sasakawa Global 2000 (SG 2000), the International Institute of Tropical Agriculture (IITA), and the Ministry of Rural Development in Benin, with funding from IDRC and SG 2000. Held at the IITA station in Cotonou, Benin, from 1 to 3 October 1996, the workshop brought together more than 60 people to discuss the constraints and opportunities presented by GMCCs in West Africa (Appendix 1). The workshop had the following objectives:

- To exchange information and experiences on the use of GMCCs by farmers;
- To identify the major constraints facing small farmers in adopting GMCC-related technologies; and
- To identify priorities for action and research.

During the workshop, participants went on a field trip to see how Benin's farmers were making use of GMCCs in three southern provinces (Atlantique, Mono, and Ouémé). Participants visited fields of *Mucuna* spp. that had been planted by farmers, sometimes with help from the Regional Action Centre for Rural Development (the national extension service of Benin), SG 2000, the National Agricultural Research Institute of Benin, or IITA. Participants also visited test sites of other GMCCs at the research stations of IITA–Benin, the National Farm Training Centre, the Regional Agricultural Research Centre at Niaouli, and the National Soil Centre at Agonkanmey. This was followed by a day of presentations of research and extension experience with GMCCs.

Working groups were established during the workshop to discuss priorities for actions and research. One of the priorities identified was the need for region-specific information on farmer experience with GMCCs. Another was the need to access seeds of a wide range of GMCC species and varieties. Access to appropriate information and seeds was recognized as a major bottleneck to further development and testing of improved GMCC systems.

After the workshop, with support from IDRC, IITA established the Centre d'information et d'echanges sur les plantes de couverture en Afrique (CIEPCA, centre for information and exchange on cover crops in Africa), which is based in Cotonou, to facilitate the flow of information and seeds in the region. A workshop participant from each country was identified to serve as a facilitator, with CIEPCA's coordination, for diffusion of GMCC seeds.

The working groups also noted the need to develop GMCC systems with multipurpose applications. The field visits and presentations had indicated that farmer acceptance of *Mucuna*-fallow practices in Benin was due in large part to *Mucuna*'s dual impacts on soil fertility and weeds. Even farmers with very small land holdings opted to dedicate some of their field to a *Mucuna* fallow, often the most weed-infested portion, with a view to improving it for the following season. This and other farmer-based experience suggests that GMCCs have the greatest potential for adoption when several serious constraints are affecting system productivity.

Although weed infestation and soil degradation are clearly serious constraints on agricultural productivity in West Africa, farmers are still reluctant to plant GMCCs on all their fields because they compete with edible or cash crops. A further complication is that an increase in soil fertility with GMCCs is often unnoticed by the farmer in the short term. GMCCs with food or forage uses are clearly needed if adoption is to become widespread.

Because some promising GMCCs, such as *Mucuna* spp. and *Canavalia ensiformis*, are already used in Ghana as a minor food ingredient (Osei-Bonsu et al. 1995), the workshop participants called for an assessment of the safety of large-scale *Mucuna* consumption. Results of a recent assessment (Lorenzetti et al., this volume) build on a workshop presentation (Versteeg et al., this volume) on a technique for processing *Mucuna* flour for use in pâte, a common West African staple food (*wo* in the Fon language [southern Benin], *akumin* in the Mina language [southern Benin and Togo], *amala* in the Yoruba and Tchabe languages [central Benin and Nigeria]). This use of *Mucuna* has the potential to significantly boost its adoption as a multipurpose crop, although further testing of acceptability is needed before general recommendations can be made.

Forage uses of GMCCs were also identified as key to the development of successful multipurpose practices, especially in the drier regions where livestock is the mainstay of many rural households. Experiences with forage uses of *D. lablab* (Mali) and *S. hamata* (Nigeria) were reported during the workshop and examined more closely in a commissioned follow-up study.

That study (Tarawali et al., this volume) and papers by Vissoh et al. (this volume) and Lorenzetti et al. (this volume) were also presented at the International Workshop on Green-Manure Cover Crop Systems for Smallholders in Tropical and Subtropical Regions, in Chapeco, Santa Catarina, Brazil, 6–12 April 1997. This workshop was organized by the Rural Extension and Agricultural Research Institute of Santa Catarina; the Rockefeller Foundation; the International Cover Crop Clearing House; Cornell University; the Association of Consultants for a Sustainable, Ecological and Humanistic Agriculture; the Gesellschaft für Technische Zusammenarbeit (organization for technical cooperation) Soil Conservation Program; the International Maize and Wheat Improvement Center; and IDRC.

The Benin and Brazil workshops have highlighted the actual and future contribution of GMCCs to sustainable agriculture. The presentations on West Africa at these workshops were developed further in written form, reviewed, and edited for this collection. The papers and the abstracts that follow them are presented in the language in which they were written — English or French — and complemented with an abstract in the other language. We believe this unique collection will both stimulate and orient further research and help to develop an agenda for actions to address Africa's pressing soil-degradation problems.

The Workshop Proceedings Committee

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Introduction

Il faut augmenter sensiblement la productivité agricole en Afrique subsaharieene dans les 10 prochaines années, si l'on veut éviter une grave crise alimentaire. Depuis les années 1970, presque partout dans la région, la production vivrière n'a pas suivi la croissance démographique. Il en résulte des pressions accrues sur les terres, une fertilité amoindrie des sols et une désertification accélérée de terres marginales.

Pour relancer la productivité agricole en Afrique subsaharieene, il faut traiter les sols dégradés de nombreuses régions d'Afrique. Des décennies de culture sans jachères ont fait perdre de sa fertilité au sol, qui s'est de plus appauvri en matières organiques (MO) et acidifié. Dans le sud du Bénin, par exemple, où les ultisols rouges du plateau d'Allada ont été cultivés intensivement, la teneur en MO est passée de 2,6 % à 0,8 % en l'espace de 23 ans, tandis que le pH a baissé de 5,8 à 4,8 et le rendement du maïs a chuté de 1 500 kg ha^{-1} à 400 kg ha^{-1}, en moyenne. Les mauvaises herbes ont envahi les terres, qui sont tellement difficiles à cultiver maintenant que certains parlent de sols « comateux ».

La dégradation des sols et la prolifération des mauvaises herbes sont tellement graves dans certaines régions que le rétablissement rapide dépendra fort probablement d'apports extérieurs tels que des engrais chimiques. Lorsque ces apports sont chers ou limités en quantité, les plantes de couverture et les engrais verts (PCEV), cultivés sur place, peuvent aider à en maximiser les avantages. Les PCEV sont des sources de N peu coûteuses et efficaces qui améliorent la structure des sols, accroissent leur activité biologique et aident à lutter contre les parasites. Ils ont pour grand avantage, notamment, de limiter l'apparition des mauvaises herbes nuisibles telles que l'*Imperata cylindrica*, qui étouffent les cultures dans bien des régions. La biomasse créée par les PCEV peut aussi être utilisée pour nourrir les animaux, ce qui encourage également à lutter contre les feux de friches qui abîment les terres labourables. Les données concernant l'Afrique de l'Ouest présentées dans cette collection donnent à penser que les PCEV contribuent à redonner vie aux terres dégradées et permettent de soutenir des cultures intensives.

Les expériences récentes d'utilisation de PCEV sont le fait, pour la plupart, d'agriculteurs de pays en développement qui appliquent des systèmes d'agriculture paysanne. L'utilisation par des agriculteurs d'Amérique centrale du *Mucuna* spp., une légumineuse asiatique agressive maintenant très répandue dans les régions tropicales humides, est à noter à cet égard. Dans le nord du Honduras, au Guatemala et dans le sud du Mexique, plus de 30 000 petits exploitants utilisent le *Mucuna* spp. comme PCEV depuis des dizaines d'années, ce qui n'est documenté que depuis peu (Bunch 1993 ; Buckles 1995 ; Artaega *et al.* 1997 ; Flores 1997 ; Buckles *et al.* 1998). Dans les États méridionaux du Brésil que sont le Paraná, le Rio Grande do Sul et Santa Catarina, plus de 125 000 agriculteurs cultivant des exploitations de petite ou de moyenne superficie utilisent actuellement plusieurs PCEV pour améliorer la fertilité du sol, lutter contre les mauvaises herbes et obtenir pâture et fourrage (Calegari *et al.* 1997). Des systèmes de jachères améliorés, traditionnels et novateurs, dans lesquels interviennent parfois des PCEV, font leur apparition dans de nombreux pays d'Asie du Sud-Est (Cairns 1997). Le succès de ces systèmes incite les scientifiques à entreprendre des recherches sur les cultures de couverture et à diffuser dans d'autres régions du monde des informations pratiques, éprouvées auprès d'agriculteurs.

En République du Bénin, État d'Afrique de l'Ouest, des milliers d'agriculteurs utilisent à présent le *Mucana* spp. pour remettre en état des champs auparavant abandonnés parce que le sol en était dégradé ou envahi par l'*I. cylindrica*. Les agriculteurs de pays plus secs d'Afrique, comme le Mali, utilisent avec succès d'autres légumineuses, dont le *Dolichos lablab* et le *Stylosanthes hamata*, qui permettent d'obtenir de meilleures pâtures, et l'*Aeschynomene histrix*, qui s'emploie en culture de rotation afin de combattre la *Striga* et d'améliorer les pâtures.

Le fait que les agriculteurs recourent aux PCEV montre que les populations locales ne restent pas passives face à des problèmes de ressource et qu'aussi pauvres soient-elles, elles recherchent des solutions par la force des choses. Les agriculteurs d'Amérique latine, d'Asie du Sud-Est et d'Afrique de l'Ouest font preuve d'une créativité remarquable par rapport aux PCEV. Ils ont mis au point et fait connaître diverses pratiques agricoles. Il ressort de cette expérience que les chercheurs devraient examiner attentivement les stratégies locales utilisées pour améliorer la gestion des terres et, si nécessaire, les renforcer par le biais de recherches actives.

Les articles présentés dans cette collection fournissent les éléments nécessaires pour élaborer une stratégie de recherche et de promotion des PCEV en Afrique de l'Ouest. À l'initiative du Centre de recherches pour le développement international (CRDI) du Canada, un atelier régional a été organisé conjointement par Sasakawa Global 2000 (SG 2000), l'Institut international d'agriculture tropicale (IIAT) et le ministère du Développement rural du Bénin, avec un financement du CRDI et de SG 2000. Cet atelier, qui s'est déroulé à la station de l'IIAT à Cotonou, en République du Bénin, du 1er au 3 octobre 1996, a réuni plus de 60 personnes qui ont examiné les contraintes et les possibilités présentées par le PCEV en Afrique de l'Ouest (Annexe 1). L'atelier avait pour objectif :

- de communiquer des renseignements et de faire part d'expériences sur l'utilisation des PCEV par les agriculteurs ;

- de cerner les principales contraintes auxquelles sont confrontés les petits exploitants qui souhaitent adopter des technologies se rapportant aux PCEV ;

- de définir les mesures à prendre en priorité et les besoins sur le plan de la recherche.

Au cours de l'atelier, les participants se sont rendus sur le terrain afin de voir comment les agriculteurs béninois de trois provinces méridionales (Atlantique, Mono et Ouémé) utilisent les PCEV. Les participants se sont rendus dans des champs que les agriculteurs avaient planté de *Mucuna* spp., soit seuls soit avec l'aide des institutions de développement ou de recherche suivantes : le Centre d'action régionale pour le développement rural (organisme national de vulgarisation béninois), SG 2000, l'Institut national de la recherche agricole du Bénin et l'IIAT. Les participants se sont également rendus dans les stations de recherche de l'IIAT au Bénin, au Centre national de formation agricole, au Centre régional de recherche agricole de Niaouli et au Centre national des sols d'Agonkanmey, afin de voir les terrains sur lesquels d'autres PCEV sont mis à l'essai. Puis il y a eu une journée de présentations de recherches et d'expériences de vulgarisation concernant les PCEV.

Des groupes de travail ont été formés pendant l'atelier afin d'étudier les mesures à prendre en priorité et les besoins en matière de recherche. Ainsi, les participants ont estimé qu'il fallait en priorité disposer, à l'échelle régionale, de renseignements sur les expériences des agriculteurs avec les PCEV. Ils ont estimé aussi que les agriculteurs devaient avoir accès à des semences de diverses espèces et variétés de PCEV. L'accès à des renseignements pertinents et aux semences voulues était considéré comme étant essentiel à la poursuite de l'amélioration des meilleurs systèmes de PCEV et, notamment, des essais nécessaires.

Après l'atelier et avec l'appui du CRDI, l'IIAT a créé le Centre d'information et d'échanges sur les plantes de couverture en Afrique (CIEPCA), qui a son siège à Cotonou, afin de faciliter la diffusion des renseignements et la distribution des semences dans la région. Une personne-ressource de chacun des pays représentés à l'atelier a été chargée de distribuer des semences de PCEV sous la coordination du CIEPCA.

Les groupes de travail ont également fait remarquer qu'il est nécessaire de mettre au point des systèmes de PCEV polyvalents. Il est apparu, durant les visites de champs et dans les exposés, que, si les agriculteurs béninois acceptent la pratique des jachères plantées de *Mucuna*, c'est surtout parce que cette plante a une incidence sur la fertilité des sols et sur les mauvaises herbes. Même les agriculteurs qui cultivent de tout petits lopins de terre en réservent une partie à une jachère plantée de *Mucuna*, souvent celle qui est le plus envahie par les mauvaises herbes, afin que le terrain soit meilleur à la saison suivante. Cette pratique, entre autres, donne à penser que c'est sans doute dans des conditions qui leur permettent de remédier simultanément à plusieurs contraintes sérieuses sur la productivité des systèmes que les PCEV présentent sans doute le plus grand potentiel.

La prolifération des mauvaises herbes et la dégradation des sols nuisent manifestement beaucoup à la productivité agricole en Afrique de l'Ouest, mais les agriculteurs continuent d'hésiter à utiliser des PCEV dans leurs champs parce qu'ils y font concurrence à des cultures consommables ou commerciales. De plus, à court terme, l'agriculteur remarque rarement l'amélioration de la fertilité des sols apportée par les PCEV. Il est évident que, pour en faciliter l'adoption générale, il faut pouvoir proposer des PCEV pouvant servir d'aliment ou de fourrage.

Certaines PCEV, comme le *Mucuna* spp. et la *Canavalia ensiformis*, étant déjà utilisés au Ghana comme ingrédients alimentaires secondaires (Osei-Bonsu *et al.* 1995), les participants à l'atelier ont demandé une évaluation de l'innocuité de la consommation de *Mucuna* à grande échelle. Les résultats d'une évaluation récente sont présentés ici (Lorenzetti *et al.*, présent volume). Ils reposent sur des travaux de recherche sur une technique de traitement de la farine de *Mucuna* avec le but de l'employer dans *pâte*, un aliment de base courant en Afrique d'Ouest (*wo* en dialecte fon [sud du Bénin], *akumin* en dialecte mina [sud du Bénin et Togo], *amala* en dialecte yoruba et tchabé [centre du Bénin et Nigéria] dont les résultats ont été exposés à l'atelier (Versteeg *et al.*, présent volume). Cette utilisation du *Mucuna* pourrait faciliter grandement l'adoption de cette plante pour une culture polyvalente, encore que des analyses plus poussées soient nécessaires quant à sa palatabilité, avant que quiconque puisse formuler des recommandations générales.

Par ailleurs, les groupes de travail ont également estimé que les utilisations fourragères des PCEV sont essentielles au développement de pratiques polyvalentes fructueuses, tout particulièrement dans les régions plus sèches où le bétail est le principal soutien de beaucoup de ménages ruraux. Il a été fait état pendant l'atelier d'expériences d'utilisation du *D. lablab* (Mali) et de la *S. hamata* (Nigeria) comme fourrage (Tarawali *et al.*, présent volume) et ces expériences ont été étudiées de plus près dans une étude de suivi qui a été demandée.

Celle-ci et les travaux de Vissoh *et al.* (présent volume) et Lorenzetti *et al.* (présent volume) ont également été présentés à l'atelier international sur les plantes de couverture et les engrais verts pour les petits exploitants des régions tropicales et subtropicales, qui s'est tenu à Chapeco, dans l'État de Santa Catarina, au Brésil, du 6 au 12 avril 1997. Cet atelier était organisé par l'institut de vulgarisation rurale et de recherche agronomique de l'État de Santa Catarina, par la Fondation Rockefeller, l'International Cover Crop Clearing House, l'Université Cornell, l'Association of Consultants for a Sustainable, Ecological and Humanistic Agriculture, le Gesellschaft für Technische Zusammenarbeit (organisation pour la coopération technique), le Programme de conservation des sols, le Centro Internacional de Mejormiento de Maíz y trigo (centre international d'amélioration du maïs et du blé) et le CRDI.

Les ateliers du Bénin et du Brésil ont mis en lumière la contribution actuelle et future des PCEV à l'agriculture durable. Les présentations de recherches et d'expériences de développement en Afrique de l'Ouest ont ensuite fait l'objet d'exposés écrits, qui ont été révisés avant d'être intégrés dans cette collection. Les documents et les résumés indépendants sont présentés dans la langue dans laquelle ils ont été écrits, c'est-à-dire en anglais ou en français, et complétés par un résumé traduit. Nous pensons que ce recueil unique stimulera et orientera plus encore la recherche future et aidera à élaborer un programme de mesures visant à remédier aux problèmes pressants causés par la dégradation des sols sur le continent africain.

Le Comité du compte rendu de l'atelier

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Experiences with *Mucuna* in West Africa[1]

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Abstract

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

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

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[1]Paper presented at the International Workshop on Green-Manure Cover Crop Systems for Smallholders in Tropical and Subtropical Regions, 6–12 Apr 1997, Chapeco, Brazil.

Résumé

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

Le *Mucuna* a été adopté pour la première fois au sud-ouest de la République du Bénin, où les chercheurs et les vulgarisateurs ont testé la technologie avec les paysans de 1988 à 1992. Compte tenu des résultats encourageants, les services de vulgarisation ont commencé à disséminer le *Mucuna* à un grand nombre de paysans. Pensant que cette technologie pourrait résoudre les problèmes des paysans dans d'autres régions d'Afrique de l'Ouest, nous avons décidé d'étudier le problème de l'adoption au Bénin pour connaître les conditions nécessaires à son adoption. Nous avons d'abord introduit le *Mucuna* dans une région ayant une forte densité de population rurale, où la pression foncière ne permettait plus la pratique de longues jachères pour restaurer la fertilité et réduire l'infestation des adventices. L'élimination du chiendent (*Imperata cylindrica*) était vue comme un avantage principal pour la jachère avec le *Mucuna* et a ainsi créé des possibilités pour l'adoption de la technologie. Sur la base des expériences paysannes et de la recherche, la diffusion de la jachère avec le *Mucuna* ne sera efficace que là où la fertilité des sols baisse, les engrais inorganiques sont chers, les adventices nocives, comme le chiendent, affectent de façon dramatique les productions des paysans et où les organisations de développement ont d'excellents contacts avec les paysans. L'adoption semble être stimulée par les nouveaux débouchés pour les semences du *Mucuna*. Les zones ayant de longues périodes de campagne agricole (7 mois ou plus) pourraient aussi être concernées. D'autres débouchés pour les jachères avec le *Mucuna* pourraient exister, tel que le besoin de fourrage supplémentaire pour le bétail ou le besoin de réduire le *Striga* ou les colonies de nématodes dans les systèmes intensifs de culture de céréales.

Introduction

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

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

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

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

Characteristics of the West African farming environment

Climate, soil, and biophysical characteristics

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

Soil conditions determine the intensity of cropping, the need for fallowing, the varieties of crops that can be grown, and the risk of drought (Mutsaers et al. 1986). Major soils are Alfisols in the savanna areas and Oxisols or Ultisols in the humid areas (Jones and Wild 1975). The Food and Agriculture Organization of the United Nations (see Manyong et al. 1996b) classified the major soil units of Africa as high fertility (very suitable), moderate fertility (suitable), and low fertility (requires major improvements or not suitable) (Figure 2). Manyong et al.

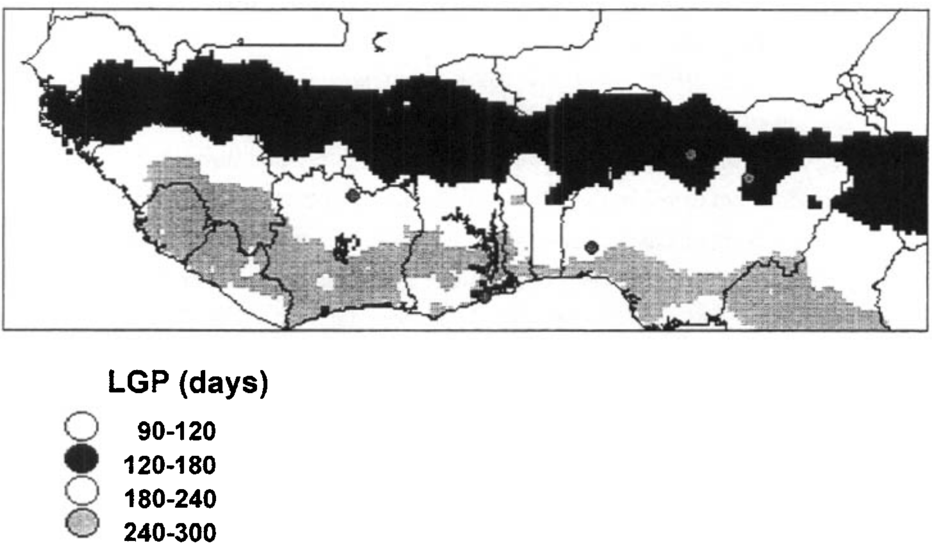

Figure 1. Major agroecological zones in West Africa, based on length of growing period (LGP). Source: Resource Information System, IITA (Jagtap 1995).

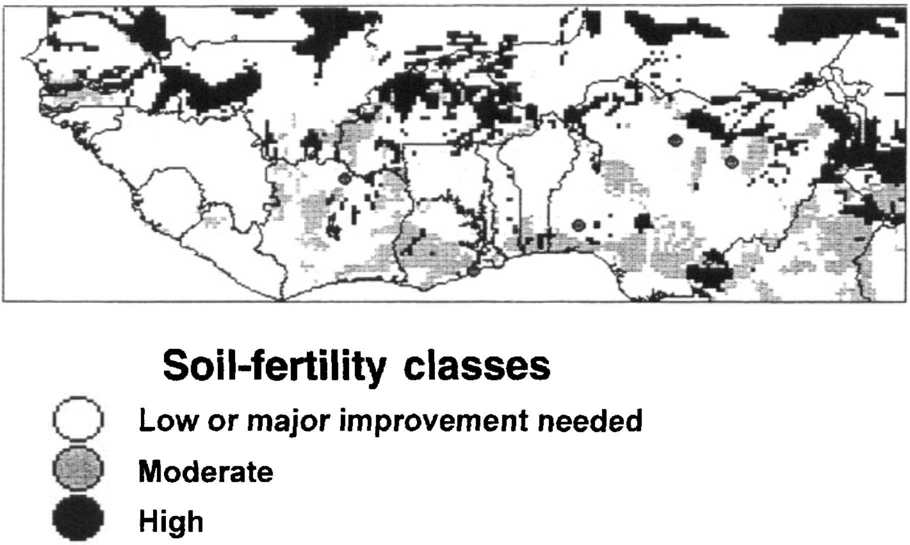

Figure 2. Soil-fertility classes in West Africa. Source: Adapted from FAO (1978, cited by Manyong et al. 1996b), Resource Information System, IITA (Jagtap 1995).

(1996b) calculated that soils in the first two categories — that is, those fertile enough to support crops — occupy only 24% of West Africa. The remaining 76% of soils in West Africa can be characterized therefore as poor, requiring judicious use of fertilizers, organic-matter (OM) management, and erosion control. Soil-improvement measures, such as agroforestry, minimum tillage, grass strips, and cover crops with herbaceous legumes, are needed to allow sustainable use of the soil resource.

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

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

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

Socioeconomic conditions of smallholders

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

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

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

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

Farming systems of smallholders

Agricultural practices in West Africa are highly diverse and far from static. Farming systems are often a mixture of crop and livestock enterprises. Cattle and sheep dominate livestock holdings in the drier areas; goats and poultry, in the more humid. Fencing is not widespread, and crops and animals commonly compete.

Cattle are important as providers of manure and draft power, but these are important elements of the farming systems only in the semi-arid and drier SHZs of Nigeria (von Kaufmann and Blench 1990) and elsewhere in West Africa. In these areas, animal traction is mostly used for land preparation and some weed control. In the rest of the region, manual land preparation dominates.

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

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

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

Some properties of *Mucuna*

According to the Food and Agriculture Organization of the United Nations (FAO 1982), Weber et a6l. (1997), and Kiff et al. (1996), *Mucuna* is adapted to a broad range of precipitation (optimum range of 1 000–2 500 mm a^{-1}) and elevation

(0–1 600 m asl). It tolerates a relatively narrow range of temperatures (19–27°C) but is still adapted to most of the humid zones and SHZs of West Africa. Osei-Bonsu and Buckles (1993) reported that *Mucuna* performs well in the forest and the forest–savanna transition zones of Ghana (bimodal precipitation pattern). In Benin, as in Côte d'Ivoire, Ghana, Nigeria, and Togo, *Mucuna* grows better in areas with a bimodal rainfall regime.

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

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

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

Mucuna-management systems in Benin

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

Sole-crop short fallow

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

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

Intercrop with maize

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

Adoption of *Mucuna* in southwestern Benin

Characteristics of the zone and the country

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

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

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

- Oil-palm–maize-based systems, found in the south, have oil palm, maize, cassava, cowpea, and groundnut as the major crops. Fire is used to clear land, and hoeing is common. Little or no fertilizer is used, and traditional crop varieties are grown. Major field problems are weeds (*I. cylindrica*), insects, and soil fertility. Oil palm is used for fallow between food-crop cycles and for the production of economic goods, such as firewood, animal feed, palm oil, palm wine, and whiskey (Kang et al. 1991). A typical farm size is less than 1 ha, and the cropping intensity is very high (67–80%). Trading is very important as a source of cash.

- Maize–cassava- and maize–yam-based systems are found in the moist SHZ in the middle of Benin. The major crops are maize, cassava, yam, cotton, and cowpea. Fire is used to clear land, and hoeing is common, although animal traction is increasingly used in places where cotton is important. Fertilizer and improved crop varieties are more commonly used because of support from cotton-development companies. A typical farm size is 1–3 ha, and the cropping intensity is low to moderate (23–50%).

- Yam-, cotton-, and sorghum–millet-based cropping systems dominate in the dry SHZ and semi-arid zones to the north. Cattle are important there and are used as a source of traction and manure in mixed farming, but conflicts arise when the cattle of nomadic herders damage crops. Fertilizer is available to cotton farmers. Because of lower population density, farm sizes are larger and cropping intensity is low, unless farmers use fertilizers or animal manure.

Introduction of *Mucuna* and its adoption

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

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

The government extension services — which included each Regional Action Centre for Rural Development (RACRD) of MRD — became interested in this success and started testing the system with farmers. In 1990, the RACRD for Mono province tested the system with 180 farmers in 12 more villages (Versteeg,

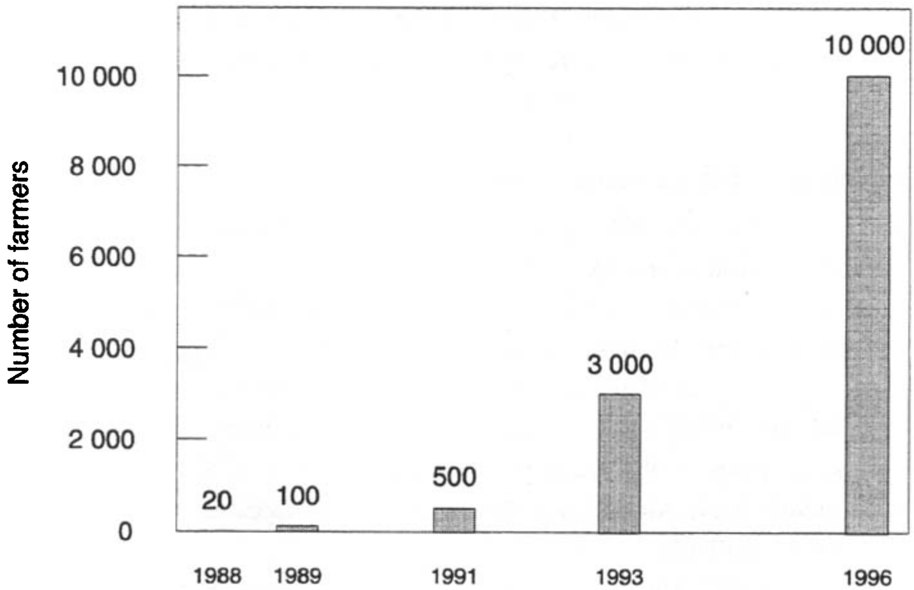

Figure 3. Estimated number of farmers testing *Mucuna* in Benin in recent years. Source: Versteeg and Koudokpon (1990), IITA (1991, 1993), and Galiba et al. (this volume).

personal communication, 1991[2]). These efforts were extended to other southern provinces in 1991, and the number of farmers testing *Mucuna* grew to about 500 (IITA 1991). Large NGOs got involved, and the estimated number of farmers testing *Mucuna* was 3 000 in 1993 (IITA 1993) and nearly 10 000 throughout Benin in 1996 (Figure 3).

Determinants of adoption in southwestern Benin

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

Field characteristics had the most influence on adoption. The most important determinant (positively related to adoption) was the number of weeding operations farmers had needed before they began the *Mucuna* testing. If fewer than three weeding operations were required, then *Imperata* was not felt to be a serious

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

problem, as farmers normally weeded twice anyway. But three, four, or five weeding operations were often needed to reduce damage from *Imperata*. If more than five weedings were required, then *Imperata* was left in the field, cut off, and sold in the market as roofing material.

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

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

Dissemination of *Mucuna* in Benin

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

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

Despite the many possibilities for *Mucuna* use, two simple but effective approaches were recommended: *Mucuna* in pure stands or improved fallow and

Mucuna in relay with maize, both described above. Pure stands were recommended to improve degraded soil and to reduce spear-grass infestation when it was serious enough to cause farmers to abandon the field to fallow.

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

SG 2000 has repeatedly purchased *Mucuna* seeds from collaborating producers to expand the diffusion of the technology. This also constitutes an incentive for small-scale farmers to adopt *Mucuna*, as a market for seeds adds value to the

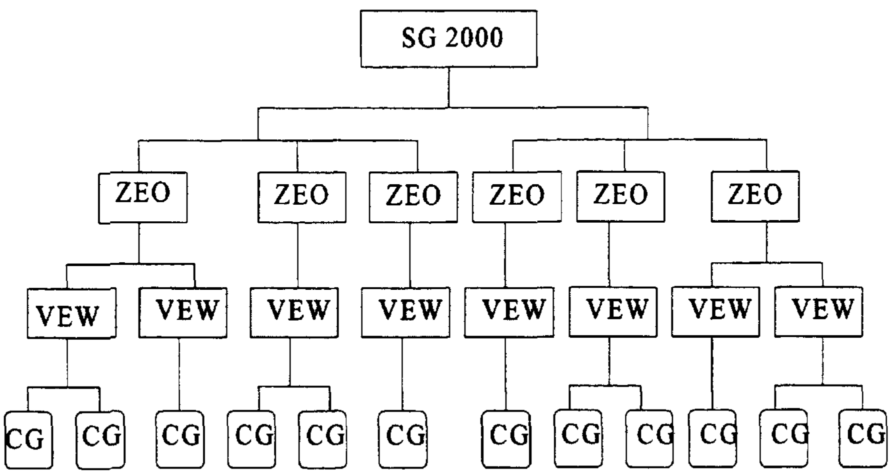

Figure 4. Organizational chart showing how Sasakawa Global 2000 disseminated *Mucuna* technology in Benin through the government's extension services. Source: Galiba et al. (this volume). Note: CG, contact group or other farmers; SG 2000, Sasakawa Global 2000; VEW, village extension worker; ZEO, zone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

crop. It may turn out to be an artificial incentive if the market for *Mucuna* seeds becomes saturated, but this strategy was clearly justified at the outset.

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

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

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

- Cropping land is abundant in the northern provinces, where the population density is quite low (<25 people km^{-2}). *Imperata* is not much of a problem in the drier zones.

- Farmers in the north specialize in cotton production, and they have access to chemical fertilizers from the cotton companies.

- The north has a single rainy season of 4–6 months. Late relay planting does not allow *Mucuna* to accumulate much DM or to produce seed.

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

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

Agronomic benefits of *Mucuna* use

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

Agronomic benefits from *Mucuna* use have not often been extensively measured, but Versteeg and Koudokpon (1990, 1993) reported maize-grain yield increases on farmers' fields of about 500 kg ha^{-1} for a local maize variety and about 800 kg ha^{-1} for an improved variety, following 1 year of fallow with *Mucuna*. In researcher-managed trials on farmers' fields in central Ghana (bimodal rainfall), Osei-Bonsu and Buckles (1993) observed that average maize-grain yields on fields that previously had *Mucuna* were 3–4 kg ha^{-1}, without application of fertilizer-N, which is similar to yields normally obtained with recommended levels of fertilization (130 kg N ha^{-1}). Grain yield on plots previously planted with maize and cowpea was 1.3 t ha^{-1}. Osei-Bonsu and Buckles estimated that *Mucuna* as an intercrop or as a sole crop provided an equivalent of more than 100 kg N ha^{-1} to

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

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

Source: Adapted from Akobundu and Poku (1984); Akobundu and Udensi (1995).
Note: Initial density, 100 shoots m^{-2}.

the following maize. This is similar to an amount Sanginga et al. (1996) estimated for the bimodal-rainfall zone of southwestern Nigeria. Codjia (1996) observed 98% higher maize yields after a *Mucuna* short fallow without chemical-fertilizer application and a 179% increase with 51 kg N, 46 kg P, and 28 kg K ha^{-1}. Thus, for high maize yields, *Mucuna* residue should be supplemented with moderate amounts of inorganic fertilizer.

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

Osei-Bonsu (unpublished data) found that 13.8 t ha^{-1} of dry mulch, with a thickness of 12.6 cm, was accumulated by *Mucuna* after a fallow of two seasons

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

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

Source: Hulugalle et al. (1986).
Note: DM, dry matter.
[a] Compared with maize–cowpea; effects are expressed as percentage differences compared with cropped control. Porosity was measured at 0- to 10-cm depth; penetrometer resistance, at 5- to 7-cm depth.
[b] After 3 h.

in the bimodal-rainfall zone of central Ghana. He estimated 4.1 million earthworm casts ha^{-1}, weighing 21.6 t ha^{-1}, under the mulch and only 1.3 million casts ha^{-1}, weighing 3.6 t ha^{-1}, for plots planted with cowpea.

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

Agronomic aspects of seed production

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

Mucuna-residue-management systems

Mucuna-residue management has been the subject of some research because labour input is very much affected by management of the often voluminous residue.

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

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

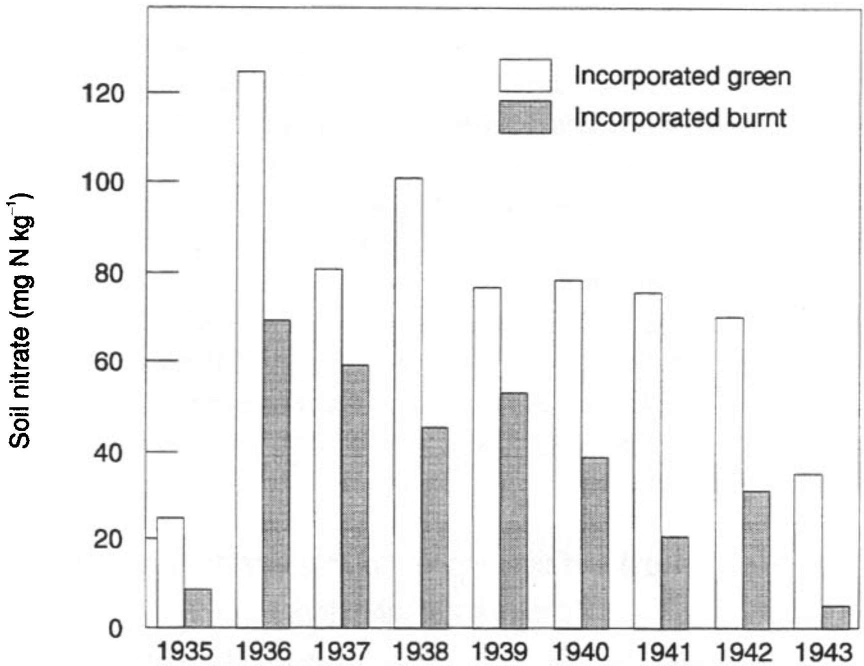

Figure 5. Effect of *Mucuna*-residue management on levels of nitrate in surface soil at Moor Plantation at the time of maize planting. Source: Vine (1953).

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

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

Source: Manyong et al. (in preparation).
Note: MRR, marginal rate of return; USD, United States dollars.
[a] Only maize seeds are sold.
[b] Both maize and *Mucuna* seeds are sold.

Economic evaluation of *Mucuna* use

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

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

Although the current rate of adoption of *Mucuna* fallowing by smallholders in Benin is promising, its acceptance as a profitable agricultural practice faces many constraints. Knowledge of these can be helpful to agricultural researchers trying

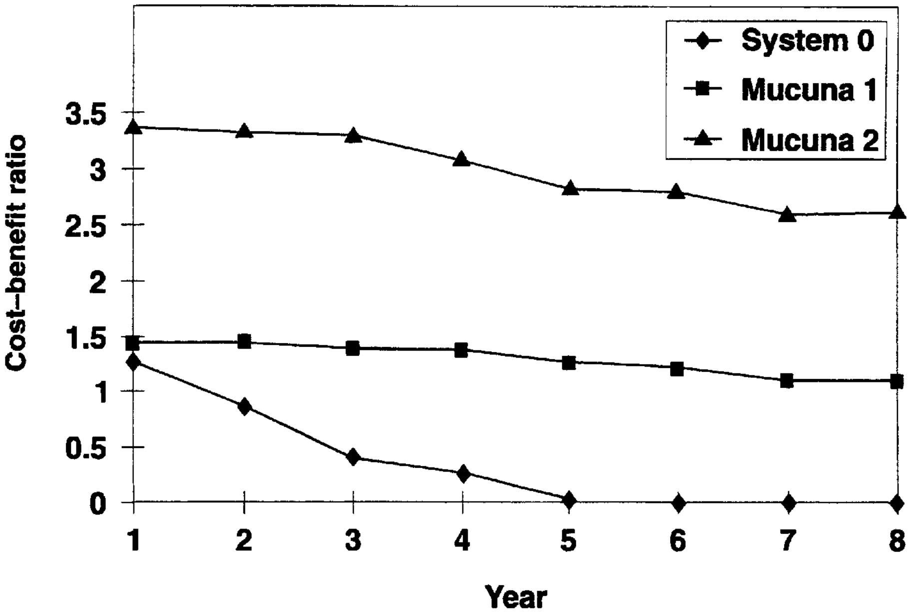

Figure 6. Trend in the benefit–cost ratio for systems without (system 0) and with *Mucuna* (*Mucuna* 1 and *Mucuna* 2), in Mono province, Benin. Note: system 0, existing system; *Mucuna* 1, only maize grain is sold; *Mucuna* 2, both *Mucuna* and maize grain are sold.

to develop improved systems and local adaptations with farmers, as well as to extension efforts in other countries.

Land scarcity

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

Land-tenure system

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

Toxicity of grain for human and animal consumption

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

Fire

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

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

Limited range of associated crops

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

Disease incidence

Although *Mucuna* has generally been free from pests and diseases in West Africa, outbreaks may occur with repeated use of the cover crop. For example, after many years of *Mucuna* rotation at the IITA farm in southwestern Nigeria, a disease outbreak occurred that was identified as *Macrophomina phaseolina* by Berner et al. (1992). It reduced ground cover and biomass drastically. Similarly, it was reported that after repeated *Mucuna* fallows, a buildup of knot nematodes is possible (Wilson and Lal 1986). Therefore, a large number of varieties of *Mucuna* and other cover crops should be collected and maintained. Although many species of *Mucuna* are known (Wilmot-Dear 1992), only *M. pruriens* var. *utilis* and *M. pruriens* var. *cochinchinensis* have been tested in Benin, Nigeria, Togo, etc. IITA, the West African Rice Development Association, the International Institute for Land Reclamation and Improvement, and various national agricultural research systems maintain several varieties of *Mucuna* and small quantities of many other cover-crop and fallow species.

Perspectives for adoption of *Mucuna* elsewhere in West Africa

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

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

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

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

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

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

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

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

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

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

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

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

Some additional research is still required on

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

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

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[3]M. Versteeg, IITA, Ibadan, Nigeria, personal communication, 1996.

Conclusion

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

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

Acknowledgments

The authors are grateful to IDRC for financial support to enable them to participate in the International Workshop on Green Manure-Cover Crop Systems for Smallholders in Tropical and Subtropical Regions, Chapeco, Santa Catarina, Brazil, 6–12 April 1997. Special thanks also are due to D. Buckles for his contribution and for outlining the salient points discussed in this case study.

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Collaboration to increase the use of *Mucuna* in production systems in Benin

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Abstract

In 1987, the leguminous cover crop *Mucuna pruriens* var. *utilis* was introduced on researcher-managed demonstration fields for novel technologies. The objective was to address the serious soil-fertility decline on the Adja Plateau in southern Benin. But farmers were more impressed by the ability of *Mucuna* to control the rampant weed *Imperata cylindrica* and requested seeds to use for their own experimentation. However, a clear soil-fertility bonus became highly visible, and this aspect was further explored by farmers with seriously depleted ("comatose") fields. Extension services and nongovernmental organizations, such as Sasakawa Global 2000, accelerated the spread of this dual-purpose technology to meet a 1995 target of having 100 000 farmers know about *Mucuna*. Adoption studies and econometric analyses carried out during 1993–95 indicated that the most important factor driving adoption was control of the *Imperata* weed. Eight more factors contributed significantly: three related to field characteristics, that is, soil fertility, clay content, and presence of young palms; four, to the farmer, that is, age, land-security situation, possession of fallow reserves, and contact with extension services; and one, to the technology, that is, farmers' reluctance to use the technology for regular soil-fertility management because it would result in unproductive fields during the short rainy season.

The farmers' reluctance stimulated researchers to look for ways to overcome this handicap. They set up trials to rotate maize–*Mucuna* relay crops with more conventional crop combinations in alternate years and began looking for ways to make *Mucuna* grains economically useful. Through interregional contacts, it was revealed that Ghanaian farmers regularly used small quantities of *Mucuna* grains in their daily food. This led us to investigate ways to promote consumption of larger quantities of *Mucuna* in flour preparations that are acceptably free of toxic substances and easily incorporated into staple dishes, as substitutes for maize flour. We found that cracking the seeds, soaking the cracked seeds overnight, boiling them for 20 min, and soaking them again overnight lowered the level of L-Dopa (the main toxic factor) from about 6% to about 0.4%. This is well below a threshold level of 1% for regular consumption of *pâte*, the most consumed staple dish in southern Benin and Togo. However, toxicologists recommend several more toxicological tests for other possible antinutritional factors before the flour is launched for large-scale consumption. Observation trials using *Mucuna* grains for animal feed for pigs and goats are under way in Benin, but no results are available yet. Other niches for *Mucuna* adoption were observed in northern Benin: use of *Mucuna*–maize relay crops for hay production (adopted by many Fulani herdsman around Nikki in eastern Borgou province) and for *Striga* control.

The essential impact of farmer interaction on the course of experimentation, results, and adoption is also highlighted in this paper.

Résumé

L'histoire du *Mucuna* a commencé en République du Bénin en 1987, lorsque le *Mucuna pruriens* var. *utilis* a été introduit aux paysans du village de Zouzouvou sur le plateau Adja. Bien qu'au départ le *Mucuna* ait été présenté aux paysans pour restaurer la fertilité des sols, ceux-ci ont été plus impressionnés par la capacité de cette plante à étouffer le chiendent (*Imperata cylindrica*). En une saison, le *Mucuna* semé en association avec le maïs de 3 à 4 semaines après le semis du maïs a ramené la densité du chiendent de 270 plantes m^{-2} à 32 plantes m^{-2}. La capacité du *Mucuna* à restaurer la fertilité du sol était également évidente. Le rendement grain du maïs produit après l'utilisation du *Mucuna* était de 70 % plus élevé que le témoin sans *Mucuna*. Les perspectives d'adoption de la technologie du *Mucuna* se sont accrues grâce à deux facteurs : (1) la rotation des cultures maïs–*Mucuna* avec les combinaisons conventionnelles pendant des années alternées, étant donné que la culture du *Mucuna* sur un terrain ne permet pas l'utilisation de ce terrain pendant la seconde saison de pluie ; et (2) le développement des méthodes de réduction de la substance toxique L-dopa contenue dans les graines de *Mucuna*, pour accroître la valeur nutritionnelle pour les hommes et les animaux. La production du *Mucuna* et la suppression de l'infestation de *Striga* dans les chanps sont les nouvelles voies pour son adoption dans le nord du Bénin.

Introduction

In 1987, *Mucuna* (*Mucuna pruriens* var. *utilis*) was introduced to farmers in the village of Zouzouvou, Benin, by the International Institute of Tropical Agriculture (IITA), the Royal Tropical Institute of the Netherlands, and the National Agricultural Research Institute of Benin (NARIB), as one of the possible low-input technologies to counter declining soil fertility in Mono province, southern Benin. Zouzouvou was chosen by the researchers because its problems were representative of most common agricultural problems of a key ecological zone in the region. Since then farmers have rapidly picked up this attractive dual-purpose technology that enriches the soil and effectively smothers the noxious weed *Imperata cylindrica*, which widely infests many fields in the region. Since 1990 Benin's Regional Action Centres for Rural Development (RACRDs), in close collaboration with the nongovernmental organization (NGO) Sasakawa Global 2000 (SG 2000), have accelerated this spontaneous adoption process. The target for 1995 was to reach 100 000 farmers all over Benin. Even so, several indications show that *Mucuna*'s propensity to leave the field unproductive during the second, short rainy season will hamper regular use of *Mucuna*. This paper describes the environment in which the use of *Mucuna* started and discusses the *Mucuna* story as it has developed and is still evolving in Benin.

The environment

Benin has an erratic bimodal rainfall that peaks in June and October and averages about 1 100 mm $year^{-1}$. This pattern allows for a long growing season (mid-April to the end of July) and a more variable, short one (September–November) and makes it possible to grow two annual crops of intermediate or short duration, such as maize, cowpea, or groundnut. Crops of longer duration, like cassava and cotton, are usually mixed or relay cropped with a crop of shorter duration. The dominant soil is sand to sandy loam, locally known as *terre de barre*, classified as Sol Ferralitique Appauvri according to the INRA–ORSTOM system (Institut national de la recherche agronomique – Office de la recherche scientifique et technique d'Outre-Mer). It resembles a degraded Ultisol and has a pH of around 6.0. The research was done mainly on the Adja Plateau, which has a high population density (200–350 persons km^{-2}).

The traditional system of restoring soil fertility, based on a 12- to 15-year densely planted oil-palm fallow (800–1 500 trees ha^{-1}), is economically attractive because, at clearance, the trees yield palm wine, which is usually distilled into marketable *Sodabi* liquor. However, demographic pressure has shortened the oil-palm fallow period to such an extent that soil recovery is barely taking place, and decline in soil fertility is a major concern (Kang et al. 1991). Analyses of such fields invariably show low organic C (0.8 ± 0.4%), low K (0.15 ± 0.05 meq 100 g^{-1}), and low cation-exchange capacity (5.6 ± 1.1 meq 100 g^{-1}) (Kater, unpublished results[1]).

For sustainable soil-fertility management, small mineral-P and -K inputs to compensate for nutrient losses from harvests and leaching are indispensable. Because most farmers have very limited financial resources, they cannot afford fertilizer treatments to keep the nutrient balance neutral. This aspect is not covered in this paper; the results presented are averages from farmers' unfertilized controls and from fields with minimal mineral amendments equivalent to 100 kg "cotton

[1]Kater, International Institute of Tropical Agriculture, personal communication, 1996.

fertilizer" ha^{-1} ($N–P_2O_5–K_2O$, 14 : 23 : 14); this fertilizer is usually the only available P–K source in most regions of Benin.

The short-season *Mucuna*-mulch technology

The short-season *Mucuna*-mulch technology consists in seeding velvetbean (*Mucuna pruriens* var. *utilis*) in relay with tall crops of short to intermediate duration, such as maize. *Mucuna* is planted about 5 weeks after the maize is sown, as earlier planting provokes smothering of the young maize plants by the aggressively developing *Mucuna*, resulting in serious yield losses. After the maize harvest, the legumes rapidly cover the field, producing a significant amount of aerial-canopy biomass, which smothers weeds and is converted into 6–12 t ha^{-1} organic manure (dry weight) for the following year's first-season maize. Legumes such as *Mucuna* and *Canavalia* are easy to establish, but the technology precludes the growing of ordinary food or cash crops during the second season.

Farmers' experiences with the *Mucuna* cover-crop technology

In 1987, *Mucuna* was sown, alongside other novel technologies like alley farming and live-mulch cropping, in a village demonstration field on the Adja Plateau to monitor effects on soil fertility. Farmers were, however, most impressed by *Mucuna*'s ability to smother the rampant spear-grass weed (*I. cylindrica*). The next year, 15 farmers asked the on-farm research team for seeds to test on their own *Imperata*-infested fields. Most of these completely farmer-managed trials confirmed *Mucuna*'s value as a weapon against spear grass. It reduced the density of spear grass from 270 plants m^{-2} to 32 plants m^{-2} (−88%; Dovonou 1994). Fields that otherwise needed an estimated 60–80 person–days ha^{-1} to eliminate the weed now needed only a fraction of that labour.

Mucuna's ability to restore fertility to the soil also proved to be very important: a 70% higher maize yield was obtained with maize following *Mucuna* than under monoculture maize (Figure 1).

Even in some very depleted fields, where maize yields had been almost nil, *Mucuna* seemed to perform much better than other legumes, such as *Leucaena* and pigeon pea. This observation prompted researchers to recommend *Mucuna* to farmers as an option for recovery of completely depleted soils. Farmers who chose *Mucuna* saw their maize yield increase from 0.48 t ha^{-1} to 1.14 t ha^{-1} (Figure 2).

Even before these results were measured, other farmers began joining the ranks of the *Mucuna* planters, attesting to its growing word-of-mouth popularity as a weapon against *Imperata* and as a soil improver. In 1990, the RACRD did

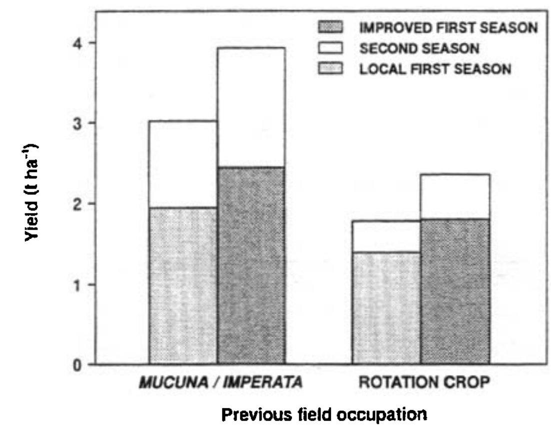

Figure 1. Effect of previous field occupation on maize yield.

a preextension test involving 180 farmers in 12 villages. The results were so satisfactory that *Mucuna* was taken up as a general extension solution for depleted soils or soil invaded by *Imperata*. In 1992, the RACRDs, in collaboration with SG 2000, established demonstration plots nationwide, with several hundred farmers. This process progressed exponentially during the succeeding years, and the goal was to reach more than 100 000 farmers by 1995, grouping them around 10 000 farmers with observation fields.

The efforts of the government's development centres and this development NGO will undoubtedly accelerate the exposure of farmers to *Mucuna*. Nevertheless, in the long run, success in establishing this agricultural practice will depend

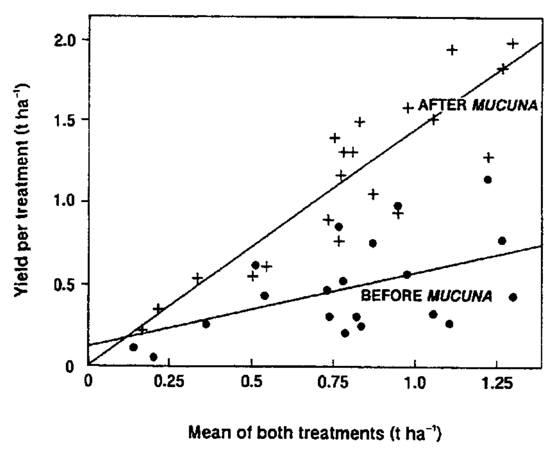

Figure 2. Maize yield before and after introduction of *Mucuna*. Note: •, yield of depleted fields (average, 0.48 t ha^{-1}); +, yield after regeneration with *Mucuna* (average, 1.14 t ha^{-1}).

on whether the farmers who adopt the technology continue using it. To get a better understanding of the adoption process, a researcher from NARIB, in close collaboration with IITA's Savannah Program, began a survey of nearly 280 farmers in four villages in 1993, aimed to reveal

- The actual uses of *Mucuna* in the area where it was first introduced;
- The magnitude of *Mucuna* adoption in this area;
- The processes that influence the diffusion of the *Mucuna* technology;
- The impact of *Mucuna* on Benin's agriculture; and
- The characteristics of zones with favourable conditions for *Mucuna* adoption.

So far, the first three investigations have been completed. From a subsample of 143 farmers who tried *Mucuna* at least once, a rather modest 24% were found to be "confirmed adopters" (defined as farmers using *Mucuna* twice or more to solve either a spear-grass or a soil-fertility problem). This percentage was lower than the calculated 35% who were "confirmed rejecters" (defined as farmers who used *Mucuna* once but did not use it again within 2 or more years, although they still had the problem in their fields). From both the survey and subsequent econometric analyses, it was determined that the most important factor in the adoption of *Mucuna* is its capacity to reduce or eliminate the spear grass in the field.

The econometric studies revealed eight more significant factors positively or negatively influencing adoption: three factors related to the field, that is, soil-fertility status, clay content, and the presence of young palms liable to be smothered by *Mucuna*; four factors related to the farmer, that is, land-security situation, age, possession of fallow reserves, and contacts with extension services; and one characteristic of the technology itself, that is, the fact that *Mucuna* precludes the use of the land for economic output during the second rainy season. The latter stimulated researchers to look for ways to overcome this problem. One possible solution considered was to rotate maize–*Mucuna* relay crops with more conventional crop combinations in alternate years, using small amounts of mineral inputs derived from cheap sources, such as the fine phosphate fraction of the Togolese phosphate mines, and inexpensive KCl fertilizer. Another possible solution was to make *Mucuna* grains economically useful as, for instance, animal feedstuffs or human food.

The prospects for the consumption of *Mucuna* grain

The success of *Mucuna* in Benin attracted visitors to Mono province from many other places in Africa, and several returned home with seeds to introduce *Mucuna* in their own countries. In one case, this resulted in an interesting and important example of farmer–researcher interaction. When Ghanaian researchers from Kumasi were presenting the Beninese *Mucuna* seeds to farmers in Ghana, they were told that the same bean (called *adua apia* in local Ashanti language) was regularly used in common sauce and stew preparations. Some of these Ghanaian researchers eventually remembered having eaten *adua apia* when they were growing up in their native villages. This discovery was communicated to the researchers in Benin (Osei-Bonsu et al. 1996), who then went with some Adja farmers to Ghana to observe the magnitude of *Mucuna* consumption by the Ashanti farmers and to learn the recipes. Preparation is critical, as the seed contains a toxic chemical, 3-(3,4-dihydroxyphenyl)-L-alanine (Levodopa, or L-Dopa), which can induce acute psychosis. Infante et al. (1990) reported an outbreak of this occurring among 200 people in Mozambique. On the other hand, *Mucuna*'s protein content is high (around 26%), and its quality is comparable to that of soybean (Ravindran and Ravindran 1988). Ghanaian farmers explained that grains were cracked and then boiled for 20–60 min and that the cooking water was thrown away before the seeds were ground up for the sauce or stew. The Beninese farmers, as well as the researchers, appreciated the taste of several *Mucuna* sauces and stews; the taste was similar when these were also prepared with Beninese grains.

Although *adua apia* is eaten regularly in soups and stews by many farmers in the forest and transition zones, *Mucuna* seeds are used in very small quantities (8–20 seeds per preparation), a consumption rate that would not put much of a dent in the large amount of seed produced in the maize–*Mucuna* system in Benin (200–600 kg ha^{-1}).

Additional information on the preparation of *Mucuna* as food came from Mexico. Researchers at the International Maize and Wheat Improvement Center who were studying experiences with *Mucuna* in Mesoamerica (Buckles 1993, 1995) contacted the researchers in Benin and helped them to obtain a recipe for making *Mucuna* flour (Derpsch and Florentin 1992) and to make contact with the Judson College laboratory in Illinois, which has extensive experience in L-Dopa determinations.

Box 1. Procedure for preparing detoxified *Mucuna* flour.

1. First day

Thoroughly crack dry *Mucuna* seeds. This can be done by hand, grain by grain, with the help of a stone or hammer (a very time-consuming operation). Alternatively, it can be done using the village mill, leaving the opening of the milling stones quite wide. (This goes very quickly and thoroughly breaks the seeds. The use of the mill results in about 5–7% loss of flour, but this can be collected and used as a protein additive in feed for goats, poultry, or pigs.)

Remove the cracked or broken seeds from the larger skin particles and put the seeds in a pot with ample water, leaving them to soak overnight.

2. Second day

Throw the water away. Wash the seeds in clean water. Remove loose seed coats and put the seeds in a pot with fresh ample water. Heat this new water, plus decoated beans, until it boils and keep it thoroughly boiling for at least 20 min. Leave the pot on the dying fire, with the grains soaking in the hot water until it has cooled to room temperature. Throw the water away. Wash the grains again and leave them once more in a pot of fresh ample water to soak overnight.

3. Third day

Throw the water away. Wash the soaked grains again and dry them in the sun. When the grains are completely dry (usually after 23 d), winnow them from the remaining seed-coat particles and grind the cleaned seeds to flour.

Using the village mill to crack the seeds, we obtained net *Mucuna* flour yields of about 50% of the dry weight of the *Mucuna* grains.

Note: Use old clothes during the work with the *Mucuna* seeds, as we found that soaked seeds and splashes of soaking water left brown–black stains on tissues, which we were unable to clean afterwards.

First results by Myhrman (Myhrman, unpublished results[2]) indicated a limited variability (4.7–6.4%) in the L-Dopa content of *Mucuna* from Benin, Ghana, Mexico, and the southern United States. Flour was produced in Benin according to a South American recipe based on toasting dry seeds. Taste tests were carried out with *pâte* (the main staple dish in southern Benin) in which one-third of the maize flour had been replaced with *Mucuna* flour. Farmers appreciated the *pâte*, as well as porridge that was also made from the flour. However, the L-Dopa content of this *Mucuna* flour was still far higher than the calculated 1% threshold for twice daily *Mucuna pâte* consumption.

Researchers in Benin made a new flour from boiled *Mucuna* grains. Significant progress was made by cracking the seeds, soaking the cracked seeds overnight (to fill the cell structures with water), boiling them for 20 min (to destroy the cell walls of the swollen cells), and soaking them again overnight (to allow the

[2]R. Myhrman, Director, World Hunger Resource Center, Judson College, Elgin, IL, USA, personal communication, 1996.

toxic substances to diffuse into the water). A description of this procedure is given in Box 1.

This procedure dramatically decreased the L-Dopa content to 0.32–0.42%, well below the 1% threshold. Furthermore, *pâte* prepared with one-third *Mucuna* flour had an even lower L-Dopa content (0.08–0.10%) (Table 1). Boiling the seeds for more than 20 min did not improve the results. However, to complete the preparation of the dish, 40–45 min of heating is required in addition to boiling; hence, heating time totals at least 1 h. Incorporation of detoxified flour in daily *pâte* would thus require more heating time for food preparation, which would require more fuelwood. This would be a gender issue, as the burden of collecting extra fuelwood would fall mainly to women. Nevertheless, the use of *Mucuna* flour would free up a significant amount of maize, which may be sold easily to provide more money for the household.

Flour from *M. pruriens* var. *cochichinensis* had a significantly lower L-Dopa content than that from *M. pruriens* var. *utilis* ($P < 0.05$), but the significance of the difference disappeared in the final *pâte* values. All in all, properly treated *Mucuna* seeds can be consumed in significant quantities. However, toxicologists recommend several additional tests for toxic proteins, carcinogenic and mutagenic components, and semichronic, allergic, or immunological effects, especially after long-term consumption (Alink, personal communication, 1996[3]).

Mucuna grains may also be incorporated in feed as an additional protein source for farm animals, a practice that was rather extensively used in the southern United States for steers and pigs at the beginning of this century (Tracy and Coe 1918). In Benin, tests are under way with goats and pigs, but results are still unavailable.

Profitable use of *Mucuna* grains may eliminate an important barrier to *Mucuna* adoption. Moreover, reasonable grain yields can be obtained with less effort, smaller investments, and a lower risk of failure than are associated with traditional second-season crops such as maize, groundnut, and cowpea. Relay-cropped *Mucuna* needs no additional land preparation, sowing, or weeding and is unaffected by drought during August and September. The major risk is the destruction of the aboveground biomass by bush fires during the dry season, so some extra effort is required to protect the field, such as installing proper fire breaks.

[3]G. Alink, Wageningen Agricultural University, 1996).

Table 1. Content of L-Dopa in detoxified flour from two *Mucuna* varieties (*Mucuna pruriens* var. *cochinchinensis* and *M. pruriens* var. *utilis*) and in a *pâte* consisting of this flour and maize flour.

	L-Dopa content (%)					
	Pure *Mucuna* flour			*Pâte* [a]		
	M. pruriens var. *cochinchinensis*	*M. pruriens* var. *utilis*	Avg.	*M. pruriens* var. *cochinchinensis*	*M. pruriens* var. *utilis*	Avg.
Boiling time (min) [b]						
20	0.32	0.42	0.36	0.10	0.10	0.10
40	0.37	0.34	0.36	0.10	0.08	0.09
60	0.34	0.38	0.36	NA	NA	
Avg.	0.34	0.38	0.36	0.09	0.09	0.095

Note: avg., average; NA, not analyzed.
[a] 1/3 *Mucuna* flour and 2/3 maize flour.
[b] Time used to lower the L-Dopa content in *Mucuna* flour.

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Déterminants de l'adoption du *Mucuna* dans le département du Mono au Bénin

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Résumé

L'analyse des déterminants de l'adoption du *Mucuna* à l'aide d'un modèle économétrique a révélé que des variables telles que le statut foncier, le nombre de sarclages avant la récolte, la source d'information, la perte de la petite saison, l'appréciation du niveau de fertilité des sols et le revenu tiré de la vente de semences de *Mucuna* avaient eu une incidence notable sur la probabilité de l'adoption. Près de 42 % des exploitants interrogés ont cité l'impossibilité de cultiver la terre pendant la petite saison des pluies comme principale raison de la non-adoption du *Mucuna*. Parmi ceux qui l'ont adopté, le degré d'infestation d'*Imperata* (indiqué par le nombre de sarclages avant la récolte) venait au premier rang des raisons à l'origine de leur décision. En général, dans les cas où le nombre de sarclages était quatre ou plus et lorsque l'exploitant avait eu accès à l'information sur le *Mucuna*, qu'il était assuré de pouvoir cultiver sa terre et qu'il était en mesure de tirer de la vente des semences des recettes pouvant atteindre 10 000 francs CFA, la probabilité de l'adoption du *Mucuna* était de 84,7 %. Par ailleurs, là où tous les exploitants jouissaient de la sécurité des terres et de l'accès à l'information, avec un nombre de sarclages égal à quatre et une carence constatée de la fertilité des sols, le niveau d'adoption s'élevait à 71,6 %.

Abstract

With the aid of an econometric model, an analysis of the determinants of *Mucuna* adoption revealed that probability of adoption was significantly affected by land ownership; number of weedings before harvest; source of information; unavailability of the land for second-season crops; soil type; appreciation of soil-fertility trend; and revenue derivable from the sale of *Mucuna* seeds. About 42% of farmers surveyed cited loss of the opportunity to use the land during the second rainy season as a reason for not adopting *Mucuna*. Among adopters, the degree of *Imperata* infestation (indicated by the number of weedings before harvest) was the strongest motive for adoption. In general, when the number of weedings was four or more and the farmer had access to information on *Mucuna*, had land security, and was able to realize up to 10 000 CFA francs on seed

sales, the probability of *Mucuna* adoption was 84.7%. On the other hand, when all farmers had land security and access to information, the number of weedings before harvest was four, and the soil fertility was poor, the level of adoption was 71.6%.

Introduction

Dans le but d'améliorer la fertilité des sols pauvres, des mesures de vulgarisation de nouvelles technologies ont été entreprises par l'Institut national de la recherche agricole du Bénin grâce à son programme de recherche appliquée en milieu réel avec l'appui de l'Institut international d'agriculture tropicale et du Royal Tropical Institute of the Netherlands. Parmi les technologies de gestion de la fertilité des sols introduites en milieu paysan dès 1987, la jachère annuelle à base de *Mucuna* est la seule à être adoptée par les producteurs. Dans le but d'évaluer l'importance des déterminants de cette adoption, une enquête sur l'adoption du *Mucuna* a été menée en 1994 (Houndékon et Gogan 1996).

Méthodes

Dans le cadre de l'enquête, 277 paysans dont 143 utilisateurs et 134 non-utilisateurs de *Mucuna* ont été sélectionnés par échantillonnage aléatoire au niveau de chacun des deux groupes dans quatre villages du département du Mono (Zouzouvou, Atindéhouhou, Eglimé et Tchi). L'analyse des déterminants a été faite à l'aide du modèle économétrique de probabilité Probit (Polson et Spencer 1991; Griffiths *et al.* 1993).

Variable dépendante

La variable dépendante est calculée de la manière suivante à partir de deux unités d'observation — la parcelle et le paysan :

- *parcelle* — a été plantée avec du *Mucuna* au moins une fois (oui ou non)
- *paysan* — a été satisfait de l'utilisation du *Mucuna* sur cette parcelle et continue de l'utiliser sur ses parcelles (oui ou non)

Ainsi, la variable dépendante y a la valeur $y = 1$ si parcelle = oui et paysan = oui, et $y = 0$ dans tout autre cas.

Tableau 1. Caractéristiques des classes de parcelle.

Classe	Nombre de sarclages	Densité de l'*Imperata* (plants m^{-2}) (*n*)	Moyenne	Écart type	Nombre d'observations
1	≤2	81–229	155	51	15
2	3–5	172–284	228	52	27
3	≥5	230–355	293	43	10

Source : Enquêtes.

Perception paysanne du problème de l'*Imperata*

Pour analyser l'importance de la contrainte liée à l'*Imperata*, les paysans classent les parcelles infestées en trois catégories en fonction du degré d'infestation. Les paysans expriment le degré d'infestation par le nombre de sarclages du maïs avant la récolte. La relation entre le nombre de sarclages nécessaires avant la récolte du maïs et la densité des plants d'*Imperata* est résumée au tableau 1. Si le nombre de sarclages est inférieur ou égal à 2, le paysan considère qu'il s'agit d'une situation normale. Si le nombre de sarclages est compris entre 3 et 5, alors l'*Imperata* constitue un problème, car sa présence accroît les besoins en main-d'œuvre. Si le nombre de sarclages dépasse 5, le paysan considère qu'il est plus utile de ne pas cultiver la parcelle et d'utiliser l'*Imperata* (comme matériel de construction des toits de maison ou de grenier) ou de la mettre en jachère.

Situation socio-économique des paysans et variables indépendantes

Au moment de l'enquête, en 1994. seulement 25,8 % des paysans étaient dans l'insécurité foncière (SL = 1 si sécurité foncière = oui, et SL = 0 dans tout autre cas). Le revenu moyen annuel que les paysans tiraient de la vente du *Mucuna* (MC) était de 947 francs CFA ha^{-1} (en 1998, 610,65 francs CFA [XOF] = 1 dollar américain [USD]). WE représente le nombre de sarclages nécessaires avant la récolte du maïs sur la parcelle ; sa valeur moyenne était de 1,8 au moment de l'enquête. EX indique si le paysan a accès ou non à une source formelle d'information (EX = 1 s'il a accès aux sources formelles d'information, et EX = 0 dans tout autre cas). Au moment de l'enquête, 22,6 % des paysans avaient accès aux sources formelles d'information. L'âge moyen des paysans de l'échantillon était de 41,4 ans en 1994.

Tableau 2. Fréquence d'utilisation du *Mucuna* en fonction des objectifs initiaux.

Raisons d'utilisation du *Mucuna*	Fréquence (%) Tindéhouhoué (*N*=24)	Eglimé (*N*=60)	Tchi (*N*=18)	Zouzouvou (*N*=41)	Ensemble (*N*=143)
Augmenter la fertilité des terres	17	33	0	24	24
Contrôler l'*Imperata*	83	67	100	76	76

Source : Enquêtes.

Résultats et discussion

Perception du problème de la perte de fertilité

La perte de fertilité se manifeste par une baisse de rendement. Le rendement est élevé sur les terres nouvellement mises en valeur après une jachère d'environ 15 ans par exemple (de 1 750 à 2 188 kg ha^{-1} de maïs), et médiocre (438 kg ha^{-1} de maïs) sur les parcelles exploitées pendant une durée équivalente à celle de la jachère. En général, plus la jachère est longue, plus le rendement est élevé. Toutefois, après 15 ans, la durée de la jachère n'a plus d'effet sur le rendement (Houndékon et Gogan 1996).

Le *Mucuna* comme solution aux problèmes : évaluations et adoption

Pour déterminer le but principal des utilisateurs du *Mucuna*, la fréquence relative des utilisateurs a été calculée pour chaque objectif et présentée au tableau 2.

Plus des deux tiers des paysans interrogés ont utilisé le *Mucuna* pour contrôler l'*Imperata*. Même sur le plateau Adja où la très forte densité de population a engendré d'importants problèmes de perte de fertilité des sols et de dégradation du système traditionnel de production, les trois quarts des utilisateurs ont visé le contrôle de l'*Imperata*.

Contrainte à l'utilisation : raisons évoquées par les non-utilisateurs

Les principales raisons évoquées par les paysans qui n'ont pas encore utilisé le *Mucuna* sont mentionnées au tableau 3. Pour l'ensemble des villages, la perte de la possibilité de cultiver la terre pendant la petite saison des pluies se révèle importante (42 % des cas) pour expliquer le comportement des paysans.

Tableau 3. Principales raisons de non-utilisation du *Mucuna*.

Raison	Paysans ayant donné les raisons					
	Tindéhouhoué (*N*=21) (*n*)	Eglimé (*N*=42) (*n*)	Tchi (*N*=20) (*n*)	Zouzouvou (*N*=51) (*n*)	Ensemble (*N*=134) (*N*)	(%)
Perte de la petite saison	5	31	0	21	57	42
Insécurité foncière	5	5	4	11	25	19
Semences non disponibles	3	4	10	4	21	16
Manque d'information	3	1	4	8	16	12
Autres	5	1	2	7	15	11

Source : Enquêtes.

Déterminants de l'adoption

L'analyse des déterminants (à l'aide du modèle économétrique Probit) a révélé que les variables telles que le statut foncier du paysan, le nombre de sarclages nécessaires sur la parcelle, la source d'information, la perte de la petite saison, le type de sol, l'appréciation du niveau de fertilité des sols et le revenu annuel issu de la vente de semences de *Mucuna* ont un impact significatif sur la probabilité d'adoption du *Mucuna*.

Simulation de l'effet de quelques variables sur le taux d'adoption du *Mucuna*

Taux d'adoption et politique foncière

Dans la situation foncière qui prévalait au moment de l'enquête (75,2 % des paysans jouissaient de la sécurité foncière), le taux d'adoption du *Mucuna* a été de 21,1 % (figure 1). Mais si, par une politique, on arrivait à une situation où la majorité des producteurs serait dans l'insécurité foncière, alors ce taux passerait à 5,6 %, soit une baisse de 73,4 %.

Taux d'adoption et sources d'information

Une politique de vulgarisation qui aurait permis à tous les producteurs d'avoir directement accès aux sources formelles d'information améliorerait le taux d'adoption actuel, qui passerait de 21,1 % à 24,2 %, soit une augmentation de 15 %. Par

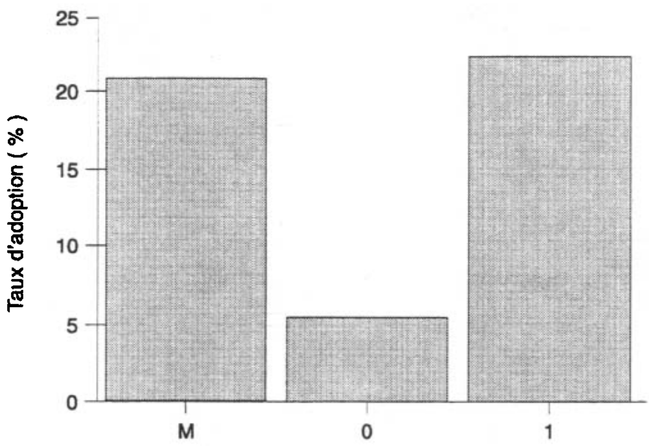

Figure 1. Effet de la sécurité foncière sur le taux d'adoption du *Mucuna*. Nota : M, référence ; 0, insécurité ; 1, sécurité.

contre, si les producteurs n'avaient accès qu'aux sources informelles, le taux d'adoption passerait à 10,8 %, ce qui constituerait une chute de 49 %. La leçon qui ressort de ce résultat est que même si les sources informelles contribuent à la vulgarisation du *Mucuna*, le rôle des sources formelles reste déterminant pour son adoption.

Taux d'adoption et nombre de sarclages

Le nombre de sarclages est un indicateur de la présence de l'*Imperata* sur la parcelle. La relation entre le nombre de sarclages et le taux d'adoption est présentée à la figure 2. La courbe présente trois zones. La zone comprise entre 0 et 2 sarclages est caractérisée par une pente faible et par un faible accroissement du taux d'adoption, ce qui signifie que les producteurs adoptent faiblement le *Mucuna* lorsque le nombre de sarclages est inférieur ou égal à 2. Ce résultat confirme bien les observations des paysans qui considèrent que 2 ou 3 sarclages représentent une situation normale et l'*Imperata* ne constitue pas encore une contrainte. L'adoption du *Mucuna* sera alors justifiée seulement pour améliorer la fertilité du sol. La zone comprise entre 2 et 4 sarclages est caractérisée par une forte pente, ce qui indique un accroissement marqué du taux d'adoption. Cela signifie que les producteurs adoptent plus rapidement le *Mucuna* dans cette phase. Pour eux, après 2 ou 3 sarclages, la présence de l'*Imperata* constitue une contrainte et les incite à adopter

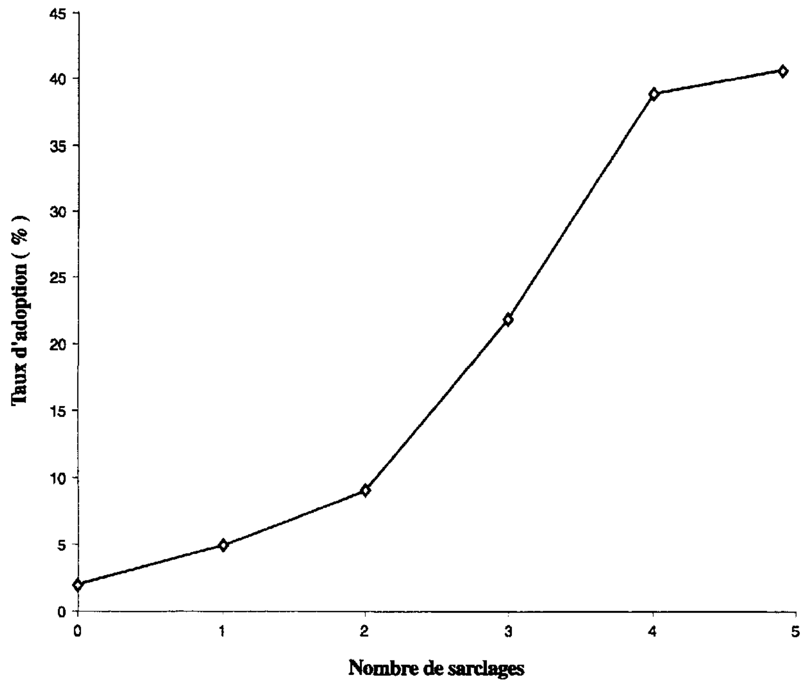

Figure 2. Effet du nombre de sarclages sur le taux d'adoption du *Mucuna*.

ou à utiliser le *Mucuna* sur la parcelle concernée. La zone qui se situe au-delà du quatrième sarclage est caractérisée par un accroissement plus faible. Le producteur préfère ne pas utiliser cette parcelle pour l'agriculture, mais la densité de l'*Imperata* permet tout de même une exploitation économique (utilisation pour couvrir les cases ou vente pour ceux qui sont dans le besoin).

Ainsi, avec moins de 2 sarclages sur les parcelles, le taux d'adoption n'est que de 9 % ; lorsque le nombre de sarclages atteint 3 et 4, le taux d'adoption passe à 21,8 et 39 % respectivement. Si la majorité des parcelles exigeaient 4 sarclages, le taux d'adoption du *Mucuna* serait alors de 39 %, soit une augmentation de 85 % par rapport à la situation actuelle.

Taux d'adoption et revenu de la vente de semences de *Mucuna*

Les recettes de vente de semences de *Mucuna* jouent le rôle d'incitation à son adoption. Les variations du taux d'adoption en fonction des recettes de vente sont

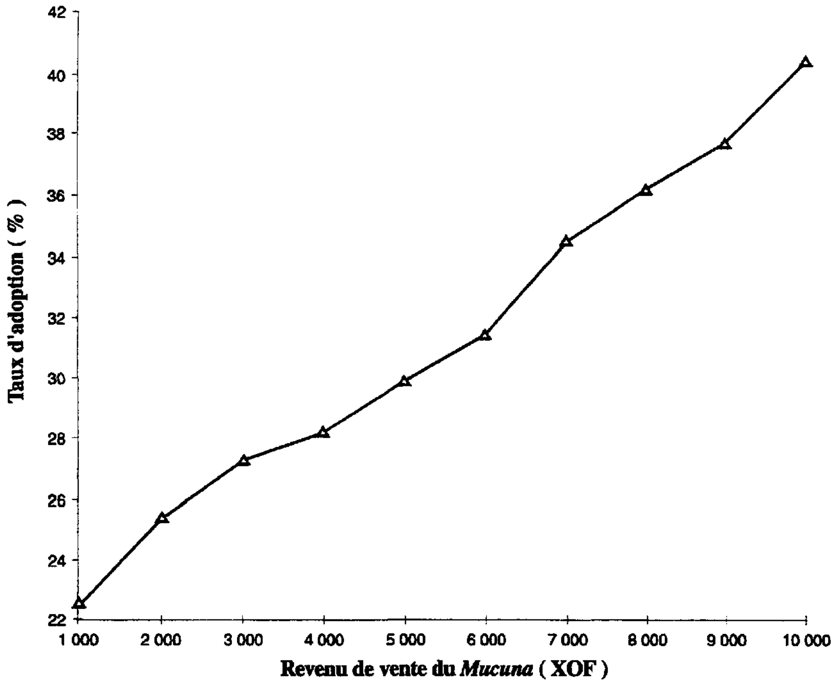

Figure 3. Effet du revenu de vente de semences de *Mucuna* sur le taux d'adoption. Nota : en 1998, 610,65 francs CFA (XOF) = 1 dollar américain (USD).

présentées à la figure 3. Comme le montre la figure, toute la politique qui permettrait au producteur d'avoir plus de revenu à partir de la production du *Mucuna* améliorera le taux d'adoption. Ainsi, avec un revenu annuel de 1 000 XOF, le taux d'adoption est de 22,6 % ; ce taux passe à 40,6 % lorsqu'on décuple le revenu. En terme de politique, différentes mesures permettront aux producteurs de tirer des revenus de la production du *Mucuna*.

Ces différentes analyses sur le taux d'adoption ont généralement tenu compte d'un seul facteur ; cependant, une combinaison de politiques et de caractéristiques des parcelles pourrait améliorer de façon marquée le taux d'adoption. En effet, lorsque toutes les parcelles exigent 4 sarclages et que tous les producteurs ont accès à l'information, jouissent de la sécurité foncière et arrivent à vendre du *Mucuna* pour 10 000 XOF, la probabilité d'adoption passe à 84,7 % (tableau 4). Par contre, lorsque tous les producteurs ont la sécurité foncière, l'accès à l'information, des parcelles exigeant 4 sarclages avant la récolte et des sols pauvres, le taux d'adoption est de 71,6 %.

Tableau 4. Simulation des taux d'adoption en fonction des caractéristiques des parcelles ou des politiques.

N°	Caractéristique du milieu ou politique	Taux d'adoption (%)
1	Toutes les parcelles sont appauvries, SL = 1	25,1
2	Parcelle nécessitant 4 sarclages avant la récolte du maïs, WE = 4	39,1
3	Tous les producteurs ont accès aux sources d'informations formelles (ONG et services de vulgarisation), EX = 1	24,2
4	Tous les producteurs ont la sécurité foncière	22,4
5	Revenu de vente des graines du *Mucuna*, MC = 10 000 XOF [a]	40,5
6	Combinaison (1) à (4)	71,6
7	Combinaison (2) à (5)	84,8

Source : Calcul à partir des données d'enquête.
Nota : EX, contact avec une source formelle d'information ; MC, revenu tiré de la vente de semences de *Mucuna* ; ONG, organisation non gouvernementale ; SL, sécurité foncière ; WE, nombre de sarclages nécessaires avant la récolte du maïs sur la parcelle.
[a] En 1998, 610,65 francs CFA (XOF) = 1 dollar américain (USD).

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Réactions et craintes des paysans liées à l'utilisation du pois mascate (*Mucuna pruriens* var. *utilis*)

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Résumé

En 1992, Sasakawa Global 2000 a entrepris son travail de vulgarisation relatif au *Mucuna*, prôné en tant que technologie utile au rétablissement des terres envahies par *Imperata* et *Striga* et à la restauration de la fertilité des sols surexploités du Bénin. Soixante-quatorze pour cent des exploitants interrogés ont utilisé le *Mucuna* au moins pendant 3 années consécutives, avec enregistrement d'un ratio de diffusion égal à sept exploitants pour chaque fermier rejoint par le personnel de projet. Tous les exploitants interrogés ont reconnu que le *Mucuna* avait contribué à améliorer la fertilité des sols, et 84 % d'entre eux ont confirmé sa capacité d'éradiquer *Imperata* dans un délai de 2 ans. Le *Mucuna* est généralement planté en culture unique au nord et en association avec le maïs au sud, où la demande des terres est plus pressante. Les contraintes à l'adoption du *Mucuna* concernent son emploi adapté à la consommation humaine et animale, les difficultés qu'éprouvent les fermiers à respecter les dates optimales de plantation en vue d'une production de biomasse idéale, le risque de feux de broussaille et de pertes attribuables au cheptel au cours de la saison sèche, et la présence de reptiles favorisée par le feuillage. Au bout de 5 années de travail de vulgarisation, le pois mascate est reconnu parmi les technologies efficaces de l'agriculture viable au Bénin.

Abstract

In 1992, Sasakawa Global 2000 (SG 2000) started extension work testing *Mucuna* as a technology for recovering land invaded by *Imperata* and *Striga* and for restoring fertility to overexploited soils in Benin. Seventy-four percent of farmers interviewed have used *Mucuna* for at least 3 years consecutively. A diffusion ratio of seven users for every farmer reached by SC 2000 staff was observed. All the farmers interviewed recognized *Mucuna*'s ability to improve soil fertility, and 84% confirmed its capacity to eradicate the *Imperata* within 2 years. *Mucuna* is generally planted as a sole crop in the north and in association with maize in the south, where land pressure is greater. The constraints to

adoption of *Mucuna* are centred around its use for both human and animal consumption; farmers' difficulties in respecting the optimum planting dates for biomass production; the risk of loss to bush fires and animals in the dry season; and the presence of snakes within its canopy. After 5 years of extension work, *Mucuna* has been accepted as an efficient technology for sustainable agriculture in Benin.

Introduction

Au Bénin, le secteur rural représente 60 % de la population active, contribue à 35 % du produit intérieur brut et assure 30 % des exportations. Le coton demeure la principale source de devises. Un surplus de 38,2 milliards de francs CFA a été obtenu en 1993–1994 grâce à une production de 277 000 t (MPREPE 1996) (en 1998, 610,65 francs CFA [XOF] = 1 dollar américain [USD]). Cependant, la dégradation des terres et la baisse croissante de fertilité des sols deviennent de plus en plus graves (Galiba *et al.* 1996), car les paysans ne pratiquent plus les longues jachères qui permettaient au sol de se reposer.

Le sud du Bénin, caractérisé par de fortes densités de population, 215 habitants km^{-2} dans le département de l'Atlantique, est le théâtre d'une agriculture continue privilégiant l'association maïs–manioc, sans utilisation d'engrais. Les terres épuisées sont envahies par le chiendent (*Imperata cylindrica*), et les paysans se tournent alors vers les terres marginales. Dans le nord du pays, avec une densité moyenne de 15 habitants km^{-2}, la culture du coton et la traction animale n'ont pas ménagé les terres (Pieri 1989). Le *Striga* est un fléau sur les terres pauvres, affectant considérablement le rendement du sorgho et du mil, qui sont les principales céréales. Le pois mascate (*Mucuna pruriens*), une légumineuse de couverture, a été introduit en milieu paysan afin d'apporter une solution aux problèmes présentés. Deux objectifs majeurs ont été poursuivis : l'éradication des adventices, surtout le chiendent, et l'amélioration de la fertilité des sols par l'augmentation de la matière organique (MO) et de N dans le sol.

La présente étude vise à faire le point après 5 années de vulgarisation du pois mascate dans le cadre du projet Sasakawa Global 2000 (SG 2000). L'écoute des paysans, utilisateurs de la technologie, devrait permettre de mesurer l'impact du *Mucuna* dans les systèmes de culture et surtout comprendre les différents canaux de diffusion et les diverses réactions à son adoption.

Stratégies de vulgarisation et technologie recommandées

L'opportunité est donnée au paysan de connaître l'innovation et, surtout, de l'évaluer dans les conditions réelles de son terroir. L'évaluation de la technologie ne se fait pas par procuration. Toute la stratégie de vulgarisation pourrait se résumer par l'aphorisme suivant :

> Ce qu'un paysan entend, il le croit rarement ;
> ce qu'il voit sur la parcelle d'un autre, il peut en douter ;
> mais ce qu'il fait lui-même, il ne peut le nier.

Malgré les nombreuses possibilités d'application du *Mucuna*, deux approches simples mais efficaces ont été recommandées : la culture pure du *Mucuna* ou la jachère améliorée, et la culture en association avec le maïs. La culture pure est recommandée pour les sols comateux, envahis par le chiendent et souvent abandonnés par les paysans. Au moins un fauchage est indispensable, surtout avant le semis, afin de donner l'avantage au *Mucuna*. La parcelle est ensuite abandonnée, et le *Mucuna* poursuit son développement jusqu'à la fin de son cycle. Cependant, un second fauchage pourrait être indispensable 1 mois après le semis. Un semis précoce est recommandé. Les jachères améliorées sont également utilisées comme parcelles semencières. La densité est de 62 500 plants ha^{-1} pour un écartement de 80 cm × 40 cm et surtout 2 plants par poquet ; 30 kg de semences sont nécessaires. L'association est recommandée dans les environnements où le paysan ne peut laisser sa parcelle en jachère. Le *Mucuna* est alors semé 42 jours après le maïs, à la densité de 31 250 plants ha^{-1}, pour un écartement de 80 cm × 80 cm et 2 plants par poquet. L'association maïs–*Mucuna* réussit bien dans le sud du Bénin où la petite saison pluvieuse, de septembre à novembre, permet à la légumineuse de boucler son cycle et de produire des graines. La lutte contre le chiendent réussit cependant mieux avec la jachère améliorée. Néanmoins, dans les deux approches, une importante production de biomasse est observée de même que l'augmentation de N dans le sol (Galiba *et al.* 1994 ; Codjia 1996).

Méthodes

De 1992 à 1994, les parcelles de démonstration mesuraient 5 000 m^2. Elles étaient également un outil privilégié de production de semences, dont l'insuffisance était la contrainte majeure à la diffusion de l'innovation. En 1995, la superficie de la parcelle de démonstration a été divisée par 10 afin de multiplier par 10 le nombre de paysans à toucher. Ainsi, 10 000 parcelles de 500 m^2 ont été conduites plutôt que 1 000 parcelles de 5 000 m^2. Un total de 15 t de semences a été remis gratuitement aux paysans qui s'engageaient à rétrocéder la même quantité de semences reçues. Le surplus de semences est acheté par SG 2000 au prix de 125 XOF kg^{-1} pour le *Mucuna* à grains noirs et 150 XOF kg^{-1} pour le *Mucuna* à grains blancs. En attendant de mieux connaître l'hérédité de la couleur du grain, le *Mucuna* noir est classé comme *Mucuna pruriens* var. *utilis* et le *Mucuna* blanc comme *Mucuna pruriens* var. *cochinchinensis.*

Échantillonnage et variables mesurées

En 1992, 128 paysans répartis dans les six départements du Bénin ont démarré l'utilisation du pois mascate. L'enquête a consisté à retrouver d'abord ces paysans de départ et à évaluer leur attitude vis-à-vis de l'innovation tout le long de cinq campagnes agricoles. L'échantillon ne peut pas être considéré comme étant au hasard. Le choix des paysans s'était fait d'abord sur le volontariat et surtout en fonction des problèmes vécus et que le *Mucuna* pourrait résoudre. En suivant la trace des premiers paysans, il a également été possible de rencontrer d'autres paysans qui avaient été influencés par les premiers et de les soumettre au même questionnaire, qui se présente en cascades avec trois niveaux : 1, adoption ou rejet de l'innovation ; 2, diffusion et exécution ; 3, réactions et craintes des paysans.

Résultats et discussion

Adoption ou rejet

L'utilisation continue de la technique de *Mucuna* a été évaluée. Il a été observé que 74 % des paysans touchés par la vulgarisation ont utilisé le *Mucuna* de façon continue pendant au moins trois campagnes successives tandis que 83 % des paysans l'ont adopté pendant deux campagnes consécutives. Le taux de rejet de la technologie est de 13 %. Les taux d'utilisation discontinue sont de 4 et 13 %, selon que la technologie est utilisée pendant deux ou trois campagnes successives. Pendant la diffusion d'une innovation, des cas de rejet, d'utilisation discontinue et de réinvention de la technique peuvent se présenter et le comportement peut être rationnel et approprié du point de vue de l'individu (Rogers 1983).

La figure 1 présente les taux d'utilisation continue du *Mucuna* sur au moins 2 et 3 ans (adoption) par département. On note que les pourcentages d'adoption observés sur deux campagnes successives sont supérieurs à ceux obtenus sur trois campagnes consécutives. Ces taux varient de 46 à 95 % pour deux campagnes et de 36 à 91 % pour trois campagnes. Ces écarts sont dus à l'utilisation discontinue de la technologie du *Mucuna*. L'utilisation discontinue de la technique suggère que certains paysans ne font usage de la technique du *Mucuna* que lorsqu'ils ont un problème réel d'envahissement du chiendent ou de la baisse de fertilité de leur sol. Cette réaction paysanne illustre « le menu à la carte » permettant à l'utilisateur de faire appel à la technologie pour un problème précis et surtout dont il est sûr d'avoir la solution. Les taux d'adoption obtenus

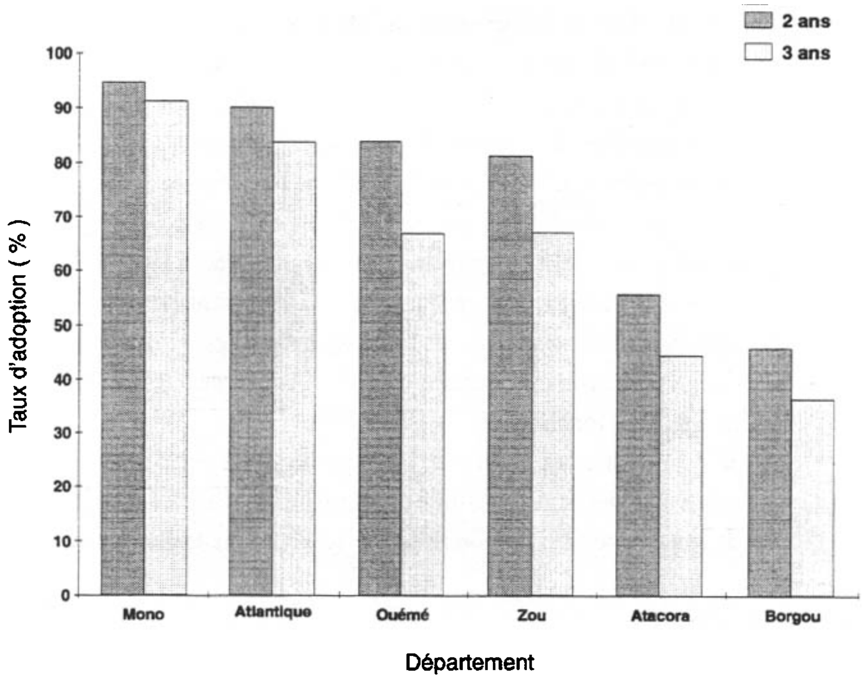

Figure 1. Adoption du *Mucuna* par département.

dans les départements du nord (Atacora, Borgou) sont faibles. Environ 50 % des cas de rejet sont observés dans ces deux départements. Les raisons plausibles de ce rejet sont de trois ordres : (1) il existe encore de vastes étendues de terres cultivables dans le nord du pays, où la densité de population est assez faible ; (2) ces départements se sont spécialisés dans la culture du coton, qui bénéficie du crédit intrant — en l'occurrence, les engrais chimiques ; (3) l'hivernage dans le nord du Bénin ne comporte qu'une seule saison de pluie de 4 à 6 mois suivant les perturbations climatiques.

Le *Mucuna* semé en relais avec le maïs avec un grand retard n'arrive pas à boucler convenablement son cycle végétatif. C'est aussi le cas quand l'hivernage s'installe tardivement, par exemple vers la mi-juillet ; les semis de *Mucuna* sont alors repoussés jusqu'à la mi-août. La légumineuse n'arrive pas à terminer son cycle de 6 mois, surtout quand les pluies cessent précocement vers la mi-octobre et que l'harmattan qui suit n'apporte pas la fraîcheur et la rosée attendues. Ainsi, en 1992, deux des trois paysans qui ont essayé l'innovation dans l'Atacora l'ont simplement abandonnée. Aussi, le *Mucuna* est considéré comme une plante non comestible et, par conséquent, semé tardivement après les cultures vivrières dans le nord.

En revanche, dans le département du Mono où les taux d'adoption sont encourageants, très peu de cas de rejet de la technologie ont été enregistrés. Sur 28 paysans qui ont essayé le *Mucuna* en 1992, 18 (64 %) l'ont utilisé pendant cinq campagnes successives. Il convient de noter que la pression foncière est plus prononcée, que les terres sont sous culture de façon permanente (surtout sur le plateau Adja) et que l'introduction du *Mucuna* au Bénin s'est faite à partir du département du Mono en 1987. Les paysans de ce département se sont spécialisés dans la production de semences qui leur procure d'intéressants revenus. Plus de la moitié des semences de *Mucuna* collectées chaque année proviennent du département du Mono. Vient ensuite le département de l'Atlantique, où les terres sont également sous pression foncière.

Dans le département de l'Ouémé, bien que les paysans bénéficient de la proximité du Nigeria où ils peuvent avoir des engrais chimiques à des prix concurrentiels, ils ont compris le rôle prépondérant de la MO dans la fertilité des sols.

Diffusion et exécution

La technique du *Mucuna* a été vulgarisée par le biais de la structure organisationnelle des centres d'action régionale pour le développement rural du ministère du Développement rural, où les agents polyvalents de vulgarisation ont joué un rôle de premier plan à la base. Les parcelles test de production installées en milieu paysan à titre démonstratif ont permis aux petits paysans d'apprécier les avantages tangibles de la technique du *Mucuna*, surtout en ce qui concerne l'éradication des mauvaises herbes (chiendent, *Striga*) et l'augmentation du rendement de maïs. Les prouesses du *Mucuna* n'ont pas laissé indifférents les paysans voisins, parents et amis de la même communauté, qui ont imité les paysans directement touchés par la vulgarisation du pois mascate. L'étude réalisée a révélé qu'il y a en moyenne sept paysans imitateurs par paysan touché par la vulgarisation. Les paysans bénéficiaires de la technologie se sont donc transformés en diffuseurs de l'innovation du *Mucuna* dans leur voisinage immédiat et même au delà de leur contrée.

Réactions et craintes des paysans

La présente étude a permis de recueillir les commentaires des paysans au sujet de la technique du *Mucuna*. Plus de 60 % des paysans ont attesté que le *Mucuna* combat le chiendent et le *Striga* caractéristiques des sols pauvres (tableau 1). Le tableau 2 indique que 32 % des paysans cultivent le *Mucuna* en culture pure, 34 % en culture associée et 34 % pratiquent les deux systèmes. La culture pure

Tableau 1. Impressions des paysans.

Impressions	*n*	%
Fertilité du sol	52	37
Lutte contre le chiendent et amélioration de la fertilité du sol	90	63

Source : Résultats d'enquête, 1996.

Tableau 2. Systèmes de culture à base de *Mucuna*.

Systèmes de culture	*n*	%
Culture pure	46	32
Culture associée	48	34
Culture pure + associée	48	34

Source : Résultats d'enquête, 1996.

s'observe généralement dans le nord. Au sud, la culture associée s'intègre mieux au type d'exploitation des terres et le *Mucuna* n'est cultivé en culture pure que dans le cas de récupération des terres envahies par le chiendent.

Dans l'Ouémé, quelques paysans ont utilisé le *Mucuna* pour contrôler les mauvaises herbes dans leurs palmeraies. Ceci leur a permis de réduire l'entretien (nombre de sarclages). Ces résultats sont conformes à ceux de Versteeg et Koudokpon (1990) et de Osei-Bonsu *et al.* (1995). L'expérience paysanne a montré que la première année, le *Mucuna* permet de remettre en valeur la parcelle abandonnée (58 % des paysans) et que l'élimination complète du chiendent n'intervient qu'au bout de 2 à 3 ans, suivant le respect strict de la mise en œuvre du paquet technologique (tableau 3).

En plus d'être un moyen efficace de lutte contre les mauvaises herbes, le *Mucuna* permet aux paysans d'améliorer la fertilité de leur sol, surtout dans un environnement où les périodes de jachères sont quasi nulles. Ainsi, presque tous

Tableau 3. Temps pour éliminer le chiendent par le *Mucuna*.

Durée d'élimination (ans)	*n*	%
1	63	58,0
2	29	26,5
3	17	15,5

Source : Résultats d'enquête, 1996.

les paysans (99 %) ont révélé que le *Mucuna* améliore la fertilité du sol. Osei-Bonsu *et al.* (1995) ont rapporté que la MO de *Mucuna* apporte 150 kg N ha^{-1}. En effet, 11 % des paysans interrogés ont appliqué des doses insignifiantes de N–P–K ou d'urée après le précédent *Mucuna*. Le précédent *Mucuna* a augmenté de façon substantielle le rendement de maïs, qui a doublé, voire triplé, comparativement au rendement du maïs sans jachère améliorée de *Mucuna*. Le rendement moyen, de l'ordre de 2 200 et 660 kg ha^{-1}, a été obtenu avec et sans jachère de *Mucuna* respectivement (figure 2). Des résultats similaires ont été rapportés par Milton (1989) et Bunch (1990), cités par Reijntjes *et al.* (1992). Le rendement du maïs associé au *Mucuna* n'est pas différent de celui du système sans précédent *Mucuna*. Les paysans ont conclu que l'effet du *Mucuna* sur le rendement de maïs n'est substantiel qu'au cours de la campagne qui suit la jachère améliorée de *Mucuna*.

Une enquête sur le revenu que procure le *Mucuna* aux paysans a révélé que plus de 50 % des paysans tirent des revenus inférieurs à 10 000 XOF et que 20 % des paysans ont des revenus supérieurs à 25 000 XOF. Les paysans qui tirent des revenus non moins négligeables se sont spécialisés dans la production de semences de *Mucuna*. Ils ont des revenus de l'ordre de 100 000 XOF, parfois plus.

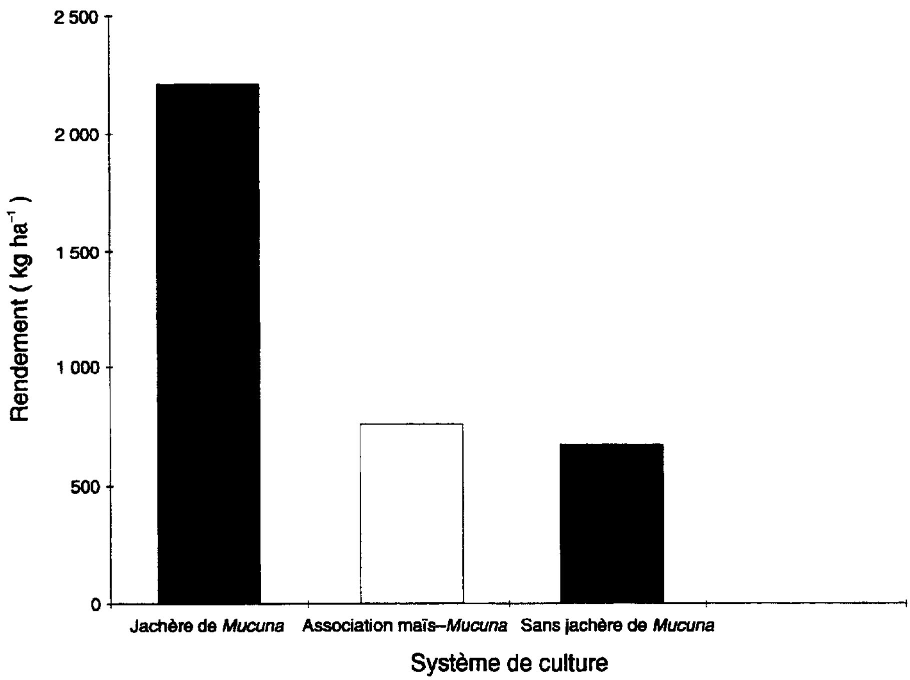

Figure 2. Rendement du maïs dans différents systèmes de culture. Nota : *n* = 110.

Contraintes liées à l'adoption du *Mucuna*

Alimentation humaine et animale

Certains paysans se sont montrés peu intéressés à cultiver une plante « non comestible » qui occupe leur sol pendant 6 mois dans le sud du Bénin, confronté à une pénurie foncière aiguë. De même, malgré son utilisation comme fourrage dans son aire d'origine (Tracy et Coe 1918), les éleveurs du nord du Bénin sont quelque peu sceptiques en ce qui concerne son utilisation comme aliment du bétail à longue échéance. Ils craignent que leur cheptel ne soit décimé par une alimentation prolongée à base de *Mucuna*.

Manque de débouchés pour l'écoulement des graines de *Mucuna*

Hormis l'alimentation humaine, le manque de débouchés pour la vente des graines produites constitue aussi un goulot d'étranglement à l'adoption du *Mucuna*. En effet, pour un produit qui n'offre aucun coût d'opportunité, le paysan qui manque de terre ne voudra pas consacrer son lopin à une culture qui ne possède aucun circuit commercial. Au Bénin, outre SG 2000 et quelques rares organisations non gouvernementales qui achètent chaque année les graines de *Mucuna* aux producteurs en vue d'une vulgarisation à grande échelle, aucune autre structure n'achète véritablement les graines de *Mucuna*. SG 2000 a acheté environ 60 % de la semence produite. Pour encourager l'autodiffusion de la technologie, les paysans touchés par la vulgarisation du *Mucuna* ont donné 21 % des semences produites à leurs voisins, amis et parents, alors que 18 % de la production a été vendue à d'autres paysans. Ceci n'est pas sans influencer le taux d'adoption du *Mucuna*. Au Mono, les terres sont de façon permanente sous culture et le petit paysan n'éprouve aucun désir de sacrifier sa petite saison pluvieuse au profit d'une culture qui ne présente aucun avantage immédiat.

Système de culture

Dans le sud du Bénin à pluviométrie bimodale, le *Mucuna* s'intègre bien dans les cultures de relais avec le maïs. Il bénéficie des pluies de la petite saison pour finir son cycle dans des conditions favorables. Dans le nord du Bénin, la pluviométrie est unimodale. Le *Mucuna* semé en culture de relais n'arrive pas à boucler son cycle. Les plants sont affectés par le stress hydrique et l'avortement des fleurs entraîne des rendements quasi nuls. La culture pure de *Mucuna* est ainsi recommandée.

Feux de brousse

Les plants de *Mucuna* se dessèchent très rapidement en saison sèche, surtout en décembre, à la faveur de l'harmattan. Lorsque les pare-feu d'au moins 5 m ne sont pas réalisés, les feux de brousse gagnent facilement les parcelles et réduisent en cendres les éléments minéraux contenus dans la partie aérienne des plants de *Mucuna*. Aussi, les bandes d'enfants au cours des battues organisées mettent le feu aux parcelles de *Mucuna* qui servent de gîte aux rats après dessèchement.

Suggestions

Il s'agira notamment de (1) accélérer, intensifier et approfondir les recherches sur l'alimentation humaine et animale du *Mucuna* ; (2) développer et vulgariser des légumineuses à cycle court ; (3) apporter une fumure minérale complémentaire de P et de K aux céréales après une jachère de *Mucuna*. À cet effet, l'utilisation des fines de phosphate naturel est une alternative peu onéreuse. La décomposition de la biomasse du *Mucuna* pourrait rendre disponible le phosphate aux plantes et sensibiliser les populations, en particuler les enfants, aux feux de brousse.

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The phytochemistry, toxicology, and food potential of velvetbean (*Mucuna* Adans. spp., Fabaceae)

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Abstract

This paper examines current knowledge of velvetbean, *Mucuna* spp. (Fabaceae), and provides new data on its phytochemistry, toxicology, and food potential. Small-scale farmers in the tropics have traditionally used *Mucuna* as a cover crop to suppress weeds. The genus *Mucuna* is large (>100 species) and includes 5 or more cultivated species, but the taxonomy is confused and has not been examined using modern molecular techniques or in relation to phytochemical markers. The most important cultivated species, *Mucuna pruriens* (L.) DC., produces the toxic principle L-Dopa and has been reported to contain the hallucinogenic compounds related to N,N-dimethyltryptamine. A new phytochemical assessment of seeds of 36 accessions of currently used cultivars shows the presence of L-Dopa, but tryptamines were not detected in any of the seeds examined. L-Dopa content in the accessions increases with proximity to the equator. An assessment of the risk of consumption of these seeds and processed material indicates that processed seeds can be safely consumed by humans. Implications for allelopathy and pest resistance if these toxic substances are removed are also considered.

Résumé

Dans le présent document, les auteurs examinent les connaissances actuelles sur le pois mascate, autrement appelé *Mucuna* spp. (Fabaceae), et présentent de nouvelles données sur sa phytochimie, sa toxicologie et son potentiel alimentaire. Les petits exploitants agricoles des régions tropicales utilisent depuis longtemps le *Mucuna* comme plante de couverture pour éliminer les mauvaises herbes. Le *Mucuna* est le nom générique d'une plante qui regroupe plus de 100 espèces, dont 5 au moins sont cultivées mais dont la taxonomie est confuse et n'a pas été étudiée au moyen de techniques moléculaires modernes ou avec des marqueurs phytochimiques. L'espèce cultivée la plus importante, le *Mucuna pruriens* (L.) DC., produit le principe toxique L-dopa, et elle contiendrait des composés hallucinogéniques apparentés au N,N-diméthyltryptamine. Une nouvelle évaluation phytochimique des semences de 36 obtentions de cultivars utilisés à l'heure actuelle montre la présence de L-dopa, mais on n'a décelé de tryptamine dans aucune des graines examinées. La teneur en L-dopa des obtentions augmente à mesure que l'on se rapproche de l'équateur. Une évaluation du risque que présente la consommation de ces semences et de matières traitées révèle que les graines traitées peuvent être consommées sans danger par l'être humain. Les auteurs examinent également les conséquences sur le plan de l'allélopathie et de la résistance aux ravageurs si l'on retire ces substances toxiques.

Introduction

Farmers practicing traditional shifting agriculture in the tropics often use fallows to manage natural succession processes. Although the fallow has a well-recognized role in restoration of soil nutrients, it also has an important role in weed control. Competition allows farmers to replace agronomically unmanageable weed species with more easily prepared secondary forest (Brubacher et al. 1989). Similarly, cover crops can be used to retard the succession to unmanageable tropical weed species, such as grasses, woody vines, and aggressive shrubs. In this case, the cover crop interferes with the weeds through allelopathy and competition for light. As scarcity of land has been forcing farmers to progressively shorten the fallow periods in recent years, the emphasis in weed management has been shifting from forest fallow toward beneficial cover crops.

Cover crops provide an added crop value in the agronomic system, but they compete with edible or cash crops. Many cover-crop species are too toxic because of high concentrations of phytochemicals, which are significant to allelopathy. Although these phytochemicals constrain the use of such cover crops for food or forage, they may provide farmers with a new opportunity: value-added phytochemical products.

Velvetbean (*Mucuna* spp.) is an example of a successful cover crop with several highly biologically active natural products. *Mucuna* Adans. spp. (syn. *Stizolobium*) have long been cultivated in humid tropical areas as soil-improving crops, as cover crops to control weeds, and as green manures and forage plants (Buckles 1995). Some species have also been used for human consumption; such foods are rich sources of minerals (especially K, Mg, Ca, and Fe), proteins, and amino acids (Duke 1981). Before the seeds are eaten, they are often cracked and removed from the seed coats, soaked for a period, and then boiled in water, roasted, or fermented to remove most of the toxic principle, which has been implicated in poisonings. Mature seed pods are regarded as less toxic than green pods and, along with leaves, have been boiled and eaten as vegetables (Bailey 1950; Duke 1981). A risk of toxicity may remain, however; thus, an assessment of the food potential of velvetbean is required.

Taxonomy

Perhaps as many as 100 species of wild or domesticated *Mucuna* can be found in the tropics and subtropics of both hemispheres; 13 have been documented in Indochina, the Malay Peninsula, and Thailand (Wilmot-Dear 1991a, b). No modern molecular studies have been performed on the genus, and as Duke (1981, p. 171) tellingly asserted, "the taxonomy of the cultivated species (of *Mucuna*) is confused." Duke recognized five species, namely, *Mucuna pruriens* (L.) DC., *Mucuna nivea* (syn. *Mucuna lyonii* Merr.) (Lyon velvetbean), *Mucuna hassjoo* (Yokohama velvetbean), *Mucuna aterrima* Holl. (Mauritius or Bourbon velvetbean), *Mucuna utilis* Wall. (Bengal velvetbean), and *Mucuna deeringiana* Merr. (Florida or Georgia velvetbean). The well-known taxonomist of Asian economic plants, Burkill (1966), recorded that *Mucuna cochinchinensis* is synonymous with *M. nivea* and *M. lyonii*; likewise *M. deeringiana*, with *M. pruriens* var. *utilis* auctt., but not *M. utilis* Wall. The United States Department of Agriculture, in a quest for plants suitable for use as cattle fodder, identified two additional species, namely, *M. cochinchinensis* A. Chev. and *Mucuna capitata*. Piper and Tracy (1910), using the generic designation *Stizolobium* instead of *Mucuna*, added the Indian species, *Stizolobium cinereum* and *Stizolobium pachylobium*; the former, identified as *S. cinerium* [sic], has been under cultivation in various countries, given a detailed nuritional assessment in Mexico, and judged to be a potentially valuable addition to human diets, especially when supplemented with wheat flour (De la Vega et al. 1981).

Some South Asian and Oceanic peoples consume the boiled seeds of the tribal pulse, *Mucuna gigantea* (Willd.) DC., which grows wild in Indian coastal areas, China, and in the region from Malaysia to Australia and Polynesia (Rajaram and Janardhanan 1991).

Mucuna pruriens (L.) DC. (syn. *Stizolobium pruriens* [L.] Medic.)

Mucuna pruriens is extensively cultivated worldwide and is the only species systematically investigated for its chemical and pharmacological properties (Ghosal et al. 1971). However, the taxonomic confusion alluded to by Duke (1981) extends to the identification of the species and its varieties. Indeed, the plant material used in a 1971 Indian study (Ghosal et al. 1971) appears not to have been subjected to a careful and thorough botanical characterization: their paper gives no indication that professional botanists were involved or that a voucher specimen was retained. Modern molecular studies would be extremely useful in defining the natural relationships between taxa.

The most commonly encountered varieties of *M. pruriens* are *M. pruriens* (L.) DC. var. *utilis* (Wall. *ex* Wight) Baker *ex* Burck. and *M. pruriens* var. *pruriens*. Velacourt (1979) listed *M. pruriens* ssp. *pruriens* and *M. pruriens* var. *utilis* (syn. *Stizolobium alterrimum* Piper & Tracy, *Stizolobium capitatum* [Roxb.] Kuntze, *Stizolobium cochinchinense* [Lour.] Burk., *Stizolobium niveum* [Roxb.] Kuntze). The *Kew Bulletin* recommends earlier publications by Wilmot-Dear (1984) for complete synonymy and detailed descriptions of both the species as a whole and its varieties.

The salient morphological differences appear to reside in the appearance of fruit and seeds of the varieties of the species. Velacourt (1979) described the fruits of *M. pruriens* as

> oblong, usually more or less S-shaped, 4–9 cm long, 1–1.5 (–2) cm wide, densely covered with brown or reddish-orange irritant bristly hairs, longitudinally ribbed under the hairs; in cultivated forms the fruits are glabrescent or velvet hairy but lack the bristles. Seeds pinkish brown, speckled black or almost entirely black (or white to black in cultivars), oblong-ellipsoid, compressed, 1–1.9 cm long, 0.8–1.3 cm wide, 4–6.5 mm thick, hilum oblong, about 4 mm long, with a cream rim-aril. Subsp. *pruriens*: Fruits with or without irritant bristles. ... Var. *utilis*: Fruits glabrescent or velvety hairy but lacking bristles ... seeds in New Guinea material seen, purple.

Wilmot-Dear (1984) recorded the following for *M. pruriens*:

> Fruit fleshy with 3–6 seeds, small, narrowly linear-oblong but swollen around seeds and sometimes misshapen usually with 1–2 longitudinal facial ridges. Seeds ellipsoid, small, 1–1.7 (–2) × 0.7–1.3 cm, 4–10 mm in thickness; hilum occupying ±1/8 circumference. ... Var. *pruriens*: Fruit narrowly linear-oblong, usually distinctly curved often in S-shape, 5–9 × 0.8–1 cm, somewhat laterally flattened ±5 mm in thickness; surface with dense covering of irritant deciduous bristles, red–gold or brownish (sometimes in longitudinal bands of alternating lighter and darker brown), completely concealing surface and ridges. Seeds fawnish brown, hilum ±6 mm long, marginal aril orange. ... *M. pruriens* worldwide ... almost always shows the details given above for var. *pruriens*. ... Var. *utilis*: Plants very similar to var. *pruriens* but with complete absence of irritant bristles, this most obvious in the fruit; differences from var. *pruriens* as follows. ... Fruit linear-oblong but often misshapen due to irregular sizes of swellings around seeds, sometimes up to 2 cm broad in places; surfaced with dense or sparse short appressed or spreading soft light-brown hairs, facial ridges usually clearly visible beneath. Seeds whitish, fawn,

pale orange or black, sometimes marbled in these colours or obliquely dark-marked; aril orange.

Phytochemical composition and toxicity

Cattle thrive on meal made from velvetbeans ground in the pod, but people have become sick from eating cooked green beans, and chickens have died from eating both raw and cooked beans (Bailey 1950). Duke (1981, p. 173) reported that "hogs, poultry and horses do not do well on velvetbeans or velvetbean meal" and that "when fed to pigs in excessive quantities, the seeds cause severe vomiting and diarrhea."

The toxic principle in *Mucuna* seed is held to be L-Dopa, 3-(3,4-dihydroxyphenyl) alanine (Figure 1), a compound chiefly used in treating the symptoms of Parkinson's disease. In addition to gastrointestinal disturbances — notably, nausea, vomiting, and anorexia — the most serious effects are reported to be (Reynolds 1989, annex)

> aggression, paranoid delusions, hallucinations, delirium, severe depression, with or without suicidal behaviour, and unmasking of dementia. Psychotic reactions are ... more likely in patients with postencephalitic Parkinsonism or a history of mental disorders.

In 1989, in Nampula, Mozambique, an outbreak of more than 200 cases of acute toxic psychosis was attributed to consumption of the seeds of *M. pruriens* (Infante et al. 1990). The seeds are usually detoxified by repeated boiling in water, which is discarded before further processing of the seed, but because of drought the people drank this water instead.

Mucuna spp. have also been reported to contain, in addition to L-Dopa, antinutritional factors, such as phenols and tannins, and to possess trypsin inhibiting and haemagglutonating activities (Rajaram and Janardhanan 1991). Duke (1981) also reported the presence of nicotine, physostigmine, and serotonin in *Mucuna* (see Figure 1). Ghosal et al. (1971) claimed that this last compound, the important neurotransmitter also known as 5-hydroxytryptamine (5-HT), is present in the golden-yellow trichomes of pods of *M. pruriens*. In addition, bufotenine, choline, N,N-dimethyltryptamine (DMT), DMT-Nb-oxide, 5-methoxy-DMT (see Figure 1), as well as two unidentified 5-oxy-indole-3-alkylamines, an unidentified indole-3-alkylamine, and an unidentified β-carboline, were isolated from a mixture of the pods, seeds, leaves, and roots of *M. pruriens* using thin-layer chromatography (Ghosal et al. 1971).

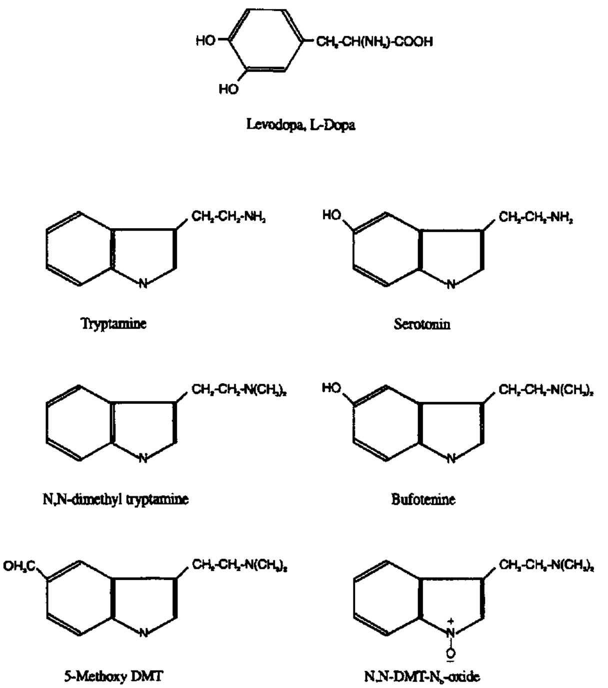

Figure 1. Phytochemical constituents of *Mucuna.*

The hallucinogenic properties of tryptamines, particularly DMT and its derivatives, are well documented, 5-methoxy-DMT being the main component of the intoxicating snuffs used by some South American Indians (Ahlborg et al. 1968). Ghosal et al. (1971, p. 283) suggested that the basis of the plant extracts used "by indigenous people as an uterine stimulant lies in the spasmolytic action of indole-3-alkylamines" and that the claimed "aphrodisiac action of *Mucuna* spp. is consistent with the presence of 5-methoxy-N,N-dimethyltryptamine." These researchers investigated the effect of *Mucuna* indole-3-alkylamines on the cardiovascular and central nervous systems, as well as on smooth and skeletal muscles, of experimental animals, but no one has so far undertaken a comparative phytochemical investigation of *Mucuna* species, subspecies, and varieties. Apart from the apparent universal incidence of L-Dopa (3-7%) in *Mucuna* spp. (Versteeg et al., this volume), one can expect variation in the alkaloid profile of plants of different genetic constitutions and species or varieties grown in different geographic locations under different climatic and environmental conditions. Burkill (1966) reported that seeds of *M. aterrima* (Mauritius or black velvetbean) grown in Nyasal and St. Vincent, West Indies, contained neither alkaloids nor glucosides; Burkill made no reference to L-Dopa content.

In short, the main concern about the utility of *Mucuna* is its toxic effects on humans, effects involving L-Dopa itself, on the one hand, and the indole-3-alkylamines, on the other. N,N-dimethyltryptamine and bufotenine are controlled substances in many countries, and they are psychoactive in humans at extremely low doses. Hence, they are unacceptable in food derived from these plants.

A phytochemical assessment of currently used *Mucuna* cultivars

Because the phytochemical literature is unclear about the taxonomic and tissue distribution of secondary substances in *Mucuna*, we undertook a survey of 36 accessions for tryptamine content of seed. These represent a selection of many common cultivars of *Mucuna* grown worldwide. We used a method of high-performance liquid chromatography (HPLC) sensitive enough to detect nanogram quantities (modified from Borner and Brenneisen [1987] and Meckes-Lozoya et al. [1990]) but detected no tryptamines in any of the seed extracts of the accessions. Although general literature reviews report these compounds in the genus, no primary journal article reports tryptamines specifically in the seed of *M. pruriens*; the Ghosal et al. (1971) report was based on an analysis of whole-plant material, including pods, seeds, leaves, and roots.

We also analyzed the seeds of the same accessions for L-Dopa content, using new rapid-extraction procedures and HPLC developed in our laboratory (Lorenzetti et al., unpublished), which gave results largely in agreement with those obtained with procedures routinely used elsewhere (Daxenbichler et al. 1971; R. Myhrman, unpublished data[1]). The L-Dopa content of the seeds of the 36 accessions available to us (summarized in Table 1) ranged from a low of 2.18% dry weight (DW) (*Mucuna* [Georgia velvetbean]) to a high of 6.17% DW (*M. pruriens* var. *deeringiana*), a range comparable to that normally found in cultivated *Mucuna*.

Because of the uncertainty underlying the identification of the cultivars (many accessions bore vernacular or locally used names), it was impossible to ascertain whether each accession effectively represent a unique genotype. However, cultivars producing seeds of the same appearance were likely to have been derived from the same parental stock. When the data were pooled by seed colour or appearance (stippled, black, speckled, or white), we found that the group containing stippled seeds, including the Georgia velvetbean, had significantly lower L-Dopa content than the other groups (Figure 2), suggesting that some genetic variation

[1]R. Myhrman, Director, World Hunger Resource Center, Judson College, Elgin, IL, USA, personal communication, 1996.

Table 1. L-Dopa content of *Mucuna* seeds tested in this study.

Accession name [a]	Accession number [b]	Seed colour	Country of origin [c]	Country grown in	Locality [d]	Source	L-Dopa (% DW)
M. blanca	1	White	Mexico	Mexico	Santa Rosa, Ver.	R. Puentes	3.95
M. blanca	2	White	Mexico	Mexico	Soteapan, Ver.	R. Puentes	4.38
M. blanca	3	White	Mexico	Mexico	La Candelaria, Ver.	R. Puentes	4.53
M. pruriens (Veracruz)	4	White	Mexico	Benin	Cotonou (IITA)	A.E. Eteka	5.63
M. pruriens (Tlaltizapan)	5	White	Mexico	Honduras	Tegucigalpa (CIAT)	H.J. Barreto	4.55
M. pruriens (IITA–Benin)	6	White	Benin	Honduras	Tegucigalpa (CIAT)	H.J. Barreto	4.70
M. pruriens (Brazil)	7	White	Brazil	Honduras	Tegucigalpa (CIAT)	H.J. Barreto	4.95
M. cochinchinensis	8	White	NA	Benin	Cotonou (IITA)	A.E. Eteka	5.89
M. cochinchinensis	9	White	NA	Benin	Cotonou	D. Buckles	5.90
M. cochinchinensis (*jaspeada*)	10	White	NA	Brazil	Santa Catarina	D. Buckles	4.85
M. cochinchinensis (*jaspeada*)	11	White	NA	Benin	Cotonou (IITA)	A.E. Eteka	5.84
M. pinta	12	Speckled	Mexico	Mexico	Santa Rosa, Ver.	R. Puentes	4.06
M. pinta	13	Speckled	Mexico	Mexico	Soteapan, Ver.	R. Puentes	3.54
M. pinta	14	Speckled	Mexico	Mexico	La Candelaria, Ver.	R. Puentes	4.83
M. pruriens (Veracruz)	15	Speckled	Mexico	Benin	Cotonou (IITA)	A.E. Eteka	5.37
M. pruriens (Veracruz)	16	Speckled	Mexico	Mexico	Sierra de Santa Marta, Ver.	D. Buckles	4.82
M. deeringiana	17	Speckled	Brazil	Benin	Cotonou (IITA)	A.E. Eteka	6.17
M. pruriens (Atlantida)	18	Speckled	Honduras	Honduras	San Francisco de Saco	H.J. Barreto	4.99
M. negra	19	Black	Mexico	Mexico	Santa Rosa, Ver.	R. Puentes	4.60
M. negra	20	Black	Mexico	Mexico	La Candelaria, Ver.	R. Puentes	4.50

M. negra	20	Black	Mexico	Mexico	La Candelaria, Ver.	R. Puentes	4.50
M. negra	21	Black	Mexico	Mexico	Soteapan, Ver.	R. Puentes	3.59
M. pruriens	22	Black	Mexico	Mexico	Sierra de Santa Marta, Ver.	D. Buckles	3.76
M. pruriens	23	Black	Mexico	Benin	Cotonou (IITA)	A.E. Eteka	5.48
M. pruriens	24	Black	NA	Honduras	Tegucigalpa (CIAT)	H.J. Barreto	4.40
M. pruriens var. *utilis*	25	Black	NA	Benin	Cotonou (IITA)	A.E. Eteka	5.74
M. pruriens (*preta*)	26	Black	Brazil (?)	Benin	Cotonou (IITA)	A.E. Eteka	5.52
M. pruriens (*preta*)	27	Black	Brazil	Brazil	Santa Catarina	D. Buckles	4.32
M. pruriens (*preta*)	28	Black	Brazil	Brazil	Santa Catarina	D. Buckles	3.77
Georgia velvetbean	29	Stippled	United States	United States	Georgia	D. Buckles	2.53
Georgia velvetbean	30	Stippled	United States	Honduras	Tegucigalpa (CIAT)	H.J. Barreto	2.18
M. pruriens (*rajada*)	31	Stippled	Brazil (?)	Benin	Cotonou (IITA)	A.E. Eteka	4.22
M. pruriens (*rajada*)	32	Stippled	Brazil	Brazil	Santa Catarina	D. Buckles	3.69
Mucuna spp. (*rayada*)	33	Stippled	Brazil (?)	Honduras	Tegucigalpa (CIAT)	H.J. Barreto	2.62
Mucuna spp.	34	Black	India	India	Mokokchung, Nagaland	D. Buckles	3.56
Mucuna spp.	35	Yellow	Ghana	Mexico	Santa Rosa, Ver.	R. Puentes	4.06
M. pruriens	36	Mainly black	Ghana	Benin	Cotonou (IITA)	A.E. Eteka	4.77

Note: DW, dry weight; CIAT, Centro Internacional de Agricultura Tropical (international centre for tropical agriculture); IITA, International Institute of Tropical Agriculture; NA, not available; Ver., Veracruz.

[a] Accession names as indicated on the label of the package received at the University of Ottawa.

[b] Accession numbers given by the University of Ottawa.

[c] Country where the cultivar has been grown traditionally.

[d] Locality where the cultivar was grown.

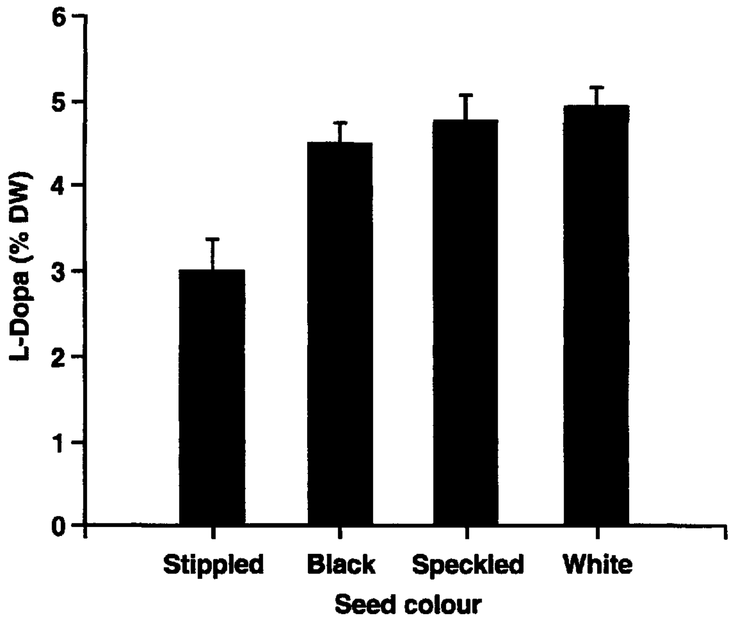

Figure 2. L-Dopa content of seeds of the *Mucuna* accessions tested in this study grouped on the basis of seed colour. Means and standard errors are shown. An analysis of variance indicated a significant variation in the L-Dopa content of seeds of different colour ($F_{3,29}$ = 7.828, P = 0.001). However, an *a posteriori* test for comparison among means (Tukey's test, P = 0.05) indicated that only stippled seeds have a significantly different L-Dopa content. Note: DW, dry weight.

occurs in the production of L-Dopa. Our study provides information not contained in previous reports on the variation in L-Dopa content in *Mucuna* spp. and cultivars (R. Myhrman, unpublished data[2]), as we observed the variation based on seed appearance pooled across different growing locations around the world.

A more detailed picture of the variation in L-Dopa content of seeds of different appearance is given in Figure 3, which shows data for each growing location. It is important to note, first, that the ranking of the types of seeds is the same when plotted by location (Figure 3) and pooled across all locations (see Figure 2). This is an encouraging observation, confirming that genetic variation is present. The second conclusion to be drawn from Figure 3 is that L-Dopa content

[2]R. Myhrman, Director, World Hunger Resource Center, Judson College, Elgin, IL, USA, personal communication, 1996.

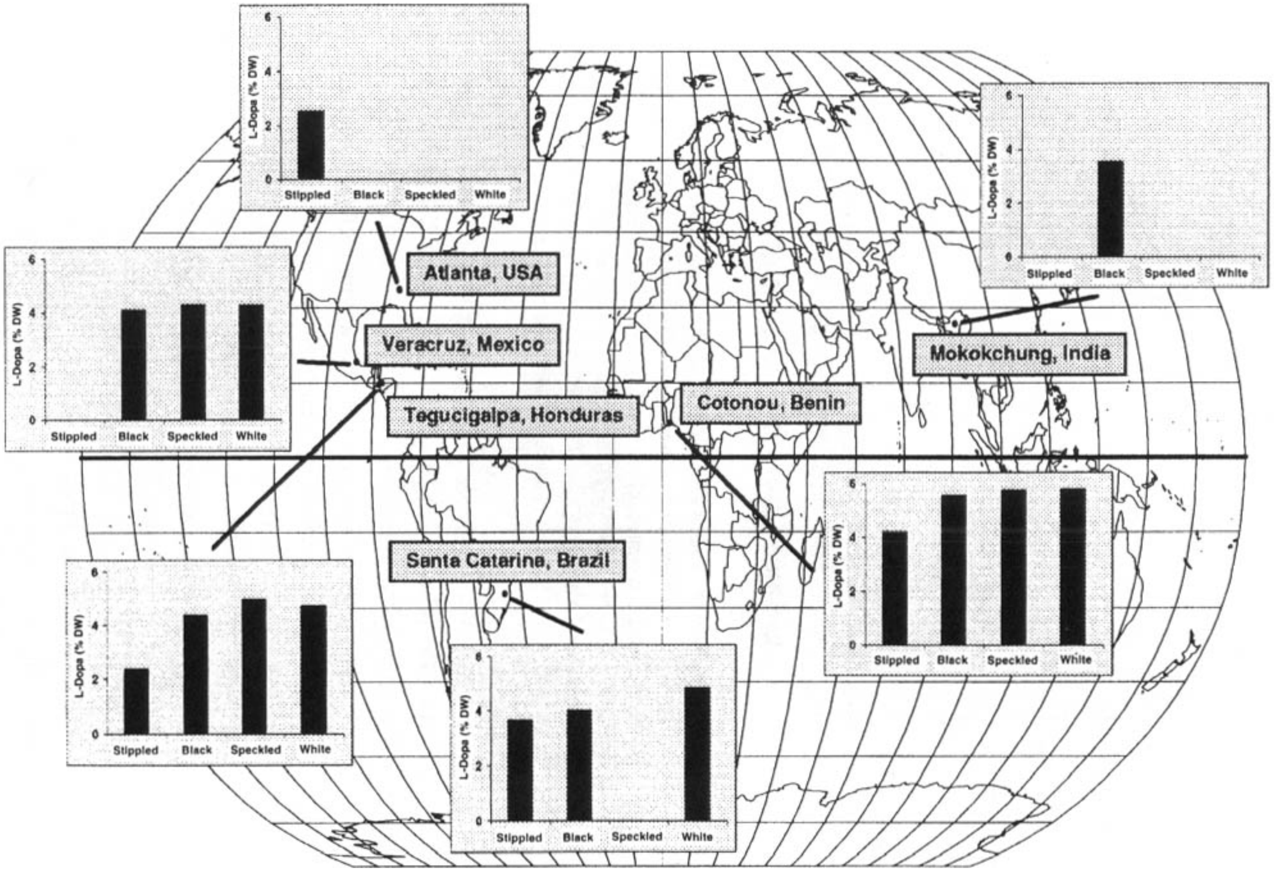

Figure 3. L-Dopa content of seeds of *Mucuna* accessions from plants grown in different locations around the world. Seeds of the same colour have not necessarily been collected from plants of the same cultivar when grown in a different location (see Table 1). Note: DW, dry weight.

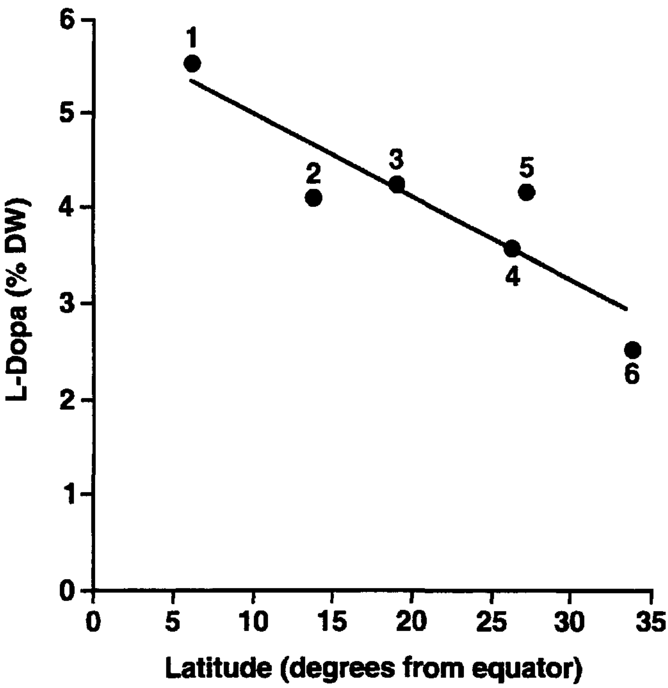

Figure 4. L-Dopa content of seeds of *Mucuna* accessions in relation to the latitude where the plants were grown. A linear regression analysis indicated that latitude significantly explained 78.2% of the variation observed in the mean L-Dopa content of the seeds ($y = -0.086x + 5.819$, $F_{1,4} = 14.386$, $P = 0.019$). Latitudes: (1) Cotonou, Benin, 6.24°N; (2) Tegucigalpa, Honduras, 14.05°N; (3) Veracruz, Mexico, 19.11°N; (4) Mokokchung, Nadaland, India, 26.20°N; (5) Santa Catarina, Brazil, 27.5°S; (6) Atlanta, Georgia, USA, 33.45°N (Collective 1968). Note: DW, dry weight.

varied between locations, with the seeds from Benin having the highest amount. A better indication of the relationship between location and L-Dopa content is given when the data are plotted in relation to latitude (Figure 4); seeds appear to contain significantly more L-Dopa in plants cultivated within 10° of the equator.

Variation in light intensity and in backscattered ultraviolet radiation, which increase toward the tropics, are potential factors underlying this relationship. In an experiment conducted by Pras et al. (1993) in which plant-cell suspension cultures of *M. pruriens* were grown under two intensities of light, more L-Dopa was produced under the lower light regime. Ultraviolet light induces the synthesis of phenylalanine-ammonia-lyase (Liu and McClure 1995), an enzyme involved in the deamination of phenylalanine, the precursor of several phenolic compounds of plants and L-Dopa. Whether ultraviolet light also increases the synthesis of the substrate phenylalanine, which in turn would stimulate the production of L-Dopa, is not known. Controlled experiments would be needed to precisely isolate the factors involved.

Table 2. Adverse reactions observed in 60 patients with Parkinson's disease treated for 12 weeks with *Mucuna* phytomedicine.

Reaction	Frequency (%)
Vomiting	1.7
Nausea	11.7
Abdominal distention	6.7
Dyskinesia	3.3
Insomnia	3.3

Source: Data from Manyam (1995).

A formally designed study of genotype × environment interaction would provide breeders with more information about the relative contribution of each source of variation in the yield of L-Dopa. At this early stage, however, our results suggest that a breeding program aiming to lower L-Dopa content in the seed should be conducted close to the equator.

Assessing and reducing the toxic risk of *Mucuna*

Fortunately, tryptamines represent no risk in any of the *Mucuna* seeds of common cultivars we have tested. Further research needs to be conducted on leaves, stems, and seedpods because these could be a hazard to farmers working with the crop and to animals consuming the foliage as fodder.

Although the acute oral LD_{50} of L-Dopa is very high in rats (4 g kg^{-1}), current European pharmacological literature gives 1 500 mg per patient as the maximum tolerable dose for the chronic treatment of Parkinson's disease, without bringing on serious physiological complications (OVP 1995). This figure could be used as an initial guideline for *Mucuna*-derived L-Dopa consumption, but other toxic interactions are always possible when *Mucuna* is consumed in foods produced from plant powder. Fortunately, some recent information is available on people's tolerance to *Mucuna* seed. In a 12-week clinical study of a standardized phytomedicine derived from *Mucuna* seed (3.33% L-Dopa) for treatment of Parkinson's disease, the mean daily dose was 45 g per individual at the end of treatment (Manyam 1995). This is the equivalent of 1 500 mg of L-Dopa per patient. The adverse reactions in 60 subjects afflicted with Parkinsonism were relatively mild (Table 2), and no significant effect on blood chemistry was observed. The reactions resembled those with refined L-Dopa. Even with chronic oral administration of the same phytomedicine to rats for up to 1 year at 10 g kg^{-1} d^{-1}, no serious abnormalities were observed.

Table 3. Consumption of *Mucuna* food products required to reach maximum daily tolerable dose of L-Dopa for adults.

Mucuna food product consumed	L-Dopa content (%)	Amount consumed to reach maximum [a] (g)
Unprocessed seed (maximum, this study)	6.170	24.3
Unprocessed seed (minimum, this study)	2.180	68.8
Pure *Mucuna* flour detoxified by boiling [b]	0.360	416.0
Pâte prepared from *Mucuna* flour–maize flour (1 : 2) [b]	0.095	1 579.0

[a] Maximum daily tolerable dose of L-Dopa = 1.5 g/individual.
[b] Data from R. Myhrman, cited in Versteeg et al. (this volume).

Although no information is available on the toxicological limit of *Mucuna* consumption specifically for children or pregnant women, for other adults at least it can be estimated from the toxicological study using the 1 500 mg L-Dopa per individual guideline (Table 3). Even a small meal (<100 g) prepared using unprocessed *Mucuna* seeds from any of the accessions exceeded safe L-Dopa limits. However, in some experiments the L-Dopa content was reduced by thoroughly cracking the seeds, soaking them overnight, boiling them for 20 min, and soaking them again overnight (Versteeg et al., this volume). When processed in this way, almost 0.5 kg of seed can be safely consumed. As reported by Versteeg et al. (this volume), a traditional West African *pâte* prepared with processed *Mucuna* flour and maize flour is safe to consume at any reasonable level.

Although processing is one option, there is still a risk of intoxication with high L-Dopa seeds, especially during times of crisis when it may be the only food readily available. Low L-Dopa genotypes are clearly desirable. Although the present study suggests a stronger environmental than genetic influence on L-Dopa content, enough variation occurs for breeders to consider a program of selection for low L-Dopa content. Reduction to a level of 1% would allow consumption of up to 150 g of seed d^{-1}, which would provide about 42 g of protein. Breeders will require a faster, less expensive analytical method than HPLC to process enough accessions for rapid selection. For this reason, we are investigating alternative techniques in our laboratory at the University of Ottawa. One attractive proposal entails cloning an enzyme for L-Dopa synthesis and using antisense technology to reduce L-Dopa levels.

Agroecological implications of altering secondary metabolism in velvetbean

Removal or reduction of velvetbean seed's secondary defences may seriously impair the plant's ability to protect itself against seed predators. Velvetbean seed is relatively free of insect problems, such as the bruchids that attack cowpea and *Phaseolus* beans. The reduction or removal of L-Dopa may make seeds more attractive to already established velvetbean pests or allow insects normally attracted to other hosts to switch to velvetbean. For example, we have found that the selection of alfalfa for lowered saponin concentration made it a suitable food substrate for European corn-borer larvae, whereas the high-saponin genotypes were inimical to insect development (Nozzolillo et al. 1997).

Conventional selection by breeders for lower expression of L-Dopa in seeds may have adverse effects on the beneficial role of *Mucuna* species as a cover crop if selection also alters the expression of secondary metabolism in vegetative parts. Suppression of weeds by cover crops is frequently related to the allelopathic and competitive abilities of the cover species. Allelopathic effects of cover crops on weeds have been clearly demonstrated in a number of studies. Rye has been used widely as a cover crop in temperate agriculture, and its ability to reduce weeds is related to the transformation of hydroxamic acid derivatives to phytotoxic azobenzenes in the soil (Chase et al. 1991).The traditionally used Mexican cover crop *Ipomea tricolor* reduces weeds in intercropped cornfields in Mexico. It produces the allelopathic resin trichlorin A, with potent inhibition of seedling growth, partly through its inhibition of plant H^+-ATPases, which are responsible for acidification and expansion of young plant-cell walls (Calera et al. 1995).

Postharvest processing

As sources of L-Dopa, *M. pruriens* and *M. cochinchinensis* have been extensively investigated (Lubis and Sastrapradha 1981; Parikh et al. 1990; Zhang et al. 1991; Su et al. 1992), as have a variety of treatment procedures for detoxification of the seeds and their food preparations (Osei-Bonsu et al. 1996; Versteeg et al., this volume). Chinese scientists have also examined *Mucuna macrocarpa* Wall. as a source of L-Dopa (Chen et al. 1993). The postharvest extraction of L-Dopa may lead to a commercially feasible chemical feedstock or fine chemical because L-Dopa is in demand in the pharmaceutical industry for treatment of Parkinson's disease. The cost–benefit of extraction would have to be evaluated. L-Dopa is prone to oxidation during extraction, and suitable procedures need to be developed to ensure good yields of pure material.

Conclusions

Tryptamines are not present in currently used cultivars of *Mucuna*, and simple processing techniques (Versteeg et al., this volume) reduce the L-Dopa content to levels safe for human consumption. Field testing of food-processing techniques and acceptability among smallholder households in West Africa should be continued, and promotional strategies for specific food products should be developed. Impacts on labour use by women and men, perceptions of taste, recipes, and nutritional composition of specific dishes are key considerations. A continuing chemotaxonomic study (phytochemical investigation, coupled with a modern molecular taxonomic assessment), is also proposed for the following species and varieties: *M. aterrima* Holl., *M. cochinchinensis* A. Chev., *M. macrocarpa* Wall., and *M. pruriens* (L.) DC. and its varieties. Selection or molecular manipulation of cultivars for lower L-Dopa content in seed should also be initiated, a step that would enhance the general utility of the crop.

Acknowledgments

This research was funded by the International Development Research Centre (IDRC) of Canada. *Mucuna* seeds were collected by D. Buckles (IDRC) or kindly provided by R. Puentes (Mexico), H.J. Barreto (International Centre for Tropical Agriculture, Honduras), and A.E. Etèka (International Institute of Tropical Agriculture, Benin). We thank Rolf Myhrman, Judson College, Illinois, United States, for providing seed samples and L-Dopa data so that we could test the quality of our analytical procedures.

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The role of legume fallows in intensified upland rice-based systems of West Africa

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Abstract

Traditional upland rice-based cropping systems in West Africa rely on periods of fallow to restore soil fertility and prevent the buildup of insect pests and weeds. Population growth and increased demand for land are forcing many farmers to intensify their rice-production systems. The farmers have shortened the fallow periods and increased the number of crops they grow before leaving the land to extended fallow. The result has been a significant yield reduction. Promising cropping-system alternatives include the use of site-specific, weed-suppressing, multipurpose cover legumes as short-duration fallows. In view of the poor rate of adoption of legume technology and the paucity of research on fallow management in the extremely diverse upland rice-based systems of West Africa, a multiscale approach to generating and extrapolating fallow technology is needed.

In this study, we determined the constraints to rice production and the yield gaps related to intensification in 190 farmers' fields in three agroecological zones (farm level). We evaluated N accumulation and weed suppression in 54 legume accessions grown for 6 months during the dry season under a range of hydrological and soil conditions (plot level). To increase the benefits of improved fallow technology, we also determined the timing of legume establishment in relation to that of rice and the effect on crop and weed growth of four treatments: removing, burning, mulching, and incorporating fallow residues before the rice crop is planted. Farmers' reactions to improved legume fallows were evaluated in group interviews. "Best-bet" technologies for given rice-based systems were being evaluated at the village level throughout the region in the framework of a regional research network (Rice Cropping Systems Task Force).

Legume fallows appeared to offer the potential to sustain rice yields under intensified cropping. Absolute effects varied as a function of site, legume species, and management practice. Weed control and multiple-use options were important determinants of legume-technology adoption. Farmers' preferences for various legume phenotypes and management practices depended on their resources and the production system.

Résumé

La croissance démographique et la pression foncière contraignent de nombreux paysans d'Afrique de l'Ouest à intensifier leur système de production de riz caractérisé traditionnellement par des jachères de courte durée pour améliorer la fertilité du sol et contrôler les ravageurs. La surexploitation des terres entraîne généralement une réduction importante du rendement. Les activités de recherches de l'Association pour le développement de la riziculture en Afrique de l'Ouest indiquent que la gestion de la jachère par l'introduction des légumineuses de couverture peut aider à stabiliser les systèmes de production à base de riz pluvial grâce à la réduction de la pression des mauvaises herbes et des ravageurs, et à améliorer des paramètres physiques du sol et la capacité d'amendement en N. Le criblage et l'évaluation de 54 espèces de légumineuses ont révélé que *Stylosanthes guianensis*, *Macroptilium* spp. et *Aeschynomene histrix* étaient les meilleures espèces sur des sols acides fixant le P (Ultisols) dans la zone de forêts humides. Dans la zone de savane, *Canavalia ensiformis* a montré la plus forte accumulation en N, *Crotalaria juncea*, *Aeschynomene afraspera* et *Sesbania rostrata* étaient plus efficace dans la lutte contre les mauvaises herbes, et *S. guianensis* était plus résistant à la sécheresse. Les légumineuses ligneuses telles que *C. juncea*, *A. afraspera* et *S. rostrata* ont fourni, outre le bois de chauffe, une capacité d'amélioration du sol en N. Une réduction considérable de la population de nématodes parasites des racines, *Hirschmaniella* spp. et *Tylencorynchus* spp., a été observée avec l'utilisation du *Dolichos*, de l'*Aeschynomene*, du *Mucuna* et du *Calopogonium*. Cette utilisation a démontré sa supériorité économique à la jachère naturelle par la réduction de la demande en main-d'œuvre. La réflexion des paysans au sujet des légumineuses a prouvé que le profit économique direct des jachères de légumineuses pourrait largement améliorer leur adoption.

Introduction

In contrast to agricultural practices in Asia, in Africa rice is largely grown in the uplands. In West Africa, the uplands constitute the most important rice-growing environment, in terms of area (60%) and regional production (40%) (Terry et al. 1994). Most food crops, including rice, are produced in extensive production systems, in which farmers traditionally rely on extended periods of fallow to restore soil fertility and to control insect pests and weeds (Johnson and Adesina 1993; Roose 1994). However, population growth has forced farmers to intensify land use in an unprecedented way (Becker, Johnson et al. 1995). Surveys of rice-based systems in West Africa indicate a reduction from about 12–15 years of secondary forest fallow in the early 1980s to 3–7 years at present (Becker and Assigbe 1995). In fallow-rotation systems of the Guinea savanna zone, the number of crop cycles between the 12- to 15-year fallows has increased from 23 to 47 during the same period. Finally, in cash-crop rotations (mainly cotton and soybean based), sedentary production systems without extended fallow periods are emerging in some areas (Le Roy 1995).

Without adaptation of management practices to the new production objectives, cropping intensification of upland ecosystems occurs at the expense of the quality of the resource base. Loss of soil nutrients is a major factor in the degradation of the African resource base, and 45.4 × 10^6 ha was estimated to have become moderately to severely degraded between 1945 and 1990 as a result of inappropriate management and nutrient depletion (Oldeman et al. 1991). Studies on shifting cultivation, mainly in maize-based systems, indicate that cropping intensification allows increased weed infestation (Nye and Greenland 1960; de Rouw 1994, 1995; Heinrichs et al. 1995) and reduces soil organic matter (Agboola 1994; Hien et al. 1994), which leads to a decrease in soil N (Gigou 1992). In cash-crop rotations, weed growth and nutrient deficiencies may be partially controlled by using herbicides and mineral fertilizers (Adesina et al. 1994). In this situation, the physical degradation (wind erosion, compaction) of the soils is rapidly emerging as the major production constraint (Wilson et al. 1982; Pieri 1992; Alegre and Cassel 1994).

Given the current intensity of land use and the fragility of upland soils in West Africa, production gains from subsistence food-crop agriculture are likely to be modest, despite the large area occupied by these systems. Efforts to generate technology should realistically aim at sustaining productivity gains and stabilizing intensified subsistence food-based systems. One of the most prominent cropping-systems alternatives is the use of leguminous cover crops to improve the quality of fallows (Balasubramanian and Sekayange 1992; Hoefsloot et al. 1993). Despite a large variability, the mean N accumulation in leguminous cover crops is reportedly high (about 100 kg N ha^{-1}). A major share of this N (about 70%) appears to be derived from biological N fixation (Peoples and Craswell 1992; Becker, Ladha et al. 1995; Peoples et al. 1995).

The encouraging results of three decades of research on leguminous cover crops in Africa (Hartmans 1981; Tarawali 1991), Asia (Yost and Evans 1988; Carangal et al. 1994), and Latin America (Lathwell 1990; Lobo Burle et al. 1992) have helped to promote and extend such technologies for improving soil fertility throughout the tropics (Bunch 1990; IITA 1993; Ladha and Garrity 1994). These efforts, however, stand in stark contrast to the poor rate of adoption of improved fallow technologies in tropical food-crop production systems (Becker, Ladha et al. 1995). Many of the studies have tended to focus on the benefits of such systems in terms of soil fertility and erosion control, ignoring system diversity, socioeconomic specifics, weeds, and farmers' perceptions and production objectives.

Rice is grown worldwide under a wider range of conditions than any other cereal crop, and rice in West Africa is no exception (Becker and Diallo 1992; Adesina 1993). However, very few studies on improved fallows in West Africa have been conducted on the rice-based cropping systems. To identify appropriate technologies and improve the likelihood that farmers will adopt new legume-fallow options, one needs to understand the diversity of regional, biophysical, and socioeconomic environments and target specific environments. Accordingly, our research involved the following activities:

- On-farm analysis of fallow-related rice-production constraints;
- Selection of legumes for a range of biophysical conditions;
- Adaptation of crop-management practices to maximize benefits from legume fallows;
- Determination of socioeconomic factors in farmers' adoption of improved fallows; and
- Participatory on-farm evaluation of "best-bet" technologies.

Materials and methods

The experiments in this study were conducted in four benchmark watersheds in three agroecological zones, as well as on the research farm of the West Africa Rice Development Association at Mbé, near Bouaké, in Côte d'Ivoire. A characterization of the five experimental sites is given in Table 1.

Constraint analysis

Diagnostic field trials were conducted in three agroecological zones of Côte d'Ivoire in 1994 and 1995 (Gagnoa, bimodal forest; Touba, derived savanna; and Boundiali, Guinea savanna). Traditional, extensive upland rice-production systems (>6 years fallow; rice as first crop after fallow) were compared with intensified cropping (<5 years fallow, rice after more than three crop cycles) in 191 farmers' fields. Weed-species composition and dry-biomass and rice-grain yields were determined under farmers' management, as well as in three superimposed researcher-managed subplots (hand-weeding at 28, 56, and 84 d; 15 kg ha^{-1} mineral fertilizer-N application; and a combination of both). Soil samples (0–20 cm) taken at the start of the cropping season were anaerobically incubated in the

Table 1. Experimental sites.

	Boundiali	Bouaké	Touba	Gagnoa	Man
Location					
Village	Poundiou	Mbé	Ouanenou	Guissihio	Yotta
Latitude	9.5°N	7.8°N	8.3°N	6.1°N	7.3°N
Longitude	6.3°W	5.0°W	7.7°W	6.1°W	8.2°W
Climate					
Agroecological zone	Guinea savanna	Derived savanna	Derived savanna	Humid forest [a]	Humid forest [b]
Growing period (d)	210	250	240	>270	>270
Annual rainfall (mm)	1 100–1 500	900–1 100	1 500–2 000	1 100–1 500	1 500–2 000
Rainfall distribution	Monomodal	Bimodal	Monomodal	Bimodal	Monomodal
Soil					
Soil class	Alfisol	Inceptisol	Inceptisol	Alfisol	Ultisol
Texture class	Loamy sand	Clay loam	Loam	Sandy loam	Sandy clay
pH range (KCl)	5.0–6.0	5.2–6.0	5.5–6.3	5.0–5.5	3.8–5.2

[a] Also referred to as bimodal forest.
[b] Also referred to as monomodal forest.

laboratory (composite samples of five soils each in five replications) and extracted after 1 and 3 months for soil exchangeable ammonium (2 *N* KCl) to determine potential soil-N-supplying capacity in a 2-month period (NH_4^+-N at 3 months − NH_4^+-N at 1 month of incubation). Yield gaps were attributed to weeds and N, based on yield response to the researchers' management in the intensified systems.

Legume adaptation

Fifty-four legume accessions (39 species of 28 genera) were selected from germplasm collections at the International Centre for Tropical Agriculture, the International Rice Research Institute, and the International Institute of Tropical Agriculture, as well as from local markets and from wild plants in West Africa. Legumes were grown during the dry season for 6 months between two crops of upland rice. Four sites were used in Côte d'Ivoire: Gagnoa (bimodal forest, sandy loam, Alfisol), Man (monomodal forest, sandy clay, Ultisol), Bouaké (derived savanna, sandy clay loam, Alfisol), and Boundiali (Guinea savanna, loamy sand, Alfisol). At each site, the legumes were grown in three replications. In addition, to determine legumes' adaptation to hydrological conditions, we grew 15 accessions for 3 months (April to July) at the research farm at Mbé, each in 1-m-wide and 60-m-long strips along a toposequence ranging from drought-prone upland, over the hydromorphic valley fringe, to a flood-prone rainfed lowland. At this site, the legumes were also grown in three replications. Dry-biomass and N content of weeds and legumes were determined at bimonthly intervals (site-adaptation study) or at monthly intervals (hydrological-adaptation study). The percentage of N derived from biological N_2 fixation was determined by difference methods (Hauck and Weaver 1986); nonfixing *Cassia occidentalis* and *Cassia tora* were used as reference plants. Farmers' reactions to fallow legumes were recorded during individual and group interviews at the sites in the forest and savanna zones.

Fallow-management practices

Considerations related to improved management of legume fallows included the following:

- At what stage of the upland rice crop the legume should be sown to maximize establishment for dry-season survival and soil cover while minimizing competition with the associated rice;
- How the fallow vegetation should be cleared in preparation for the succeeding rice crop; and

- How to fit a range of technology packages into existing rice-based cropping systems.

The timing of fallow establishment in relation to that of rice was examined at the research farm at Bouaké for the legumes *Tephrosia, Stylosanthes,* and *Calopogonium*, sown at 1, 28, 56, and 112 d after planting (DAP) rice (WAB 56-50), in three replications. At the same study site, the effects of four treatments — of removing, burning, mulching, and incorporating fallow residues before the rice crop is sown — on crop and weed growth were compared. The fallows consisted of the legumes *Calopogonium, Canavalia, Centrosema, Mucuna, Pueraria,* and *Vigna* and the natural vegetation (weeds), in three replications. In each experiment, rice, weed, and legume growth were recorded at monthly intervals.

Best-bet legume species and management practices for the major rice-based systems are being evaluated in seven countries of West Africa in the framework of a regional research network, involving rice scientists from 12 national programs (Rice Cropping Systems Task Force).

Results

Analysis of biophysical constraint

Diagnostic field trials were conducted to determine whether long-term productivity of upland rice can be sustained at current levels of intensification. Land-use intensification increases total upland rice production in the short term but results in a substantial reduction in plot-level grain yield (Table 2). These intensification-induced yield losses were higher in the forest zone (41%, $P = 0.03$) than in the derived savanna (31%, $P = 0.05$) or the Guinea savanna (20%, not significant) and appeared to be related mainly to increased weed infestation and reduction in soil-N-supplying capacity. The relative importance of weeds and N varied by agroecological zone.

Weeds seem to be the dominant factor responsible for yield loss in the forest (68% of the yield gap) but appeared to play a lesser role in the savanna. Short-fallow fields in the forest zone were dominated by broadleaf species (mainly *Chromolaena odorata*), whereas grasses (*Imperata, Digitaria, Hackelochloa,* and *Andropogon*) were dominant in the intensively cultivated fields in the savanna zones.

Cropping intensification generally reduced soil-N-supplying capacity. This reduction was greatest in derived savanna soils, where N supply explained 39%

Table 2. Effect of intensification of upland rice-based cropping systems on grain yield, weed biomass, soil-N supply, and the relative contributions of weeds and soil-N supply to intensification-related yield gaps, on-farm trials, Côte d'Ivoire, 1994–96.

	Bimodal forest [a]			Derived savanna [b]			Guinea savanna [c]			Intensification-induced changes across sites (%)
	Extensive (*n* = 35)		Intensive (*n* = 39)	Extensive (*n* = 25)		Intensive (*n* = 27)	Extensive (*n* = 28)		Intensive (*n* = 35)	
Observations										
Rice yield (Mg ha^{-1})	1.55	*	1.02	1.48	*	1.15	1.12	NS	1.02	–26
Weed weight (g ha^{-1})	1.56	*	30.2	27.4	*	43.9	36.8	NS	39.4	+72
Soil-N supply (mg kg^{-1})	14.9	*	11.3	24.9	*	16.6	14.0	NS	11.8	–26
Yield gap										Yield gap (%)
Total gap (Mg ha^{-1}) [d]	0.53			0.33			0.10			
% attributed to weeds [e]	68			34			44			51
% attributed to soil-N supply [f]	28			39			24			30
% unaccounted for	4			27			32			19

[a] Bimodal forest, Gagnoa, Ultisol on migmatite; 14 versus 4 years of fallow.
[b] Derived savanna, Touba, Inceptisol on basalt; rice first versus third crop after fallow.
[c] Guinea savanna, Boundiali, Alfisol on schist; rice first versus third crop after fallow.
[d] Yield difference between extensive and intensive systems.
[e] Based on yield in clean-weeded subplots.
[f] Based on yield in subplots receiving 30 kg N ha^{-1}.
* Significant at $P \leq 0.05$; NS, not significant.

of the yield gap. Changes in the soil's physical properties and increased pest pressure appear to have played a role in the observed yield decline (data not shown). This may be particularly true for the nearly continuously cultivated, mechanized rice–cash-crop rotations of the savanna zone, where more than 30% of the yield gap could not be explained by either weeds or N supply. These results clearly suggest that long-term upland rice productivity cannot be sustained at current levels of intensification. Improving the quality of the fallow vegetation by introducing leguminous cover crops may help to stabilize upland rice-based systems because legumes can reduce the buildup of weed infestations during short periods of natural fallow and improve the soil-N supply through biological N fixation.

Legume adaptation

The screening and evaluation of legume species for growth, weed suppression, and N accumulation in different agroecological zones, hydrological situations (as determined by toposequence position), soil types, and farmers' production systems indicated that no single species performs satisfactorily (>30 kg N ha^{-1} and >50% reduction in weed biomass) in all environments (Table 3; Figures 1 and 2). The forage-legume species *Stylosanthes guianensis, Canavalia ensiformis, Macroptilium latyroides,* and *Aeschynomene histrix* outperformed other legumes on acid P-fixing Ultisols in the humid forest zone in terms of biomass production (P = 0.05) and weed suppression (P = 0.01) (Table 3).

In the savanna zones, where N supply and soil cover are prime objectives of cover-legume use, *C. ensiformis* showed the highest biomass accumulation; *Crotalaria juncea* and *Mucuna* spp. showed good ground cover and suppression of weeds; and *Cajanus cajan* showed best dry-season survival. *Aeschynomene histrix, C. ensiformis,* and *S. guianensis* appeared to be well adapted across sites, producing good biomass and suppressing weeds. *Cajanus cajan, C. juncea,* and *Crotalaria retusa* (data not shown), which did well at three sites, failed at the forest–Ultisol site. The woody shrubs, *C. juncea, Aeschynomene afraspera,* and *Sesbania rostrata,* accumulated the largest amounts of N in rainfed lowland ecosystems (>60 kg N ha^{-1}) and effectively suppressed weed growth (Figure 3). The creeping annual legumes *Mucuna* and *Vigna* produced good growth relative to the natural weed growth in all studied hydrological situations (>1 000 kg ha^{-1}).

Farmers' reactions

The results of our survey of farmers' perceptions of legumes should be considered preliminary, as the sample size was small and interviews were limited to only two

Table 3. Maximum dry-biomass accumulation by some selected short-season fallow legumes and associated weeds during 6-month off-season growth between two crops of upland rice, four West African Rice Development Association key sites in Côte d'Ivoire, dry season 1995/96.

		DM accumulation (Mg ha^{-1}) [a]							
		Mbé		Man		Boundiali		Gagnoa	
Fallow vegetation	Legume type [b]	Legume	Weeds	Legume	Weeds	Legume	Weeds	Legume	Weeds
Aeschynomene histrix	F	3.59*cd*	0.47	2.90*bc*	0.64	1.94*bcd*	0.09	13.68*b*	0.00
Arachis hypogaea	F–G	2.64*de*	0.61	0.65*e*	1.35	0.99*d*	0.19	3.66*e*	2.16
Cajanus cajan	G	6.69*b*	0.21	0.00*f*	1.76	1.39*cd*	0.28	21.11*a*	0.00
Calopogonum mucunoides	GM	4.55*bcd*	0.41	0.17*e*	0.89	0.65*de*	0.10	3.94*e*	0.92
Canavalia ensiformis	GM	9.54*a*	0.43	4.09*a*	0.60	2.90*a*	0.17	11.03*b*	0.80
Centrosema pubescens	F	3.02*cd*	0.45	0.22*e*	1.55	0.39*ef*	0.13	3.59*e*	0.29
Clitoria ternata	F	2.75*de*	0.51	0.00*f*	1.84	0.66*e*	0.21	0.98*ef*	3.36
Crotalaria anageroides	GM	1.16*fg*	1.01	0.38*de*	1.19	1.29*d*	0.25	19.87*ab*	0.00
Crotalaria juncea	GM	8.36*ab*	0.50	0.00*f*	1.76	2.46*b*	0.04	6.33*cd*	1.30
Dolichos lablab	F–G	3.88*cd*	0.56	0.11*ef*	2.08	1.28*cde*	0.14	3.42*e*	1.10

Macroptilium latyroides	GM	3.63*cd*	0.68	1.49*cd*	1.04	1.81*c*	0.05	2.31*e*	2.08
Macrotyloma geocarpum	G	0.83*fg*	0.97	2.00*c*	1.43	0.69*e*	0.36	0.83*ef*	3.72
Mucuna cochinchinensis	GM	5.14*c*	0.35	1.77*cd*	1.14	2.98*a*	0.07	11.71*c*	0.00
Mucuna pruriens var. *utilis*	GM	4.15*cd*	0.30	0.98*d*	0.86	2.80*ab*	0.04	12.74*bc*	0.00
Pueraria phaseoloides	GM	1.62*ef*	0.41	0.51*de*	1.81	0.56*ef*	0.17	4.93*de*	0.00
Stylosanthes guianensis	F	5.11*cd*	0.58	2.99*b*	0.40	1.98*bcd*	0.03	16.55*b*	0.00
Tephrosia villosa	F	4.16*cd*	0.28	1.50*cd*	1.25	0.98*de*	0.14	7.53*cd*	0.34
Vigna unguiculata	G/F	1.92*ef*	1.16	0.74*d*	1.49	0.67*e*	0.10	0.31*ef*	2.34
Voandzeia subterranea	G	1.44*efg*	1.39	0.42*de*	1.28	1.27*d*	0.22	0.38*f*	2.95
Weedy-fallow control	—	—	1.12	—	1.70	—	0.29	—	3.59
$LSD_{0.05}$	—	1.29	0.70	0.54	0.81	0.49	0.08	3.58	1.56

Note: DM, dry matter; LSD, least significant difference.
[a] Mbé, derived savanna, Inceptisol; Man, monomodal forest, Ultisol; Boundiali, Guinea savanna, Alfisol; Gagnoa, bimodal forest, Alfisol.
[b] G, grain legume; F, forage legume; GM, green-manure legume.
a–g Values followed by the same letter within one column do not differ significantly by Duncan's multiple-range test ($P \leq 0.05$).

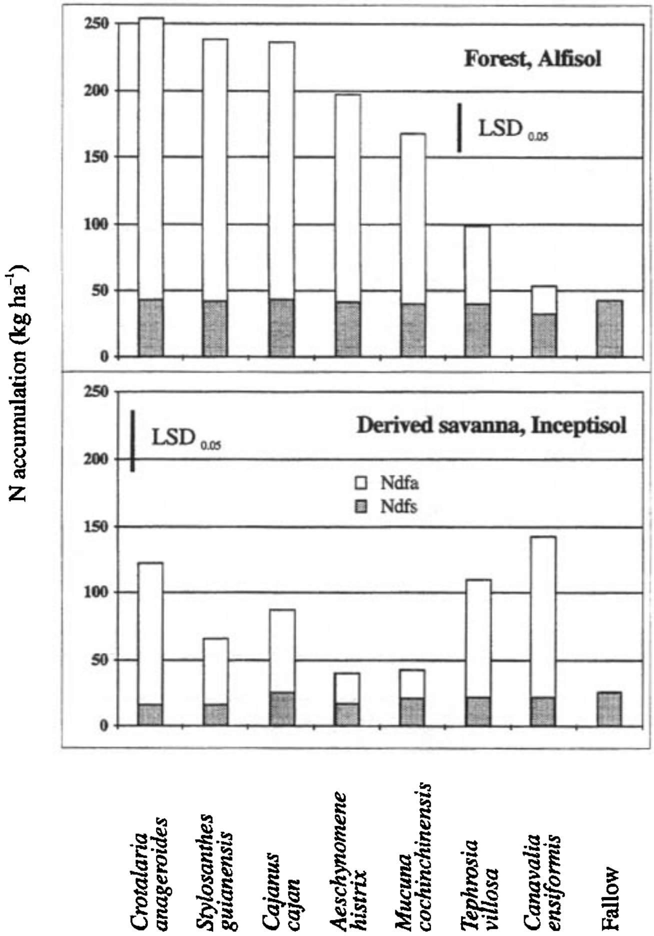

Figure 1. Nitrogen accumulation by selected cover legumes grown as short-season fallow during the 1995/96 dry season at two sites (Bouaké and Gagnoa) with favourable soil (Inceptisol, Alfisol) and hydrological conditions (bimodal rainfall). Note: Ndfa, N derived from atmosphere; Ndfs, N derived from soil.

sites in Côte d'Ivoire. Farmers who rely on cutting and burning to clear land (as in the forest zone of Côte d'Ivoire) considered creeping-cover legumes, such as *Calopogonium, Centrosema, Mucuna,* and *Pueraria*, inappropriate for their farming system, as these legumes are difficult to cut. In addition, *Centrosema, Calopogonium,* and *Pueraria* were known to these farmers as weeds that are difficult to control in upland rice. However, large-seeded legumes, such as *Mucuna* and *Canavalia*, were appreciated for their ability to suppress weeds, although, once slashed, they were considered hard to dry and difficult to burn.

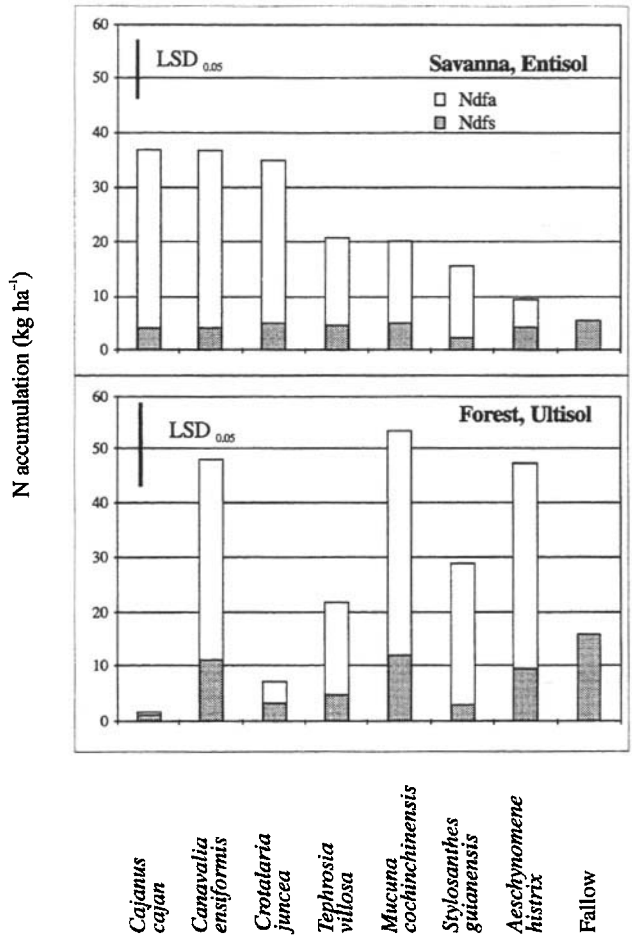

Figure 2. Nitrogen accumulation of selected cover legumes grown as short-season fallow during the 1995/96 dry season at two sites (Man and Boundiali) with unfavourable soil (Ultisol, Alfisol) and hydrological conditions (monomodal rainfall). Note: Ndfa, N derived from atmosphere; Ndfs, N derived from soil.

An additional problem was that dense stands, particularly of *Mucuna,* harboured snakes. Nevertheless, farmers who depended on slash-and-burn practices considered erect woody legumes, such as *Crotalaria* and *Cajanus*, manageable and appreciated their ability to provide firewood and sticks for fencing (for example, for agouti [bush rat] control). By contrast, farmers who incorporated residues into the soil, mainly manually (savanna upland rice-based systems and traditional or semi-improved lowlands), generally favoured creeping plants over erect ones, such as *Crotalaria* or flood-tolerant *Sesbania* spp., because labour requirements for incorporating creeping-legume residues were perceived to be less demanding.

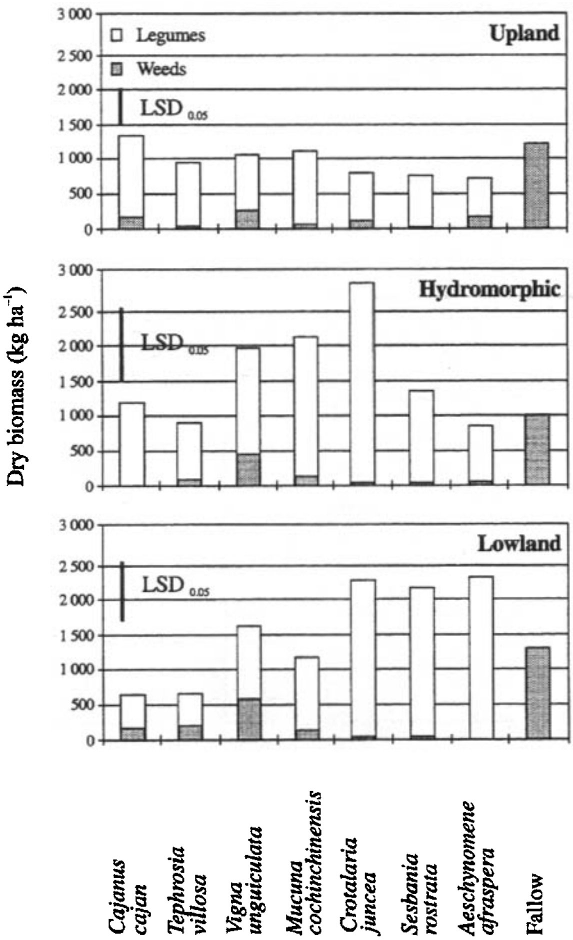

Figure 3. Dry-biomass accumulation by selected 3-month-old cover legumes and the associated weed flora along a hydrological gradient, inland valley toposequence, Bouaké, April–June 1995.

Farmers were interested in other possible uses of the legumes. Weed suppression by the fallow vegetation was considered essential in both forest and savanna ecosystems, and most savanna rice farmers considered the availability of high-quality forage during the dry season as being desirable. A direct economic benefit of improved fallows would, reportedly, increase farmers' adoption of legume technology.

Fallow-management practices

Across species, sowing the legumes at the same time as rice provided the best ground cover and the highest N accumulation (39 kg ha^{-1}) in the fallow biomass at the onset of the dry season but led to very low rice yields (0.3 Mg ha^{-1}) because of the interspecific competition (data not shown). There were no significant

Table 4. Effect of short-season fallow vegetation (October 1994 to May 1995) and residue management on weed infestation and grain yield of upland rice, field experiment, Bouaké, 1995.

	Weedy fallow	Legume fallow [a]	$LSD_{0.05}$
N accumulation before seeding (kg N ha^{-1})	26	81	17
Mean weed biomass across residue treatments (g m^{-2})	126	21	26
Rice-grain yield (Mg ha^{-1})			
Residues removed	0.34	0.88	0.38
Residues burnt	0.40	0.93	NS
Residues mulched	0.29	1.05	0.55
Residues incorporated	0.26	1.15	0.34
Mean yield	0.32	1.01	0.33
$LSD_{0.05}$	NS	0.23	

Note: LSD, least significant difference; NS, not significant.
[a] Mean of five legumes (*Calopogonium, Canavalia, Centrosema, Mucuna, Pueraria*).

differences in rice yields when legumes were sown at 28, 56, or 112 DAP rice (1.2 Mg ha^{-1}), but legume N accumulation at rice harvest increased with earlier fallow establishment (6, 19, and 36 kg N ha^{-1} when seeded 84, 56, and 28 DAP rice, respectively). The presence of legumes significantly reduced natural weed growth in rice at 56 and 84 DAP, compared with no-legume control plots. Modeling tools are being developed, as optimal legume-fallow establishment dates are likely to vary with rice cultivar, legume species, and ecosystem.

A summary of the results of the residue-management study is shown in Table 4. Across species, the legume-fallow vegetation accumulated more than three times as much N as the weedy fallow did and at the end of the fallow period contained only one-sixth as much weed biomass. Rice-grain yields after legume fallow were significantly higher than those following a weedy fallow ($P = 0.01$), and these tended to be highest when legume residues were incorporated. Across fallow-management treatments, weed growth at 28 DAP rice was lower when fallow vegetation had been removed than when it had been burnt, mulched, or incorporated (32, 67, 57, and 76 g m^{-2}, respectively, $LSD_{0.05} = 22$).

Based on a preliminary analysis of legume performance, site adaptation, and farmers' adoption criteria, we propose a number of best-bet legume scenarios for the major upland rice-based cropping systems in West Africa (Table 5). Major rice-growing environments, associated farming-system characteristics, relative importance in Côte d'Ivoire, some of the proposed fallow-legume species, and associated management practices are presented in this table.

Table 5. Major upland rice-based farming systems in West Africa, their relative importance in Côte d'Ivoire, and suggested fallow legume species and associated management practices, based on preliminary evaluation.

Agroecological zone	System characteristics	Share of rice-growing area in Côte d'Ivoire [a] (%)	Best-bet legume species	Associated management practices
1. Monomodal forest	Acid soils, subsistence, slash and burn, broadcast	10	*Aeschynomene histrix* *Stylosanthes guianensis* *Tephrosia villosa*	Relay seeding, burning
2. Bimodal forest	Neutral soils, subsistence, slash and burn, dibble	22	*Crotalaria anageroides* *Cajanus cajan* *T. villosa*	Post-rice seeding, burning, mulching
3. Forest	Valley fringes and hydromorphic areas	12	*Aeschynomene afraspera* *Crotalaria juncea*	Post-rice seeding, incorporation
4. Forest	Cash-crop based	<1	*Mucuna pruriens* *Canavalia ensiformis*	Relay seeding, mulching, incorporation
5. Savanna	Subsistence, slash and burn	2	*C. juncea* *C. cajan* *T. villosa*	Relay seeding, burning
6. Savanna	Subsistence, manual tillage	4	*C. ensiformis* *M. pruriens*	Relay seeding, incorporation
7. Savanna	Animal traction, cash-crop rotations	15	*S. guianensis* *A. histrix*	Relay seeding, grazing, incorporation
8. Savanna	Valley fringes and hydromorphic areas, manual	2	*Calopogonium mucunoides*	Post-rice seeding, incorporation

Source: Adapted from Becker and Diallo (1992).
[a] Represents 68% of total rice area.

Discussion

Weeds, N, and labour are important biophysical and socioeconomic production constraints in upland rice rotations under shortened-fallow management. Future problems in forest fallow and savanna cash-crop rotations may include P deficiency (Sanchez and Salinas 1981) and soil degradation, including erosion (Pieri 1992). Legumes can sustain productivity gains in intensified systems (Lathwell 1990; Becker, Ladha et al. 1995; Peoples et al. 1995). However, new fallow-management options must take account of the diversity of cropping systems, management practices, and farmers' production objectives. Our studies have shown that no single legume is adapted to the wide range of biophysical and socioeconomic rice-production environments of West Africa. One clearly needs to exploit the existing genetic diversity and to select appropriate legumes for given environments and farmers' production objectives. Creeping legumes, such as *Calopogonium, Centrosema, Mucuna,* and *Pueraria,* have attracted much research attention (Agboola and Fayemi 1971; Akobundu 1993; Tarawali and Ogunbile 1995). However, farmers who rely on burning to clear land in the forest zone have not adopted such legumes, as they do not suit their farming system.

The use of creeping legumes that are fit for human consumption, such as, *Mucuna* and *Canavalia* (Osei-Bonsu et al. 1995), may partially overcome this problem. In mechanized systems in the savanna zone, where soil erosion and physical degradation pose a serious threat to systems sustainability (Pieri 1992) and where cattle have to be fed during the dry season (Hoefsloot et al. 1993), forage legumes may provide an acceptable alternative to weedy fallows. Crop survival and good soil cover during the dry season (Lobo Burle et al. 1992), however, may necessitate relay establishment of the legume crop (Balasubramanian and Blaise 1993). Such practices may not be acceptable in mixed cropping systems, where the cover legume would compete for land with associated noncereal crops (Milton 1989). Similarly, benefits arising from modified residue-management practices (mulching and incorporation, instead of burning) have to be evaluated in relation to practicability (establishment, farm equipment, termites, etc.). Further, the effects of legume fallows on populations of nematodes and insects and their natural enemies are likely to become more important as rice-based systems intensify (Becker, Johnson et al. 1995).

Improvements in traditional systems must aim at increasing returns per unit of labour, because labour is commonly the greatest constraint to production in smallholder systems. In the traditional rice-production systems, for example, returns per unit of labour are about half those of the improved systems that use purchased inputs (Adesina 1994). Ouattara (1994) reported that farmers in the savanna zone of Côte d'Ivoire spend 408–506 h ha^{-1} hand-weeding their upland rice crop, which represents 40% of the total labour invested in rice. Early attempts to introduce *Mucuna* to farmers in Nigeria were rejected by farmers because the legume involved extra labour (land preparation, sowing, and fallow management) and did not fit into the traditional mixed-cropping system (Faulkner 1934). Similarly, Rwandan farmers considered short-season fallows less attractive, partially because of the additional labour needed for planting and managing the fallow vegetation (Balasubramanian and Blaise 1993).

Weed suppression is an essential factor in the success of improved fallow management. In several Task Force trials throughout the region, researchers reported that labour requirements (for example, for hand-weeding of upland rice) were substantially lower with legumes than with a weedy-fallow control, which may justify farmers' investing in an improved legume fallow. The ability of *Mucuna* to suppress the perennial grass *Imperata cylindrica* in maize-based cropping systems (Versteeg and Koudopon 1990; Akobundu 1993) prompted farmers to adopt cover-legume technology in areas of Benin where agriculture was plagued by this weed. Widespread adoption of *Mucuna* in maize-based cropping systems of northern Honduras appears to be partially related to the reduced labour requirements for field preparation and weed control (Triomphe 1996).

Conclusions

Legume fallows and associated management practices must be considered in the context of the cropping systems in which they are used (including farmers' resource base and aspirations). Because farmers are looking for direct returns on their investments, legumes in most situations have to perform functions in addition to providing N; in particular, they also have to reduce labour requirements or increase returns per unit of labour. They may achieve this by suppressing weeds or by providing additional harvestable products, such as food, fodder, or fuel. Improved productivity through reduced requirements for labour and for maintenance of soil fertility, without additional cash investment, is likely to achieve progress in this direction. As discussed in this paper, particular solutions must take account of the biophysical and socioeconomic specifics of prevailing systems if these solutions are to be successful. Researchers working within the framework of the Task Force are investigating the effects of legume fallows on rice pests and their natural enemies, as well as conducting *ex ante* and *ex post* economic analyses and participatory on-farm evaluations of best-bet options throughout the region.

Acknowledgment

DEJ was funded by the Overseas Development Administration, United Kingdom.

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Smallholders' use of *Stylosanthes* for sustainable food production in subhumid West Africa[1]

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Abstract

The subhumid zone of West Africa has 180–270 growing d and receives 900–1 500 mm of rainfall. The zone is covered mainly with ferruginous tropical soils that have very low levels of N and P and a low cation exchange capacity. The common farming system is crop–livestock, with a predominance of cash crops wherever these have been introduced. The genus *Stylosanthes*, which originated mainly in South America, was tested in West Africa as early as the 1940s in an attempt to improve livestock nutrition and soil fertility. Some of the major attributes explaining the success of this genus are tolerance to the fungal disease anthracnose, adaptation to infertile soils, drought resistance, ability to fix N without special *Rhizobium* inoculum, and high seed yield.

Integration of *Stylosanthes* into the West African farming systems intensified with the opening of the International Livestock Centre for Africa's subhumid research site in Kaduna, Nigeria, in 1978, and since then the genus has been exploited to suit the domestic needs of various countries.

The management systems included sole crops of *Stylosanthes* ("fodder banks") to supplement natural range or improved grass–legume and legume–legume associations. *Stylosanthes* has also been successfully integrated in crop rotations as an intercrop and relay crop.

Tremendous variation occurs in the research–development efforts and diffusion of *Stylosanthes* in the West African region. For instance, in Nigeria, this legume is exploited by smallholders for agropastoral herds, small ruminants, and crop production. More recently, the concept of mixed cover crops involving *Stylosanthes* was introduced, and evidence suggests that such a management system leads to more profitable and sustainable crop–livestock production systems. In Cameroon, a lot of potential exists for the

[1]Paper presented at the International Workshop on Green-Manure Cover Crop Systems for Smallholders in Tropical and Subtropical Regions, 6–12 Apr 1997, Chapeco, Brazil.

expansion of *Stylosanthes*-based enterprises into agropastoral herds, but the smallholders have not fully exploited such benefits. This is mainly because on-farm research and extension are in their infancy in this region. In Côte d'Ivoire, the use of *Stylosanthes* has been geared toward the dairy industry through the Eco-farms Project, a scheme jointly sponsored by the African Development Bank, Gesellschaft für Technische Zusammenarbeit (organization for technical cooperation), and the Ivorian government. The aim has been to enable smallholders to generate incomes equivalent to those of their counterparts in the cities. In Mali, *Stylosanthes* could improve cereal production and the performance of traction animals.

Some constraints to adoption, such as lack of labour and capital, plant disease, insufficient quantities of seed, and the expense of fencing, cut across all the four countries studied; other problems are specific to individual countries. The land-tenure constraint affecting agropastoralists, for instance, is more acute in Nigeria. In Côte d'Ivoire, pasture management is a serious problem in the Eco-farms where *Stylosanthes* is grown in association with aggressive grasses. Also, the scheme is too capital intensive. In Cameroon, the weak support for on-farm research and extension is unique, whereas in Mali, the successful cotton industry is providing capital for *Stylosanthes* adoption.

The potential of *Stylosanthes* for feed improvement, land reclamation, and control of noxious weeds should be further exploited by integrating the legume in crop rotations and promoting it to farmers with more profitable enterprises, such as those involving beef cattle, dairy cattle, traction animals, and cotton.

Other measures recommended for the long-term sustainability of *Stylosanthes* systems include the establishment of an adequate seed supply, identification of highly productive and disease-resistant varieties, use of live poles (for example, *Ficus*) for fencing, and the use of draft power. Government policies that promote loan schemes and protect land rights are also needed.

Résumé

La zone subhumide de l'Afrique occidentale se caractérise par une pluviométrie de 900 à 1 500 mm par année et par une période de croissance allant de 180 à 270 jours. Cette zone est principalement couverte de sols ferrugineux tropicaux qui ont un niveau très bas de N, de P et de capacité d'échange cationique. Le système d'exploitation agricole habituel est l'exploitation culture–élevage où prédominent les cultures commerciales là où celles-ci ont été introduites. Le genre *Stylosanthes*, qui provient surtout de l'Amérique du Sud, a été mis à l'essai en Afrique occidentale dans les années 1940, afin d'améliorer le fourrage ainsi que la fertilité des sols. Certaines des qualités essentielles attribuées au succès du genre *Stylosanthes* sont une tolérance à la maladie fongique, l'anthracnose, une adaptation aux sols infertiles, une résistance à la sécheresse, une capacité fixatrice de N sans inoculant rhizobien particulier, et un rendement grainier élevé.

L'intégration des *Stylosanthes* dans les systèmes d'exploitation agricole de l'Afrique occidentale s'est accrue depuis l'ouverture du site de recherche subhumide du Centre international pour l'élevage en Afrique à Kaduna, au Nigeria, en 1978. Depuis, le genre a aussi été exploité pour répondre aux besoins locaux de divers pays.

Les pratiques de gestion utilisées comprenaient les cultures de rangée de fourrage de *Stylosanthes* seules pour compléter la gamme naturelle ou les associations améliorées herbe–légumineuse et légumineuse–légumineuse. Les *Stylosanthes* ont aussi connu un succès dans leur intégration aux rotations de cultures comme culture intercalaire ou culture de relais.

Les efforts de recherche et de développement ainsi que les efforts de diffusion liés aux *Stylosanthes* en Afrique occidentale sont nombreux et variés. Par exemple, au Nigeria, cette légumineuse est cultivée par de petits exploitants pour la production de bovins, de petits ruminants et de cultures. Plus récemment, le concept de cultures de couverture mixtes utilisant les *Stylosanthes* a été introduit et semble démontrer qu'un tel système de gestion favorise une exploitation culture–élevage plus profitable et durable. Au Cameroun, il existe un grand potentiel pour l'expansion d'entreprises utilisant les *Stylosanthes* pour les troupeaux de pâturage, dont les petits exploitants n'ont pas encore complètement tiré parti. La raison principale est que la recherche en ferme et la vulgarisation en sont encore à leur début. En Côte d'Ivoire, l'utilisation des *Stylosanthes* est dirigée vers l'industrie laitière au moyen du Projet de fermes écologiques, une entreprise conjointement appuyée par le Groupe de la Banque africaine de développement, le Gesellschaft für Technische Zusammenarbeit (agence allemande de coopération technique) et le gouvernement ivoirien. Le but était de permettre aux petits exploitants de générer des revenus équivalant à ceux de leurs homologues des villes. Au Mali, les *Stylosanthes* offrent la possibilité d'améliorer le rendement des animaux de trait et celui de la production céréalière.

Les contraintes liées à l'utilisation de la légumineuse, telles que le manque de main-d'œuvre et de capitaux, les maladies des plantes, le manque de semences et les coupures imposées aux quatre pays à l'étude, s'ajoutent aux problèmes spécifiques de chacun des pays. Par exemple, la contrainte de la tenure qui nuit aux agropasteurs fulanis est typique du Nigeria. En Côte d'Ivoire, l'exploitation des pâturages est un sérieux problème pour les fermes écologiques, où les *Stylosanthes* poussent aux côtés d'herbes envahissantes. De plus, la structure fonctionne à trop forte intensité de capitaux. Au Cameroun, il existe peu de soutien pour la recherche en ferme et pour la vulgarisation, alors qu'au Mali, le succès des nouvelles technologies dans l'industrie du coton nuit à la popularité des *Stylosanthes*.

Il est recommandé d'exploiter davantage les possibilités que représentent les *Stylosanthes* pour l'amélioration alimentaire, la récupération des terres et le désherbage, en intégrant la légumineuse dans les rotations des cultures et en visant les entreprises plus rentables telles que le bœuf, les bovins laitiers, les animaux de trait et le coton.

Pour favoriser la durabilité des systèmes utilisant les *Stylosanthes*, il est également recommandé de s'approvisionner suffisamment en semences, d'utiliser des variétés hautement productives et résistantes à la maladie et de recourir à des intrants à moindre coût, tels les engrais, pour le billonnage cloisonné, en plus d'utiliser une puissance de traction, des politiques gouvernementales favorables aux systèmes de prêts et axées sur la protection des droits terriens.

Introduction

Subhumid West Africa

The West African subhumid zone (SHZ) covers Burkina, Benin, Cameroon, Côte d'Ivoire, The Gambia, Ghana, Guinea, Liberia, Nigeria, Senegal, Sierra Leone, and Togo. The SHZ has a single growing season (180–270 d) and covers 45% of sub-Saharan Africa (SSA). The common farming system is crop–livestock In some areas, cash crops predominate. The SHZ offers the greatest potential in SSA for growing crops and producing livestock, both of which are currently in crisis.

A major constraint to meeting the food demands in the SHZ is that SSA is experiencing substantial land degradation, leading to decreasing total agricultural productivity (Lal 1989). Marginal lands are increasing, as a result of land pressure from rapid population growth. Traditional grazing lands are acquired for cultivation, and the long fallow periods (crucial for regenerating the soil's fertility) have become unfeasible (Ruthenberg 1980). Recent studies suggest that the population of SSA (0.5 billion in 1990) will reach 1.2 billion by 2025 (Winrock International 1992). The studies also predict a demographic shift, with urban dwellers increasing from 29% to 55% of the population, implying that the rural sector will have to produce more food to feed the urban population.

Some technical developments have improved the crop–livestock production systems in the region. An example is the dual use of *Stylosanthes* as feed for starving animals and as an amendment for poor soils. Over the years, West African countries have developed various scenarios for exploiting the potential of this genus, based on their own needs. For instance, in Nigeria and Cameroon, *Stylosanthes* is used mainly for agropastoral herds, small ruminants, and crop production. In Côte d'Ivoire, the legume is used to boost the dairy industry; in Mali, to improve soil fertility and the performance of traction animals.

This paper provides a synthesis of the ways *Stylosanthes* is used in four West African countries — Nigeria, Cameroon, Côte d'Ivoire, and Mali — and the constraints to adoption of the technology. We selected these countries because they are known to use *Stylosanthes* at all levels and stages, from research through to on-farm adoption. We discuss the critical points and future opportunities for the long-term sustainability of *Stylosanthes*-based systems in subhumid West Africa. To obtain information, we reviewed the existing literature, made field visits, and held detailed discussions with smallholder farmers, researchers, and extension workers. This information is probably applicable to other countries in subhumid West Africa.

Brief history of *Stylosanthes*

Stylosanthes, a genus of the subtribe Stylosanthinae, tribe Aeschynomenae, subfamily Papilioniodae, family Leguminosae, occurs naturally in the tropical, subtropical, and temperate regions of the Americas, tropical Africa, and southeast Asia (t'Mannetje 1984). The major centres of diversification are the southern neotropics, particularly Brazil; a secondary centre is in the Mexican–Caribbean basin (Stace and Cameroon 1984). About 45 species and subspecies belong to the genus; these are classified into two sections, *Stylosanthes* and *Styposanthes*. *Stylosanthes* is self-fertile and predominantly self-pollinating. The range of photoperiod response in the genus is wide: short day, long day, day neutral, and long–short day. *Stylosanthes* spp. differ from most tropical pasture legumes in other genera because of their nonclimbing growth habit. Growing points are often close to the ground, and this is advantageous under grazing. Another rare feature of *Stylosanthes* is its single seed in an indehiscent pod, which helps to regulate germination and improve seed survival (Gardener 1975). *Stylosanthes* is the genus that has received most attention in the search for tropical pasture legumes, and this has resulted in the release of a wide range of commercial cultivars, as summarized in Table 1.

Overall, the genus is adapted to the tropics and subtropics. The natural habitats of *Stylosanthes* are usually areas of low soil fertility, especially where the soil has a low P content and an acidic nature, although forms adapted to alkaline soils are common in the Caribbean, Central America, and Mexico.

Stylosanthes has been shown to perform well under both drought and waterlogged conditions (Edye and Grof 1984). In contrast to most other tropical pasture species, *Stylosanthes* usually exhibits a high N content, combined with a very low P content, and the P content decreases as the plants age, especially under water stress. Although the amount of P is inadequate for the nutrition of grazing animals, other minerals seem to be available in sufficient amounts. In addition to improving natural rangeland and animal performance, *Stylosanthes* spp. have shown particular promise for inclusion in ley systems and as a cover crop in plantation agriculture (McCowan et al. 1986; Tarawali 1991).

Table 1. Released *Stylosanthes* cultivars.

Country and species	Common name	Cultivars	Year of release	Country of origin
Australia				
S. guianensis var. *guianensis*	Common stylo	Schofield	—	Brazil
		Cook	1971	Colombia
		Endeavour	1971	Guatemala
		Graham	1979	Bolivia
S. guianensis var. *intermedia*	Fine-stem stylo	Oxley	1965	Argentina
S. hamata (2*n* = 40)	Caribbean stylo	Verano	1973	Venezuela
		Amiga	1991	—
S. humilis	Townsville stylo	Common type	—	Australia
		Gordon	1968	Australia
		Lawson	1968	Australia
		Paterson	1969	Australia
S. scabra	Shrubby stylo	Seca	1976	Brazil
		Fitzroy	1979	Brazil
Brazil				
S. guianensis	Alfalfa de Nordeste	IRI 1022	1966	Brazil
S. guianensis var. *pauciflora*	Tardio stylo	Bandeirante	1983	Brazil
S. macrocephala		Pioneiro	1983	Brazil
China				
S. guianensis		Pia Hua Dou = CIAT 184 = Pulcallpa	1987	Colombia
Colombia				
S. capita		Capica	1982	Brazil
Peru				
S. guianensis		Pulcallpa = CIAT 184	1985	Colombia
Thailand				
S. humilis	Khon Kaen stylo	Khon Kaen	1984	Venezuela

Source: Peters (1992).

The response to inoculation with *Rhizobium* varies largely among and within species; the N-fixation efficiency presumably depends on the environmental conditions of the collection sites. There is some evidence that tetraploid and allotetraploid plants of *Stylosanthes* tend to be of the promiscuously nodulating type, whereas diploid species collected from alkaline soils are more specific. In glasshouse studies, *Stylosanthes* has shown positive reactions to inoculation with *Rhizobium* (Saif 1987). However, infection with native strains of *Rhizobium* is likely to occur under most field conditions; therefore, inoculation is usually unnecessary (Howeler et al. 1987).

The most damaging disease, and thus one of the major constraints to propagation of the *Stylosanthes*, is the fungal disease anthracnose, caused by *Colletotrichum gloeosporioides*. An extensive pathogenetic specialization and variation for virulence can be found among strains of *C. gloeosporioides*. *Stylosanthes* shows some field resistance, although this varies widely between accessions and agroecosystems.

Major attributes of *Stylosanthes hamata*

The genus *Stylosanthes* has provided ample germplasm for a wide variety of agroecological situations in the tropics. *Stylosanthes hamata* cv. Verano was found to be particularly adaptable in agropastoral farming systems in the SHZ of West Africa. This could be attributed to the following characteristics (de Leeuw and Mohamed-Saleem 1994):

- Rapid germination of seeds (50–80% within 2 d);
- Requirement for high temperatures (>50°C) to break dormancy (which means that out-of-season rainfall does not cause a problem);
- Rapid root growth, leading to deep penetration and high soil-water extraction at an early age;
- Fast aboveground growth rates during periods of high soil-water content and high temperatures (>25°C);
- Facultative-perennial nature (some plants survive into the next growing season, further assuring sustained seed production in most growing seasons);

- Species indeterminacy (nonselective defoliations during flowering and seed setting have no serious effects on subsequent seed yield);

- Efficient seed-dispersal mechanisms (herbivores ingest seeds, which are then spread by feces and transported by ants and termites);

- High anthracnose tolerance; and

- Low relative palatability (compared with grass) early in the growing season, but high levels in the late rainy and early dry seasons.

The subhumid zone of Nigeria

Climate and soils

The studies were mainly conducted in the SHZ of central Nigeria (Figure 1), which has an average annual rainfall of 1 200 mm (more than 95% of this falls between April and October) and a growing period of 180–270 d. It has a long, 6-month dry season (October–April). The soils are essentially ferruginous, with low C and N contents, poor drainage, and a low cation exchange capacity (CEC).

The herbaceous cover of the SHZ of Nigeria consists mainly of annual grasses (*Andropogon*, *Hyparrhenia*, *Pennisetum*, *Loudetia*, etc.), with a low percentage of native legumes (*Alysicarpus*, *Tephrosia*, etc.) and trees such as *Daniellia oliveri* and *Isoberlinia doka*.

Socioeconomic conditions and cultural features

In the Nigerian SHZ, *Stylosanthes* interventions target three major categories of livestock and crop farmers (Waters-Bayer and Taylor-Powell, 1986):

- *Pastoralists* — Full-time livestock keepers, ranging from those with no consistent association with a particular area (nomads) to those based at one site (pure pastoralists);

- *Agropastoralists* — Livestock keepers who practice some cropping but as an enterprise subsidiary to animal husbandry:

  - Transhumant agropastoralists — those who grow crops at one site but seasonally move all or some of their cattle to other grazing areas;

- Sedentary agropastoralists — those who keep cattle year-round close to the site of their cropping activities; and

- *Crop farmers* — Mostly indigenes who keep some livestock, mostly small ruminants, but as an enterprise subsidiary to cropping.

The agropastoralists are Fulani who no longer consider it necessary to move their small herds. These Fulani have settled close to farming communities, which provide markets for their meat, milk, and manure. In addition, they value the presence of public services, such as schools and dispensaries.

The settled Fulani live year-round at one site but shift every few years to another a few kilometres away, in contrast to the transhumant Fulani, who come into central Nigeria from the north each dry season. The influx of transhumant herds creates competition for grazing resources. The homesteads of settled Fulani

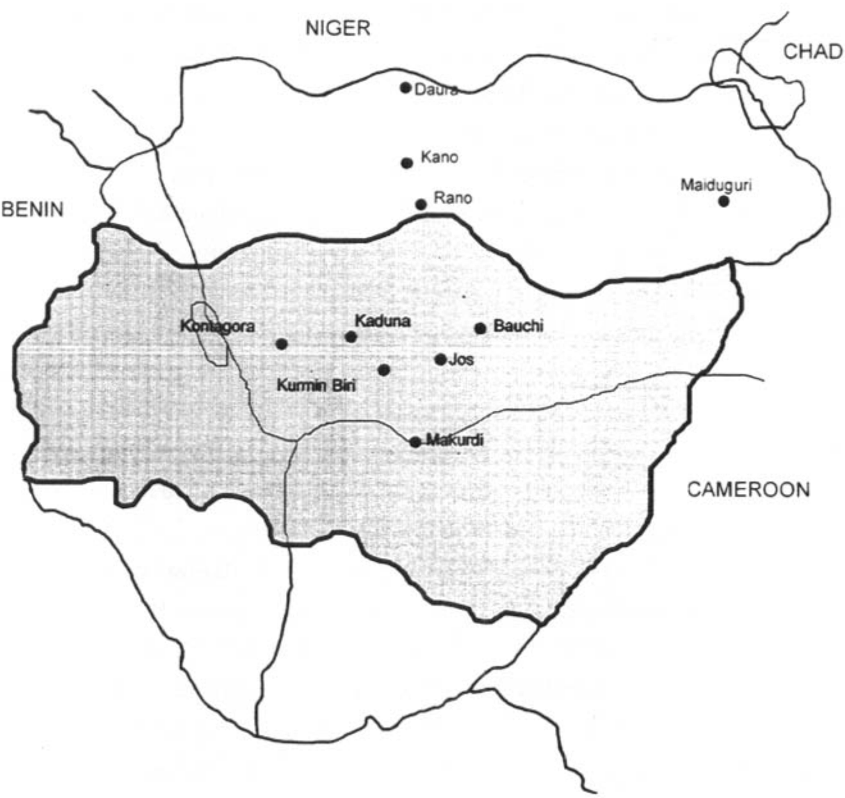

Figure 1. The subhumid zone of Nigeria, showing research–extension sites.

are generally on marginal lands bordering hamlet areas and on fields that farmers have left fallow for several years. The Fulani own no land in central Nigeria and have no certificates of occupancy.

Most of the crop farmers in central Nigeria are from the Kaje, Kamantan, Ikulu, Aten, and Hausa ethnic groups. Their main crops are sorghum, millet, maize, cocoyam, and yam, and the animals they raise include cattle, sheep, goats, pigs, and poultry (Ingawa 1986).

Average household size is nine persons, who contribute virtually all the labour. Peak labour demands occur in May to August (cultivation) and in November (harvest). Seasonal labour shows some age- and gender-related differences.

Farming systems and *Stylosanthes* management

Adopting a farming-systems research approach and promoting the use of *Stylosanthes* in the region, the International Livestock Centre for Africa (ILCA, now the International Livestock Research Institute [ILRI]) identified animal diseases, poor nutrition, and difficulties arising from land-tenure systems as the main constraints affecting the livestock industry in the SHZ (ILCA 1979). Serious cattle diseases, such as rinderpest and contagious bovine pleuropneumonia, can be fairly well controlled with available vaccines and techniques. The land-tenure issues tend to be site specific and highly political; the best approach is therefore thought to be to accept this limitation and work with it. ILCA considered malnutrition, especially in the dry season, the area in which some improvement could be made.

Productivity-monitoring of traditionally managed herds in the SHZ revealed that poor nutrition leads to low milk offtake per lactating cow (700 mL d^{-1}), long calving intervals (2 years), drastic weight losses (15–20%) in the dry season, high calf mortality (30%), and low fecundity (50%), a result of nutritional anestrus (Mani et al. 1988; Rege, von Kaufman, and Mani 1993; Rege, von Kaufman, Mwenya et al. 1993). Obviously, the natural vegetation cannot adequately support the existing cattle population. The accepted minimum level of 7.5% crude protein (CP) in the ruminant diet (Crowder and Chheda 1982) is attained only from June to September, and the digestibility of the natural forage is also low.

Farmers in Nigeria try to overcome this feed constraint by providing the cattle with crop residues after harvest (mostly of maize, sorghum, millet, and rice), at the beginning of the dry season. In the late dry season, the animals browse and graze forage resources on *fadama* (lowland areas where residual moisture permits plant growth throughout the dry season). Agropastoralists also supplement their animals' diets with agroindustrial by-products and local salt lick (*kanwa*). Although the agropastoralists take advantage of this wide variety of feed resources, these measures are still inadequate, as the productivity of their cattle remains low.

Recently, it was found that the crop farmers' traditional practice of tethering goats in the wet season to prevent them from damaging crops creates feed stress. This feed stress leads to undernutrition and weight losses in breeding females, with consequent low reproductive performance (ILCA 1991), which poses a new problem for crop farmers who are landowners but have no interest in livestock other than small ruminants.

Crop yields per unit of land and per unit of labour are low mainly because fertilizers are not readily available to smallholders. For instance, average grain yields in farmers' fields were 1 800 kg ha^{-1} for maize, 1 420 kg ha^{-1} for sorghum, and 700 kg ha^{-1} for millet (Powell 1984).

The poor nature of savanna soils contributes to the poor quality and low productivity of the herbage and crops in the SHZ. Any attempt to promote livestock production in the SHZ should, therefore, consider a program for maintaining soil fertility, as well as improving the nutritional value of the pasture. Herbaceous legumes offer an attractive option in this context, as they can provide both fodder for livestock and N to the soil.

Extension agents recommended the use of agroindustrial by-products — such as cottonseed cake, groundnut meal, urea, and molasses — to improve the productivity of lactating and pregnant cows. However, supplies of these products are not readily available, and prices are escalating. Similarly, a recommendation to use chemical fertilizers to boost crop production is problematic, as supplies of these chemicals are irregular. The fertilizers are too expensive for the small-scale farmer, and they also create environmental concerns.

In view of these ecological and financial constraints, ILCA considered a sustainable enterprise, such as planted forage legumes ("fodder banks"), as a more appropriate long-term option for improving cattle nutrition and soil fertility. This is because leguminous plants, such as *Stylosanthes*, can maintain a CP content of more than 8% in the dry season and the associated *Rhizobium* can fix N. It is against this background that low-input techniques have been developed for establishing *Stylosanthes* on natural range (Otsyina et al. 1987) and in cropped areas (Mohamed-Saleem 1985) to improve forage quality and soil fertility.

Stylosanthes on natural range

Sowing forage legumes can improve the nutritive value of the natural vegetation in rangelands. The low-input guidelines developed by ILCA (Otsyina et al. 1987) for the establishment, management, and use of these pastures are as follows:

Establishment

- Select an area close to the homestead (often 4 ha is adequate for an average-sized herd [40–50 animals per household]);
- Fence the area, using either metal or live poles, to prevent communal or untimely grazing;
- When the rains commence in April or May, prepare land for planting by confining animals as long as necessary or by using animal traction;
- Sow scarified seeds (10–12 kg ha^{-1}) after mixing with Single Superphosphate™ (SSP) at a rate of 150 kg ha^{-1};

Management

- Control grasses by early-season grazing, slash any shrubs, and destroy termite mounds;
- Leave forage to bulk up;
- Construct fire breaks at the beginning of the dry season; and
- Control dry-season grazing to ensure sufficient seed drop and adequate stubble for *Stylosanthes* regeneration in subsequent seasons.

ILCA's recommendation aims at feeding 15–20 lactating and pregnant cows for about 2–3 h d^{-1}, but herd owners tend to prefer strategic "survival feeding" for the whole herd.

Stylosanthes fallows in cropped areas

The undersowing technique is considered the most feasible method for introducing *Stylosanthes* into crop mixtures in the year before a piece of land is left to lie fallow. The understorey of stylo increases the nutritional value and quantity of the succeeding crop residue and improves soil fertility faster than a natural fallow. Undersowing exploits the land preparation primarily done for the crop and does not affect the cultural practices of the agropastoralists and farmers because it is based on intercropping, which is already the most common practice. When undersowing sorghum with *Stylosanthes*, a farmer must sow the legume 3–6 weeks after planting sorghum to avoid competition between the two crops (Mohamed-Saleem 1985).

Stylosanthes in legume–legume mixtures

Earlier evaluation work had identified several accessions of legumes that grew well in the West African SHZ, including *Aeschynomene histrix*, *Centrosema brasilianum*, *Centrosema pascuorum*, *Centrosema pubescens*, *Chamaecrista rotundifolia*, *Stylosanthes guianensis*, and *S. hamata* (Peters et al. 1994a, b). Tests made on collections of these species to identify material best adapted to the agroecological zone showed that none of these species is ideal. *Centrosema pascuorum* establishes well but soon disappears from a pasture. *Centrosema brasilianum* and *C. pubescens* establish slowly but stay green in the dry season. *Aeschynomene histrix*, *S. guianensis*, and *S. hamata* establish well and can persist for several seasons but do not stay green throughout the dry season. Individually, none of the legumes is ideal, but in the right combination, they might provide sustainable year-round grazing.

Therefore, our research efforts focused on developing legume–legume mixtures to replace the more commonly used grass–legume mixtures. A large-scale grazing trial was established to evaluate selected legume mixtures (such as *C. pascuorum* + *S. guianensis* + *C. pubescens* and *C. pascuorum* + *S. guianensis* + *Centrosema macrocarpum*) as supplementary pastures for young heifers (Tarawali et al. 1996).

Stylosanthes capitata, identified in similar environments in South America as a highly productive, drought- and disease-tolerant species adapted to soils with low fertility (Thomas et al. 1987), was evaluated for its potential in subhumid West Africa. This legume failed to nodulate in preliminary trials. However, later observations on abandoned plots in the same area revealed that several years after introduction, *S. capitata* nodulated and produced higher yields than *S. hamata*, the most widely used forage legume in subhumid Nigeria. An on-farm trial was therefore initiated to study the effects of *S. capitata* and *S. hamata* in various mixtures on forage and subsequent crop yields.

Animal evaluation

An on-farm study was conducted for 10 years (1977–87) at four locations in the SHZ of Nigeria (Mani et al. 1988). Fifty-eight herds of Bunaji cattle were involved, each with about 40–50 animals. In each herd, the animals were divided into two groups: those allowed to graze on *Stylosanthes* pastures for 2–3 h d^{-1} during the dry season (October–March), in addition to grazing on natural pasture; and those grazing strictly on natural pasture all year round. Calves were weighed every 2 weeks until they were weaned, and adult animals were weighed periodically. All births, deaths, and milk yields were recorded for statistical analysis. Cattle with access to forage legumes in the dry season produced more milk, lost less weight, and had shorter calving intervals and a better rate of calf survival (Table 2).

A similar study, involving West African Dwarf goats in 32 flocks owned by 45 smallholder farmers, was carried out for 30 months (Tarawali and Ikwuegbu 1993). At the beginning of the wet season, the goats were allowed to graze freely on one of two main treatments: natural vegetation and *Stylosanthes* pasture (miniature fodder bank). Animal performance was measured in terms of birth weights, deaths, stillbirths, abortions, etc. Weights were recorded fortnightly; the kids were weighed within 24 h of birth and weaned at about 5 months. A comparison of the wet-season liveweight (LW) changes of nonpregnant adults showed that those grazing on the *Stylosanthes* pastures had reduced ($P < 0.05$) weight losses (Figure 2). The kids' survival rate was also improved ($P < 0.05$) by legume supplementation (Ikwuegbu and Ofodile 1992).

In experiments with legume–legume mixtures (Tarawali et al. 1996), the differences between heifers grazing on the legume mixtures and those grazing on unimproved pasture were dramatic. For instance, in the 1994/95 dry season, the former gained an average 140 g d^{-1}, whereas the latter lost an average 58 g d^{-1}

Table 2. Effect of dry-season dam supplementation on the productivity of Bunaji cattle.

Variable	Grazing only	Fodder bank [a]	Improvement (%)	Significance (*P*)
Cow survival (%)	92.2	96.0	4.7	NS
Calving (%)	53.8	58.1	8.0	NS
Calf survival (%)	71.8	86.3	20.2	0.05
Calf weight at 1 year (kg)	98.1	103.4	6.6	0.05
Total milk yield (kg)	300.2	312.5	4.1	NS
Productivity index	51.5	69.1	34.2	NS

Source: Mani et al. (1988).
Note: NS, not significant.
[a] Planted forage legumes.

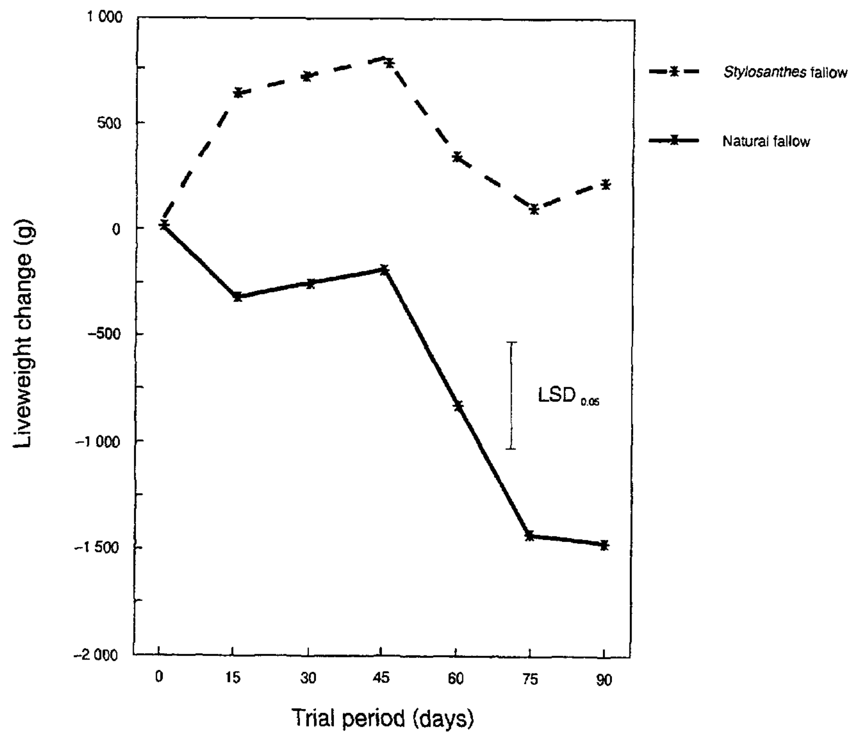

Figure 2. Liveweight changes of West African Dwarf goats grazing on *Stylosanthes* and natural pasture. Source: Tarawali and Ikwuegbu (1993).

(Figure 3). The trial, which ran for two dry seasons (1994/95 and 1995/96) and one wet season (1995), compared the performance of heifers (three per treatment) grazing on one of two legume mixtures or on native range. The trial was run for two dry seasons (1994/95 and 1995/96) and one wet season (1995). Animals were weighed fortnightly and received routine veterinary care. The animals on the native pasture recovered on their own at the beginning of the wet season (this compensatory growth was due to the rapid improvement in the quantity and quality of pasture vegetation at the onset of the rains). However, this group was not as productive as those on improved pastures.

Agronomic evaluation

Pasture productivity

Yields from natural pasture and *Stylosanthes*-based fodder banks were compared at the end of the growing season, before grazing (Tarawali and Mohamed-Saleem 1994). Table 3 shows yields of about 4.3–7.9 t DM ha^{-1} for fodder banks containing 52–68% *Stylosanthes*. These data were generated from researcher-managed on-farm trials. The yields were measured from randomly placed 1 m × 1 m quadrats,

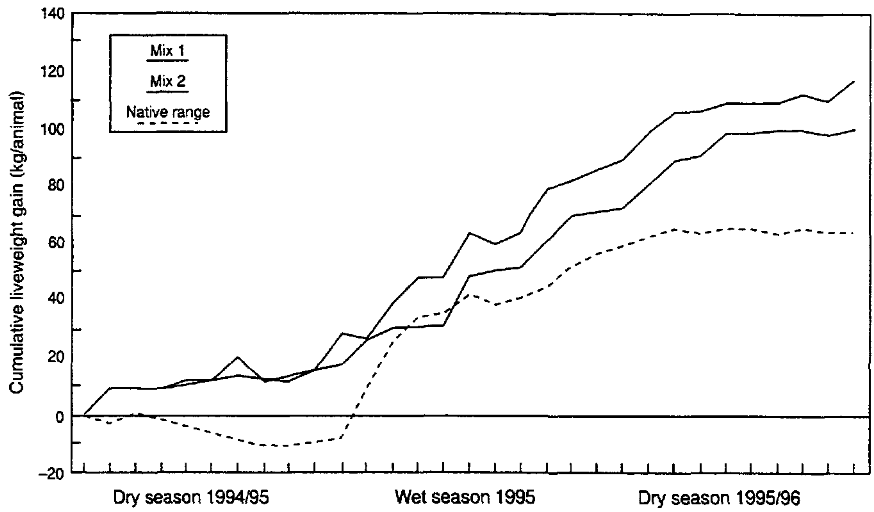

Figure 3. Effect of supplemental mixed-legume pastures on liveweight gains of Bunaji heifers. Source: Tarawali et al. (1996). Note: Mix 1 = *Centrosema pascuorum* + *Stylosanthes guianensis* + *Centrosema pubescens*; mix 2 = *Centrosema pascuorum* + *Stylosanthes guianensis* + *Centrosema macrocarpum*).

from which the herbage was cut and separated into legume, grasses, and forbs. The material was later dried at 60°C and then weighed to determine productivity. The information presented in Table 3 is just for *Stylosanthes* pastures, but the corresponding yield for natural pasture (control) generated in a similar way was 2.4–2.9 t DM ha^{-1}. The productivity for farmer-managed pastures with 30–60% *Stylosanthes* was about 4–5 t DM ha^{-1}.

Table 3. Average DM yield and proportion of *Stylosanthes* in selected fodder banks in International Livestock Centre for Africa's study areas.

Location	DM yield (t ha^{-1})	*Stylosanthes* component (%)
Abet	4.28	58
Ganawuri	7.90	60
Kachia	7.11	68
Kontagora	6.12	52
Kurmin Biri	6.10	60
Avg.	6.30	60

Source: Tarawali and Mohamed-Saleem (1994).
Note: Avg., average; DM, dry matter.

Table 4. Effect of different proportions of *Stylosanthes capitata* and *Stylosanthes hamata* on forage yields (total of 3 years), soil properties, and subsequent maize (fertilized with only P and K) production.

S. capitata–S. hamata ratio	Forage yield, 1990–92 (kg ha^{-1})	Maize yield, 1993 (kg ha^{-1})	Total soil N (g kg^{-1})	Organic C (g kg^{-1})
100 : 0	10 209	303 ± 70	0.15 ± 0.04	8.57 ± 1.2
75 : 25	14 822	587 ± 172	0.19 ± 0.01	9.85 ± 1.7
50 : 50	12 925	492 ± 114	0.22 ± 0.01	11.56 ± 0.5
25 : 75	11 959	509 ± 141	0.23 ± 0.18	10.48 ± 2.5
0 : 100	10 495	460 ± 190	0.20 ± 0.04	9.53 ± 2.2

Source: Tarawali and Peters (1997).

Results of an *S. hamata–S. capitata* compatibility trial (Tarawali and Peters 1997) showed that total forage-DM yields in the mixtures were higher than in the sole stands of either species (Table 4), with *S. capitata* increasing its contribution over time. This trial was initiated in 1990; *S. capitata* and *S. hamata* were sown at a seed rate of 10 kg ha^{-1} each in 2 m × 3 m plots. Four to six weeks after planting, the plants were thinned to 100 seedlings m^{-2} in various proportions (see Table 4). The five treatments were arranged in a randomized complete-block design, with four replicates. Plots were kept weed free and were fertilized with SSP at 150 kg ha^{-1} at planting and at 100 kg ha^{-1} in subsequent years (1991 and 1992). Forage parameters were studied for the first 3 years; in 1993, plots were cropped with maize to obtain information on the effect of various proportions of the two legumes on cereal production. The maize did not receive any N fertilizer, but basal dressings of P and K were each applied at 60 kg ha^{-1} as SSP and muriate of potash, respectively. Before maize planting, soil samples were taken for determination of total N and organic C.

Total soil-N concentrations were higher in plots following 3 years of *S. capitata–S. hamata* mixtures than in plots that had had sole stands of *S. capitata* (see Table 4). Organic C concentrations were higher in plots after the mixtures than in plots after either sole *S. capitata* or sole *S. hamata*. Maize yields were correspondingly higher following the mixtures than after either of the sole stands. The higher soil-N and organic C contents and maize yields in the plots following the mixtures suggest the complementarity of *S. capitata* and *S. hamata*. Thus, although not recommended for sole-legume pastures, *S. capitata* could be used in mixtures with other complementary legume species, such as *S. hamata, C. brasilianum,* and *C. pubescens*.

Crop production

In another trial (Tarawali 1991), maize yields at three levels of applied N (0, 60, or 120 kg ha^{-1}) were greater on plots that had had a leguminous cover crop than on plots that had been natural pasture. Without fertilizer-N additions, the average grain yields were 1 700 kg ha^{-1} in the leguminous area and 800 kg ha^{-1} for the natural pasture (Figure 4). The trial, which was initiated in 1986, was conducted at four locations in central Nigeria to evaluate the fertilizer response of maize grown after at least 4 years of uncropped natural fallow or 3 years of *Stylosanthes* pasture (fodder bank). The experiment was a split-plot design, with the *Stylosanthes* and non-*Stylosanthes* areas as the main plots and the levels of N as subplots. Basal dressings of P and K were each applied at 60 kg ha^{-1} in the form of SSP and muriate of potash, respectively. At the end of the growing season, in October, the crops were harvested, dried, and weighed to determine grain yield.

In the first year of cropping, maize grown on the natural pasture needed 45 kg N ha^{-1} to produce a yield equivalent to that of unfertilized maize grown on a good *Stylosanthes* pasture. In the second year, the yields were much lower, but

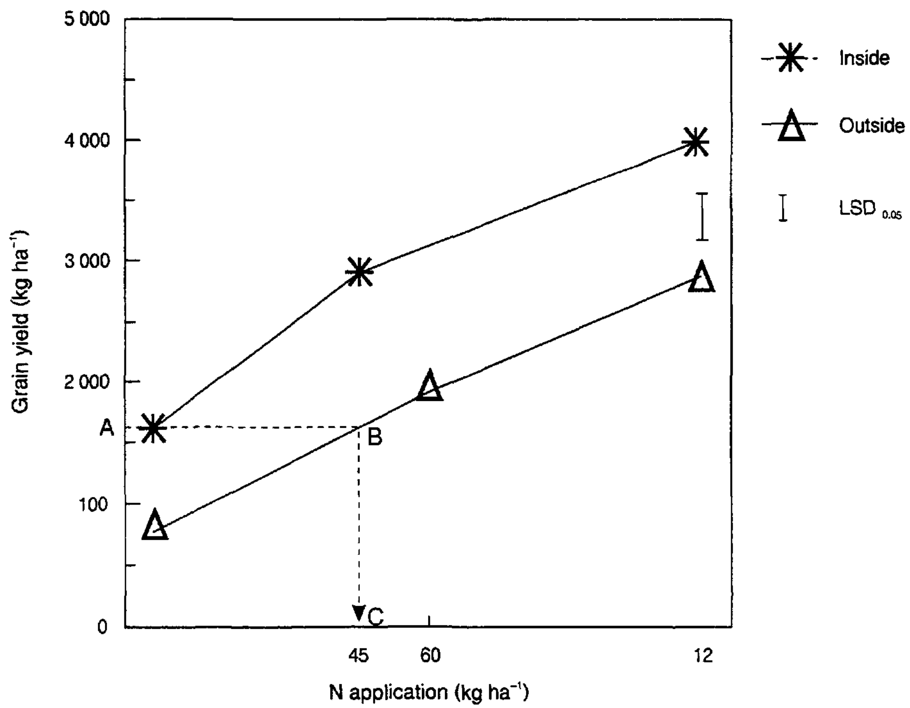

Figure 4. Effects of fertilizer-N on grain yield of maize inside and outside *Stylosanthes* plots. Source: Tarawali (1991).

the proportional increase in yield attributable to forage legumes was similar to that in the first year. This suggests that the legumes still had some positive residual effect, but this was insufficient for the optimum growth of maize.

In the case of *acha* (*Digitaria exilis*) grown after *Stylosanthes,* no response was shown to the supplemental addition of fertilizer-N. A multilocation trial (Tarawali and Pamo 1992) compared the performance of *acha* grown in two main plots, previously under *Stylosanthes* or natural fallow, at various levels of N (0, 40, 80, and 120 kg ha^{-1}). P and K were each applied to all the plots at 60 kg ha^{-1}. The experiment was a split-plot design, and each treatment was replicated four times. At the end of the trial, grain yield was determined. The highest *acha*-grain yield (560 kg ha^{-1}) was obtained on the *Stylosanthes* pasture, with no N application (Figure 5). The highest yield on natural fallow required 40 kg N ha^{-1}. This trial shows that maximum *acha* yield can be obtained if the grain is planted after a *Stylosanthes* pasture and receives no N fertilizer.

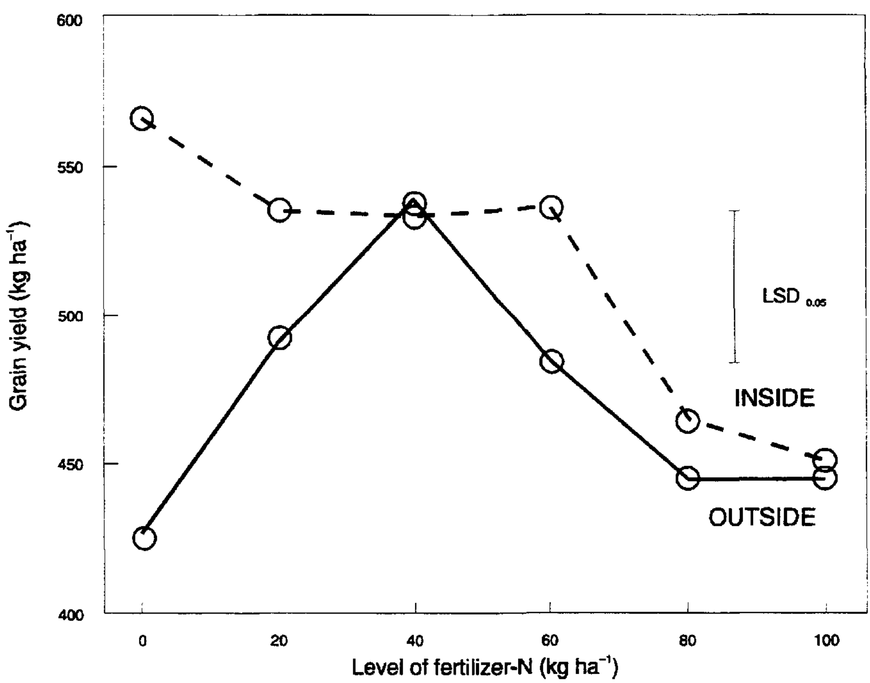

Figure 5. Response of *acha* inside and outside *Stylosanthes* plots to fertilizer-N. Source: Tarawali and Pamo (1992).

Table 5. Soil chemical and physical properties under *Stylosanthes* and natural fallow.

Property	*Stylosanthes* (3 years)	Natural fallow (>4 years)
N content (g kg^{-1})	1.14	0.87
CEC (cmol kg^{-1})	3.24	2.22
Organic C (g kg^{-1})	4.31	2.70
Bulk density (g cm^{-3})	1.51	1.66
Total porosity (%)	43.1	37.4
Macroporosity (%)	42.1	36.4
Microorganisms ($n \times 10^7$ g^{-1})	34	12

Source: Tarawali and Ikwuegbu (1993).
Note: CEC, cation exchange capacity.

The positive impact of *Stylosanthes* on crop production has also been demonstrated for other crops, such as millet, sorghum, and soybean (Tarawali and Mohamed-Saleem 1995).

The higher crop yields on the *Stylosanthes* pastures were due to the legume's improvement of the soil's physical and chemical properties. For instance, a series of measurements (Tarawali and Ikwuegbu 1993) showed that *Stylosanthes* decreased the soil's bulk density and increased its porosity (capacity to retain moisture), its CEC, and its organic C and N contents (Table 5). No standard errors are presented for these data because the analysis was conducted for a limited number of fodder banks.

Economic evaluation

The economic benefit of fodder banks was assessed by von Kaufmann and Mohamed-Saleem (1989), who compared the cost of producing a unit of CP from fodder banks (1.96 NGN kg^{-1} CP) with the market price of a given unit of cottonseed cake (2.27 NGN kg^{-1} CP) (in 1998, 75.2 Nigerian naira [NGN] = 1 United States dollar [USD]). It was shown that CP produced from fodder banks was cheaper than that from purchased cottonseed cake, an alternative form of dry-season feed supplementation (Table 6). Given the current high rate of inflation, coupled with the scarcity and high cost of cottonseed, the agropastoralists who established their fodder banks a few years ago should now be making some gain from their investments. Using a model to appraise the economic returns of fodder banks over 10 years, von Kaufmann and Mohamed-Saleem confirmed that fodder

Table 6. Costs of obtaining crude protein from a 4-ha fodder bank and from cottonseed cake, subhumid Nigeria, 1989.

	Quantity
Fodder bank (4 ha)	
DM produced (kg)	16 000
DM available (kg)	8 000
CP content (kg) [a]	720
Capital cost (NGN)	5 944
Recurrent cost (NGN kg^{-1} CP)	1.96
Cottonseed cake	
CP	720
Required DM at 30% CP (kg)	2 400
Capital cost (NGN)	0
Recurrent cost [b]	2.27

Source: von Kaufmann and Mohamed-Saleem (1989).
Note: CP, crude protein; DM, dry matter; NGN, Nigerian naira (in 1989, 7.3 NGN = 1 United States dollar [USD]; in 1998, 75.2 NGN = 1 USD).
[a] Assumes 9% crude protein content available in dry matter.
[b] Calculated as 680 NGN t^{-1} of cottonseed cake, at 30% CP.

Table 7. Economic returns on fodder banks in subhumid Nigeria over 10 years, 1989.

	Net present value [a] (NGN)	Internal rate of return (%)	10th-year herd value: Without fodder bank (NGN)	10th-year herd value: With fodder bank (NGN)	10th-year incremental net revenue (NGN)
IHP	1 414	22.5	49 907	90 833	4 950
IHP + reduced forced sales	7 538	34.1	49 907	90 833	7 138
IHP + increased crop yields	9 395	36.3	49 907	90 833	8 544

Source: von Kaufmann and Mohamed-Saleem (1989).
Note: IHP, improved herd productivity; NGN, Nigerian naira (in 1989, 7.3 NGN = 1 United States dollar [USD]; in 1998, 75.2 NGN = 1 USD).
[a] Calculated at 20% discount rate.

banks could be attractive investments (Table 7). For instance, their evaluation, which included capital and recurrent costs (such as those for fencing, seed, fertilizer, labour) of a 4-ha fodder bank and benefits (such as those from animal products and crop yield), showed an internal rate of return varying from 22.5 to 36.3% for fodder-bank-supplemented herds.

Adoption of *Stylosanthes* and farmers' perceptions

Agropastoralists in the Nigerian SHZ originally exploited *Stylosanthes* for cattle, but crop farmers later took advantage of the soil-improving properties of this cover crop for small ruminants and crop production (miniature fodder banks). Formal and informal surveys were conducted by a multidisciplinary team of scientists and extension workers to record farmers' reactions to the innovations and the associated benefits. Both farmers and agropastoralists acknowledged the beneficial effects of the fodder-bank intervention in terms of improved agricultural productivity (and hence increased income) as well as increased environmental protection. This was reflected in an increase in the number of fodder banks from 2 in 1980 to about 620 in 1991 (Figure 6). The documented adoption trend (Ajileye et al. 1994) was influenced mainly by the ILCA–ILRI projects and the Nigerian Livestock Department's promotion of *Stylosanthes* among agropastoralists and farmers, though there was evidence of farmer-to-farmer dissemination. The data came from records and were verified on field visits by extension staff. According to more recent reports, the technology has continued to expand in the farming systems of Nigeria and other West African countries (de Leeuw et al. 1994; ICTA 1995).

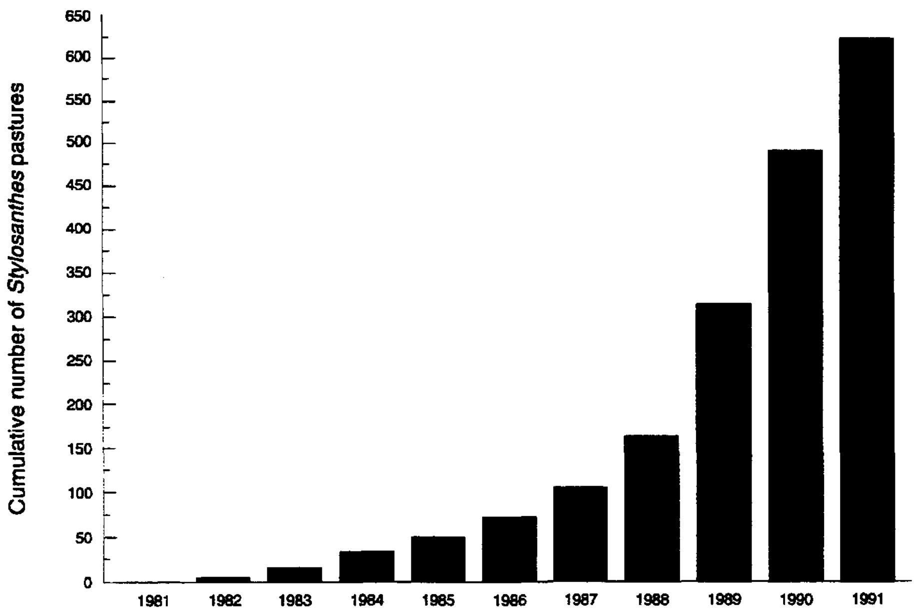

Figure 6. Cumulative number of *Stylosanthes* pastures in Nigeria from 1981 to 1991. Source: Adapted from Ajileye et al. (1994).

The subhumid zone of Cameroon

Climate and soils

In Cameroon, most of the earlier work on *Stylosanthes* was conducted on the Adamawa Plateau (Wakwa Animal Research Station, near Ngaoundéré), at an altitude of 900–1 500 m asl (Figure 7). The climate is characterized by a long-term mean annual rainfall of 1 706 mm and a growing period of 240 d. Most of the rain (91%) falls between April and October, with a peak during August and September.

The soil in the region is basaltic and slightly acidic (pH of 5.5) and has a clay texture, 4.9% organic matter (OM), 2.3% total N, 26 ppm P (Olsen), and low CEC. The vegetation is typically Guinea savanna, with tall grasses, such as *Andropogon*, *Hyparrhenia*, and *Pennisetum*, and a dense tree cover comprising *Isoberlinia doka*, *Lophira lauceolata*, *Daniellia oliveri*, *Parkia biglobosa*, *Anogeissus leiocarpus*, etc.

Socioeconomic conditions and cultural features

The potential users of *Stylosanthes* in northern Cameroon are agropastoralists who own livestock and practice some level of cropping (maize and sorghum, usually intercropped with cowpea). They are from the Fulani ethnic group. Unlike their counterparts in Nigeria, they have access to land, and each family owns up to 10 ha or more. They live in villages in which the houses are mostly constructed from mud, with grass roofing. Richer farmers use aluminium sheets. Agropastoralists try to overcome dry-season feed shortages by practicing transhumance, which imposes more trekking on the herders and the animals. During trekking, some of the animals die.

Farming systems and *Stylosanthes* management

As in the Nigerian SHZ, ruminant production on the Adamawa Plateau is constrained by the poor quality and quantity of the dry-season forage, and this situation has led to numerous problems. For instance, breeding, and hence calving, take place year-round. Many calves are born during the dry season, when forage is insufficient; cows are extremely weak and unable to produce enough milk to feed their calves. Not surprisingly, therefore, calf losses are high, and calves that do survive have health problems. In addition, animals that depend solely on natural vegetation for their nutrition suffer severe weight loss during the dry season (Lhoste 1967), with consequent reproductive failures (Voh et al. 1984). Nomadism and transhumance can to some extent compensate for this feed shortage by allowing pastoralists to exploit a wide range of natural herbage, but such a lifestyle removes them from basic social and technical-support services.

Figure 7. The subhumid zone of Cameroon.

To reduce the impact of the dry-season feed shortage on animal production, extension officers in Nigeria have been advocating the purchase of supplementary feeds, such as cottonseed cake, at least for animals at risk. However, these products are generally scarce and expensive. Planting forages (such as *Stylosanthes*) as an alternative was tested at the Wakwa station of the Institut de recherches zootechniques (IRZ, institute of animal research) in 1987, with a view to extending the concept to agropastoralists in the region.

The Wakwa station began testing several forage legumes as early as the 1950s (Rippstein 1985), and some, such as *S. guianensis*, *Desmodium* spp. and *C. pubescens*, have been found promising for the region (Yonkeu et al. 1994). However, scientists have never found an appropriate way to use these improved pasture species to suit the needs and capabilities of the traditional herders. Government efforts to improve rangeland and its management have been unsuccessful because range legislation cannot be enforced. The fodder-bank intervention, developed by scientists at ILCA in the SHZ of Nigeria, presents an alternative approach to introducing and managing improved forages (Otsyina et al. 1987). In an effort to test and possibly extend the concept, researchers established a fodder bank, using *S. guianensis* cv. CIAT 184, at the Wakwa station (Tarawali and Pamo 1992).

During the 1987 rainy season, a 4-ha paddock, fenced with metal and live posts (mainly *Ficus thonningii*), was cleared, plowed, and harrowed with a disc harrow. Seed of *S. guianensis* cv. CIAT 184 was first scarified in boiling water for 30 s and then sown (broadcast) at a rate of 10 kg ha^{-1}. This effort was not very successful in the first year, mainly because the pasture was dominated by grasses. Because of the scarcity of seed, a new fodder bank could not be established. Instead, the grasses in the 1987 paddock were hand-cleared, and the areas with poor regrowth were selectively reseeded. Contrary to Otsyina et al.'s (1987) recommendation, just after hand-weeding, N–P–K (20 : 10 : 10) fertilizer was applied to the pasture at the rate of 385 kg ha^{-1}.

Animal evaluation

Research on the response of livestock to *Stylosanthes* is very rare. However, Table 8 summarizes a feeding trial carried out in Cameroon using *Stylosanthes* hay or silage for Zebu heifers. In general, the heifers showed a preference for hay over silage (Rippstein 1985).

Table 8. Average consumption of *Stylosanthes* silage and hay by young female Zebu heifers.

	Silage		Hay	
Age (d)	kg DM head^{-1} d^{-1}	kg DM 100 kg^{-1} LW d^{-1}	kg DM head^{-1} d^{-1}	kg DM 100 kg^{-1} LW d^{-1}
0–20	2.8	1.1	4.7	1.6
20–40	3.1	1.2	5.1	1.8
40–57	2.5	1.0	4.3	1.5
Avg.	2.8	1.1	4.7	1.7

Source: Rippstein (1985).
Note: Avg., average; DM, dry matter; LW, liveweight.

Agronomic evaluation

Pasture productivity

The *S. guianensis* in Tarawali and Pamo's (1992) study had an average height of 1.41 ± 0.12 m. A total DM production of 5.5 t ha^{-1} from grass and *Stylosanthes* was recorded. The botanical composition indicated that *S. guianensis* constituted 93.4% of the pasture. The remaining 6.6% was made up of perennial grasses, such as *Brachiaria ruziziensis*, *Hyparrhenia rufa*, and *Hyparrhenia filipendula*. The performance of *S. guianensis* was very good, given the locality of the site and the poor terrain. According to guidelines developed by Otsyina et al. (1987) for classifying fodder banks (60–100% *Stylosanthes* = excellent; 23–34% *Stylosanthes* = poor), the fodder bank in Wakwa was in excellent condition (93.4% *Stylosanthes*).

The DM productivity of 5.5 t ha^{-1} is comparable to the average DM yield of *Stylosanthes* (4.0–5.0 t ha^{-1}) obtained in the Nigerian SHZ (Mohamed-Saleem and Suleiman 1986), where the fodder bank was developed. This suggests that, given the soils in the Adamawa region, 4 ha of improved pasture is sufficient for the dry-season supplementation of 15–20 stressed animals. On-farm trials in the SHZ of Nigeria have shown that agropastoral herds with access to *Stylosanthes* supplementation performed better than nonsupplemented herds (see Table 2). *Stylosanthes* can be expected to perform even better under Cameroonian conditions.

It is worth noting that annual burning of vegetation, whether accidental or intentional, is common on the Adamawa Plateau, especially at the end of the dry season. In this study, a fire that burned all the paddocks of dry grass around the site was stopped by the thick stand of green *S. guianensis* in the fodder bank. A good fodder bank therefore appears able to resist fire, at least early in the dry season.

Table 9. Effect of preceding cover crop on maize-grain yield, 1992/93.

Treatment (previous cover crop)	Maize-grain yield (t ha^{-1})	
	Without fertilizer	With fertilizer [a]
Natural fallow	1.22	2.45
Canavalia	1.48	2.88
Mucuna	1.67	2.69
Stylosanthes	2.30	3.68
Calopogonium	1.52	2.73

Source: Youri (this volume).
[a] N–P–K at 100 kg ha^{-1}.

Stylosanthes fallows

The principal constraints limiting cereal production (maize and sorghum) in northern Cameroon (Garoua; see Figure 7) are low levels of OM, deficiency of soil nutrients, *Striga* infestations, and high costs of inputs. Looking for ways to combat these constraints, the Institute of Agronomic Research (IAR) at Garoua focused on the use of cover crops (Youri, this volume).

In the 1992 growing season, four species of legumes were established: *Canavalia ensiformis*, *S. hamata*, *Mucuna pruriens*, and *Calopogonium mucunoides*. DM production was measured about 4 months after seeding: *S. hamata* had the highest yield (11.28 t ha^{-1}), followed by *Canavalia* (8.38 t ha^{-1}), *Calopogonium* (7.41 t ha^{-1}), and *Mucuna* (5.02 t ha^{-1}). The outstanding performance of *Stylosanthes* and the low yield of *Mucuna* in this study could be related to the fact that the former can thrive under low-P conditions, whereas the latter has a high P requirement (Sanginga, Okogun et al. 1996).

In the second year (1993), the leguminous plots and an adjacent natural fallow were planted with maize at two levels of fertilization (0 and 100 kg N–P–K ha^{-1}). The fallow preceded by *Stylosanthes* gave maize yields of 2.30 t ha^{-1} (0 kg N–P–K ha^{-1}) and 3.68 t ha^{-1} (100 kg N–P–K ha^{-1}). The natural fallow yielded the least: 1.22 t ha^{-1} in unfertilized plots and 2.45 t ha^{-1} in fertilized plots (Table 9).

In a separate experiment in 1991, three species of legumes (*C. ensiformis*, *S. hamata*, and *C. mucunoides*) were each intercropped with maize; a fourth treatment was a maize–maize intercrop. All the legumes were planted 3 weeks after the maize (one row of the legume and two rows of the cereal). In the second year (1992), each of the plots was split into two subplots: one to study the effect of the cover crops on weeds; the other, to evaluate the impact of the respective fallows

Table 10. Effect of preceding maize–legume intercrop on maize-grain yield, 1991/92.

Treatment (previous cover crop)	Maize-grain yield ($t\ ha^{-1}$) (%)	
	Without fertilizer	With fertilizer [a]
Maize	1.17 (100)	3.20 (100)
Canavalia ensiformis	2.14 (182)	4.44 (138)
Calopogonium mucunoides	2.17 (185)	4.00 (125)
Stylosanthes hamata	2.25 (192)	4.40 (137)

Source: Youri (this volume).
[a] N–P–K at 100 kg ha^{-1}.

Table 11. Effect of preceding cover crop on maize-grain yield, 1993.

Treatment (previous cover crop)	Maize-grain yield ($t\ ha^{-1}$) (%)	
	Without fertilizer	With fertilizer [a]
Natural fallow	1.59 (100)	4.08 (100)
Calopogonium	3.80 (238)	5.51 (135)
Stylosanthes	3.42 (215)	5.13 (125)

Source: Youri (this volume).
[a] N–P–K at 100 kg ha^{-1}.

on a succeeding maize crop. Again *Stylosanthes* gave the highest maize yields: 2.25 t ha^{-1} in unfertilized plots and 4.40 t ha^{-1} in fertilized plots (Table 10). Furthermore, *Stylosanthes* and *Calopogonium* provided excellent weed control.

In a trial in which maize was planted following a 1-year fallow of *Calopogonium*, *Stylosanthes*, or natural pasture, the legume-based plots yielded 2.21 t ha^{-1} (+138%) and 1.83 t ha^{-1} (+115%) more maize grain than the plots that had had a natural fallow (Table 11) (Youri, this volume).

Adoption of *Stylosanthes*

Stylosanthes guianensis appears to be well adapted to the Adamawa Plateau, and the fodder-bank package currently used by pastoralists in Nigeria stands a good chance of being adopted by small-scale farmers in Cameroon. The Cameroonian extension agency, in collaboration with a Gesellschaft für Technische Zusammenarbeit (GTZ, organization for technical cooperation) team at IRZ, encouraged pastoralists to establish *Stylosanthes* pastures for their animals. The idea took off in 1987, but it slowed down from 1988 on. Shortage of funds at IRZ meant that support services, such as the provision of seeds to extensionists, were no longer possible.

Stylosanthes was also introduced in the Bamenda region of Cameroon (Markon and Bambui; see Figure 7) in evaluation trials as early as 1974. Currently, Heifer Project International (HPI) is promoting the legume for dairy production. HPI is a charitable nongovernmental organization (NGO) committed to integrated agricultural development for resource-poor farmers (Nuwanyakpai, personal communication, 1997[2]).

In the researcher-managed trials involving *Stylosanthes* at IRA–Garoua, farmers showed interest in the use of the legume for *Striga* control and soil improvement, but this on-station–on-farm activity is still in its infancy. It is hoped that the program will involve more small-scale producers in the near future, especially if funds for a regional project involving Cameroon, Central African Republic, Zaire, and maybe Nigeria are approved by donors (Kounmenioc, personal communication[3]).

The subhumid zone of Côte d'Ivoire

Climate and soils

Bouaké in the central SHZ and Korhogo in the northern Guinea savanna are the centres for the adoption of *Stylosanthes* in Côte d'Ivoire (Figure 8). The average rainfall in the area is 1 000 mm. The soil is the ferruginous-tropical type (N'Guessan 1994); it is sandy, with a high proportion of gravel, and has a pH of about 6.0. Levels of P and N are <5% and 0.4–0.59%, respectively; the level of OM is 1.13% at Kohorgo and 1.55% at Bouaké. All these parameters vary considerably throughout the whole region.

The region is typified by broken savanna vegetation, with shrubs and trees, such as *Daniellia*, *Isoberlinia*, *Parkia*, *Lannea*, and *Pterocarpus*, and a number of grasses, such as *Andropogon*, *Hyparrehenia*, *Digitaria*, *Cymbopogon*, *Loudetia*, and *Pennisetum*.

Socioeconomic conditions and cultural features

The farmers, who mostly belong to the Baoulé and Senoufo tribes, live in villages and settlements, with about 10 persons per household. The Baoulés and the Senoufos are the landowners around Bouaké and Kohorgo. The economic activities in the Bouaké area are based on crops, whereas those in the Korhogo area are mainly based on crops and to a lesser degree on livestock managed by Fulani herders.

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[2]M. Nuwanyakpai, HPI, Cameroon, personal communication, 1997.

[3]J. Kounmenioc, IRZ, Cameroon, personal communication, 1997.

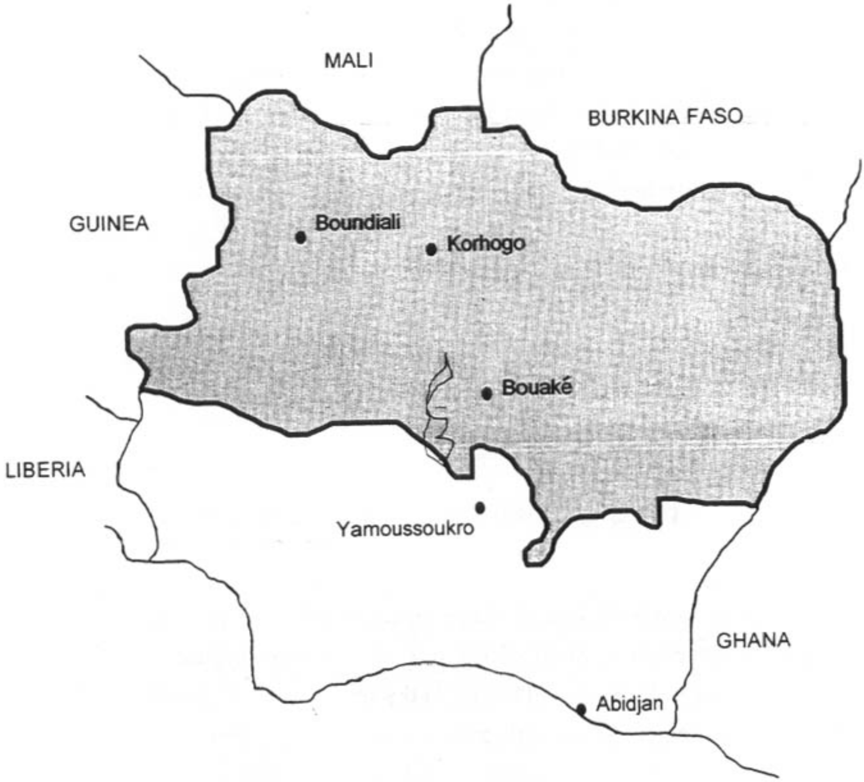

Figure 8. The subhumid zone of Côte d'Ivoire.

The male farmers, who are also the heads of the households, are 25- to 40-years old and have 1–5 children and one or several wives and associates within the compound. Children are sent to government schools, and in Bouaké fees are usually paid from farm income. Medical facilities are provided by the government, but individuals are expected to buy their own drugs. Some of the houses of the richer farmers and those participating in the peri-urban dairy project have aluminium roofing, but many other smallholders in the various communities use grass materials. The roads around the villages and farms consist of laterite, but they are better developed than other feeder roads in northern Côte d'Ivoire.

As in Nigeria and Cameroon, the low quantity and quality of the savanna vegetation, especially in the dry season, precipitated the introduction of improved pastures, such as those with *Stylosanthes*, which has a higher CP content as a result of its ability to fix soil N.

Farming systems and *Stylosanthes* management

The smallholders who currently cultivate *Stylosanthes* for dairy production in central Côte d'Ivoire are crop farmers who adopted livestock production after the introduction of the Eco-farms Project (see below). Although they keep other animals (such as chickens, goats, sheep, and pigs) on their farms, other tribes from the north (such as the Fulbe and Malinga, who have extensive farming systems) manage the Baoulé and Senoufo herds.

The peasants own both lowland and upland farms and practice mixed cropping, with up to 10 crop combinations on a single farm. Tobacco, soybean, rice, and especially cotton are grown as important cash crops The most common food crops are maize, yam, cassava, pepper, tomato, sweet potato, groundnut, and rice. Yam (usually grown in mounds and heavily mulched) and maize are usually grown as sole crops. Rice and vegetables are generally grown in lowland areas. Farm areas under crops vary from 1 to 5 ha. The high cost or unavailability of fertilizers has forced these farmers to rely entirely on green manures, animal manures, and fallow periods. Farmers who include cotton in their rotation have access to draft animals, fertilizers, and credit through the Compagnie ivoirien de développement du textiles (Ivorian textiles development company).

Stylosanthes was introduced and tested in the SHZ of Côte d'Ivoire (Bouaké and Korhogo) more than 35 years ago (Toutain et al. 1994) in an effort to improve the nutritional value of the low-quality natural range and to establish artificial pastures. Most of the experiments, which were mainly on station, focused on *S. guianensis* cv. Schofield and covered plant behaviour, management, and maintenance; sowing techniques; seed production; performance evaluation; and the importance of these species in livestock-production systems.

Low animal prices at that time and damage to *S. guianensis* cv. Schofield from anthracnose in 1980 retarded the introduction of this legume to smallholders. Screening of *Stylosanthes* varieties later identified disease-resistant ones, such as *S. hamata* cv. Verano (Toutain et al. 1994). Researchers recommended the use of this cultivar, in association with *Panicum maximum* (a perennial grass) cultivars C1 and T58, for future *Stylosanthes*-based pastures to discourage attack by fungal diseases (favoured by high *Stylosanthes* densities and humidity) and to take advantage of low-cost production techniques. In a new set of evaluation trials, the *S. guianensis* cultivars CIAT 184, L348, L359, and IRI 1022 were found to be high yielding and anthracnose tolerant (N'Guessan and Dosso 1995).

Eco-farms Project

The Eco-farms Project was jointly established by the Côte d'Ivoire government and Germany, through GTZ. The project sought to create a supply of milk around big cities to reduce the importation of dairy products, which had become very costly; intensify agricultural production; and create jobs for youth. The project got under way in 1987 through the extension support of the Société pour le développement des production des animaux (SODEPRA, society for the development of animal production) and GTZ; the general mandate of both agencies was to promote integrated animal production, with special emphasis on milk. SODEPRA, which ceased to function in the 1980s, was later replaced by the National Agency for the Support of Rural Development (NASRD). Côte d'Ivoire's Institut des savanes (savanna institute) supported the on-farm pilot studies with research and expertise.

Eight farmers around Bouaké were initially selected for this project. They focused on the production of milk for the city, and they were each given 10 crossbred cows, a shed, a borehole, 10 ha of *Stylosanthes*-based pastures, and a farmhouse, where the participant lived with his immediate family. In the past, installing such a structure cost 5–7 million CFA francs (XOF), but after the devaluation of the XOF, the same model was expected to cost around 10 million XOF (Eco-Farms Project 1995) (in 1986, 320 XOF = 1 United States dollar [USD]; in 1998, 610.65 XOF = 1 USD). Under this scenario, the farmer provided all the land required, and the facilities were provided to him on a loan-recovery basis.

To establish the improved pastures, the project workers prepared the land with a tractor and then broadcast *S. hamata* cv. Verano seed (5 kg ha^{-1}), in association with *P. maximum* cv. C1 or T58 seed (each at 5 kg ha^{-1}). N–P–K (10 : 18 : 18) was applied at the rate of 300 kg ha^{-1} to boost the performance of this grass–legume mixture in the initial year. The dairy animals were encouraged to graze the pastures year-round.

Animal evaluation

Interviews with about eight adopters and extension agents revealed that daily milk yields varied from 2.5 to 5.0 L per cow, but a systematic study jointly conducted by GTZ and NASRD in 1994/95 reported that, on average, the N'dama × Abondance crossbreds each produced 5.5 L d^{-1}, although some yielded up to 9 L in one milking. Table 12 shows the excellent potential of the crossbreds to be exploited for milk and beef production. For instance, one dairy cow produced about 1 500 L

Table 12. Some characteristics of the cattle used in the Eco-farms Project.

Parameter	Avg.
Weight at birth (kg)	26.3 ± 5.4 (M) 24.3 ± 3.6 (F)
Weight at 1 year (kg)	245 ± 28 (M) 226 ± 22 (F)
Weight at adulthood (kg)	397 ± 52 (M)
Rate of adult mortality (%)	3.3
Rate of calf mortality (%)	5.0
Age at first calving (months)	24.4 ± 3.2
Calving interval (d)	382 ± 14
Rate of fecundity (%)	87.6 ± 3.7
Duration of lactation (d)	382 ± 14
Milk yield per cow per lactation (L)	1 489 ± 355

Source: Eco-farms Project (1995).
Note: Avg., average; F, female; M, male.

of milk over 235 d of lactation. The weight of the calves at birth was 25 kg, although some were up to 30 kg. At 1 year, a bull weighed 230–300 kg, equivalent to the LW of an adult N'dama.

Economic evaluation

Some of the farmers collected up to 90 000 XOF month^{-1} from this enterprise (Kaligha, personal communication, 1997[4]), and such an income enabled them to pay school fees for their children, increase their herd sizes, and buy other farm inputs.

A systematic economic analysis conducted on six farms during 1994/95 demonstrated that milk accounted for 68.2% of the total income, followed by beef (20.6%) and crops (11.1%) (Table 13). The total revenue from each farm varied from 0.74 million to 1.78 million XOF, with a mean of 1.25 million XOF (Figure 9). This evaluation was based on variable inputs, such as seed, herbicides, fertilizers, labour, feeds, veterinary drugs, and fuel. The income included sales of milk, meat from both large and small ruminants, poultry, and crop produce.

The Eco-farms Project at Bouaké had the initial aim of ensuring that each farmer earned a revenue of 0.72 million XOF year^{-1}, which would be equivalent

[4]M. Kaligha, Agence nationale d'appui au developpement rural, Côte d'Ivoire, personal communication, 1997.

Table 13. Contribution of various products and enterprises to the total income of six Eco-farms, 1994/95.

	Farm income (× 10^6 XOF) (%)		
	Milk	Beef	Crops
F1	1.63 (71.9)	0.32 (14.3)	0.31 (13.8)
F3	1.15 (72.2)	0.29 (18.4)	0.15 (9.4)
F4	1.33 (70.6)	0.45 (23.8)	0.10 (5.6)
F6	1.08 (66.7)	0.43 (26.5)	0.11 (6.8)
F7	0.84 (70.7)	0.22 (18.2)	0.13 (11.1)
F8	0.48 (57.5)	0.18 (22.3)	0.17 (20.2)
Avg.	(68.2)	(20.6)	(11.1)

Source: Adapted from Eco-farms Project (1995).
Note: Avg., average; XOF, CFA franc; in 1998, 610.65 XOF = 1 United States dollar (USD).

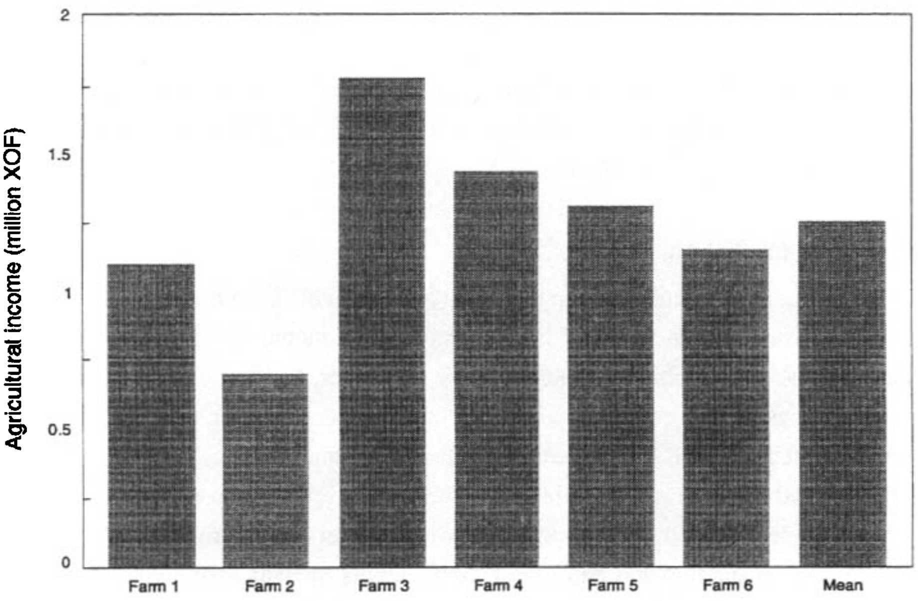

Figure 9. Agricultural income from six farms in the Eco-farms Project, Côte d'Ivoire. Source: Eco-farms Project (1995). Note: In 1998, 610.65 CFA francs (XOF) = 1 United States dollar (USD).

to the income of their counterparts in the towns. Three years after installation, each farmer was able to earn a total revenue of 1.50 million XOF $year^{-1}$. These interesting economic results — the regular and attractive revenue and the new perspectives of domestic dairy production, especially after devaluation — are some of the factors that prompted the further expansion of the Eco-farms Project around Bouaké.

Stylosanthes as improved fallow

In Bouaké, NGOs (for example, the Société de développement des forêts [society for forest development]) are promoting the use of cover crops, including *Stylosanthes* around Bouaké, mainly to reclaim land abandoned to aggressive weeds. In this system, the land is prepared with a tractor, and *S. guianensis* cv. CIAT 184 is sown in pure stands at the rate of 10 kg ha^{-1}; N–P–K (10 : 18 : 18) is applied at the rate of 300 kg ha^{-1} during the establishment year. The following year, the legume is plowed under, and the land is cropped with a cereal.

The assessment of crop performance following various periods of *Stylosanthes* fallow is still in its infancy, but previous on-station work in the SHZ of Côte d'Ivoire (N'Gguessan 1994) established the potential of using such fallows to boost crop yields and restore soil fertility. That study was conducted in Bouaké and Korhogo to assess the residual effects of *S. hamata* cv. Verano and *S. guianensis* cv. Cook, with or without fertilizer-N and fertilizer-P, on a subsequent maize crop. The legumes were grown from June 1982 to November 1983. Maize was planted the following wet season, which commenced in May 1984, after the legume biomass had been incorporated into the soil (relay cropping). For simplicity, only the results for the unfertilized *Stylosanthes* plots will be reported here.

Maize yields on plots preceded by *S. hamata* were 450 and 1 300 kg ha^{-1} in Korhogo and Bouaké, respectively; on plots preceded by *S. guianensis*, 1 000 and 1 400 kg ha^{-1} (Figure 10). Although these are preliminary results, they reflect the potential role of *Stylosanthes* in agricultural intensification.

Adoption of *Stylosanthes*

Stylosanthes was introduced in the SHZ of Côte d'Ivoire about 35 years ago, mainly in on-station evaluation trials. These initial materials were obtained from the Commonwealth Scientific and Industrial Research Organisation (Australia), the International Centre for Tropical Agriculture (Columbia), the Food and Agriculture Organization of the United Nations (Rome), and ILCA, now ILRI (Ethiopia). During those pioneer days, further extension of these leguminous pastures to farmers was inhibited because of the susceptibility of *S. guianensis* cv. Schofield to anthracnose in 1980.

Following intensive evaluations, some disease-resistant or -tolerant varieties were identified, notably *S. hamata* cv. Verano and *S. guianensis* cv. CIAT 184.

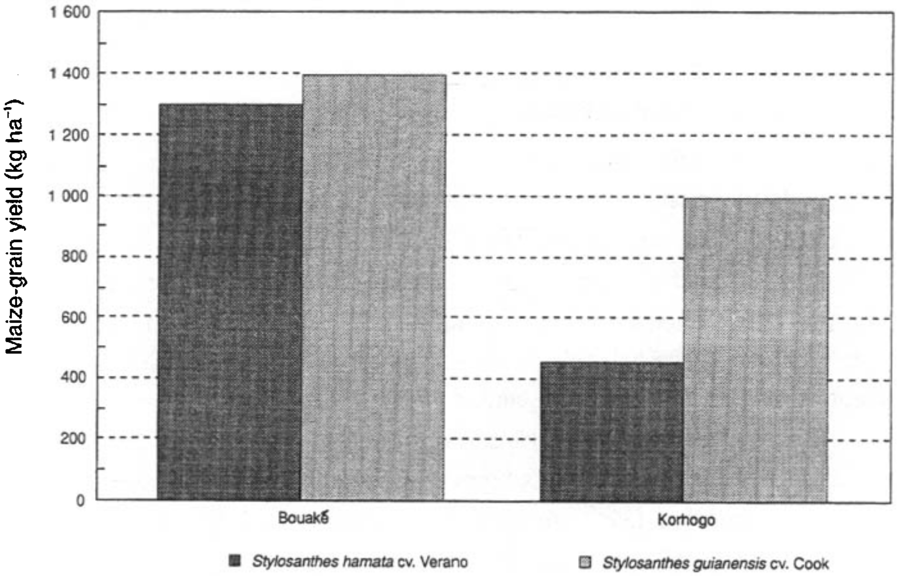

Figure 10. Grain yield of maize after unfertilized *Stylosanthes* at two locations. Source: N'Guessan (1994).

This successful evaluation program was supported at Badikaha (80 km from Korhogo) by a commercial seed-multiplication farm established to supply high-quality *Stylosanthes* materials to livestock owners, including adopters of Eco-farms in Côte d'Ivoire and other West African countries (Table 14). On this farm, *Stylosanthes* was sown on 183 ha, and a seed yield of about 100–300 kg ha^{-1} was reported for 1986.

Records and recent visits have shown that between 1987 and 1995 in Côte d'Ivoire, eight farmers each adopted 10 ha of *Stylosanthes*-based pastures around Bouaké to promote the dairy enterprise. It is expected that *Stylosanthes* pastures will be established between 1996 and 1998 for 30 farmers in central, 13 in southeast, and 13 in west Bouaké, making a total of 56 new adopters and 560 ha, although there have been 90 applicants (Eco-farms Project 1995; Mill, personal communication, 1997[5]). Funds for this new phase will be provided by the African Development Bank (ADB) and GTZ. The recent application of *Stylosanthes* in fallow management will also increase this acreage during the same period.

The West African Rice Development Association (WARDA) and its national partners are testing *S. guianensis* cv. CIAT 184 and *S. hamata* in rice-based

[5]E. Mill, GTZ, personal communication, 1997.

Table 14. Seed production at Badikaha seed farm, Côte d'Ivoire, 1986.

Species or cultivar	Area grown, 1986 (ha)	Expected yield (kg ha^{-1})	Estimated germination (%)	Seed price (XOF kg^{-1})
Panicum maximum				
T58	210			
C1	133			
1 A50	5			
2 A4	7	150	25–40	3 500
2 A5	19			
2 A6	12			
2 A22	4			
Brachiaria ruziziensis	80	500	70	1 500
Stylosanthes hamata	182	100–300	90	3 500
Stylosanthes guianensis				
CIAT 184	1	200	—	—
CIAT 136	0.25			
Aeschynomene histrix	8	300	80–90	3 500
Desmodium tortuosum	5	—	—	—

Source: M. Koffi Dongo, Badikaha Seed Farm.
Note: XOF, CFA franc; in 1986, 320 XOF = 1 United States dollar (USD); in 1998, 610.65 XOF = 1 USD.

systems in Côte d'Ivoire (four sites) and Burkina (two sites) and on lowlands (irrigated off-season crop in Vallée du Kon, Burkina) and flooded plains (Boundiali, Côte d'Ivoire). If successful, this has the potential to improve many hectares of land in the region (Becker, personal communication, 1997[6]).

The subhumid zone of southern Mali

Climate and soils

The SHZ in southern Mali is situated between latitudes 10 and 14°N and longitudes 4 and 8°W (Figure 11). The rainy season lasts from June to October and is followed by a dry period, which lasts from October to May. This dry period is divided into a cool spell, which is dominated by the harmattan, a cold wind from

[6]M. Becker, WARDA, personal communication, 1997.

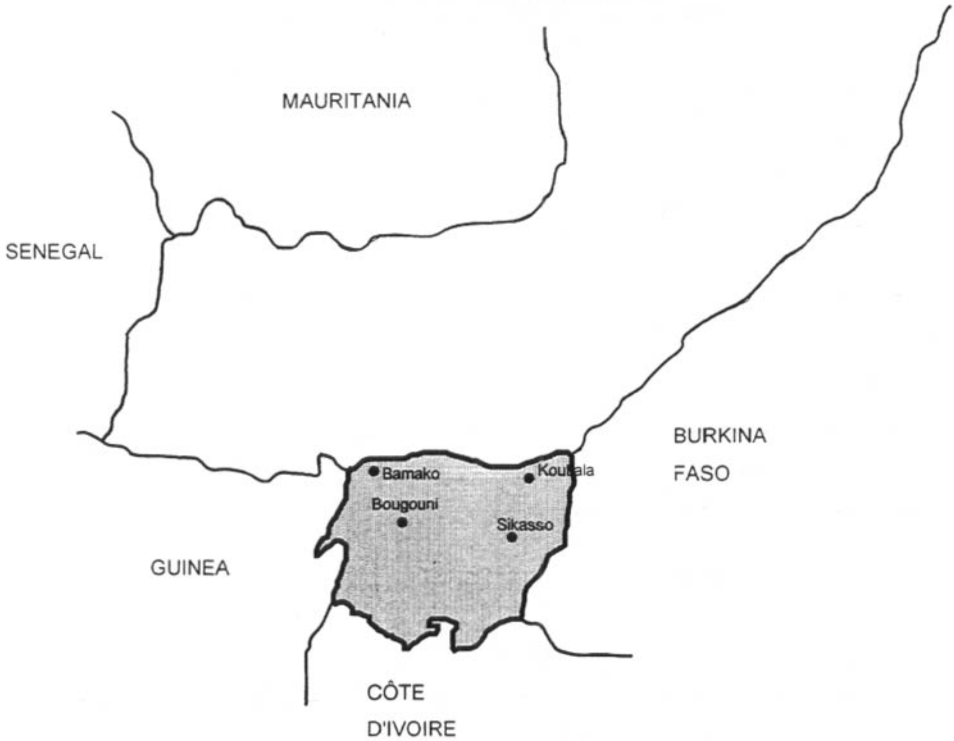

Figure 11. The subhumid zone of Mali.

the Sahara desert (December to February), and a hot spell (March to May). The average rainfall is 750 mm in the northern part (San), 980 mm around Koutiala, and up to 1 300 mm in the Sikasso area.

The soils are of the tropical-ferruginous type, with low levels of N and P and a low CEC. The typical toposequence comprises uplands, steep slopes, colluvial soil, banks, and lowlands.

The vegetation in the cultivated areas is the savanna type, with large trees, such as *P. biglobosa*, *Acacia albida*, *Adansonia digitata*, and *Butyrosprmum parkii*, all of which are useful to people. Other common vegetation includes *Pterocarpus*, *Combretum*, *Isoberlinia*, and *Deutarium*. The grasses are *Andropogon*, *Loudetia*, *Schoenefeldia*, *Hyparrhenia*, and *Pennisetum*.

Socioeconomic conditions and cultural features

The farmers in southern Mali live in village communities in Sahelian houses built of mud. The farmers are predominantly from the Minianka, Senoufo, and Bambara tribes. Population densities are high, and annual population growth rate is greater than 3%. The main economic activity is cotton production, which represents

20–30% of the cultivated land. Each household cultivates about 2–3 ha of cotton. The cotton is sold through cooperatives to the government for export and is Mali's main foreign-exchange earner. The enterprise is very well organized, and the farmers get very good prices for this crop. Over the years, this undoubtedly has improved the standard of living of the indigenous farmers, and they have developed a good knowledge of agricultural techniques. Average cotton yields are up to 1 100 kg ha^{-1}. About 70–80% of the farmers have at least a full team of oxen (plow, harrow) and a donkey-drawn cart; most of them own motorcycles, ox-drawn carts, and wheelbarrows, all of which make farm operations more efficient.

The smallholders tend to keep large herds, as this confers social prestige in the community. The farmers consider cattle herds a reliable option (compared with banks) for investing money generated from cotton. Southern Mali is not traditionally a cattle-husbandry zone, but the introduction of cotton, accompanied by animal traction, led to the growth of herds. Because of their Islamic background, the children attend Koranic schools, usually situated in bigger villages. Hospitals are provided in towns, and mobile clinics usually visit the villages.

The main problems affecting the communities are low soil fertility and land degradation caused by the expansion of cultivated lands, with few or no possibilities for fallow; roaming animals; lack of high-quality forage during the dry season; poor management of traction animals, labour, and equipment; disintegration of social unity within farmers' associations; and a tendency toward the breakup of extended families.

Farming systems and *Stylosanthes* management

The farmers in southern Mali depend on rain-fed agriculture. They produce cereals such as millet, sorghum, maize, and *fonio*, generally intercropped with cowpea. The main cash crops, in order of importance, are cotton, maize, rice, and groundnut. Cotton is usually grown in biennial and often triennial rotations with cereals. This farming practice is meant to benefit the food crops, for which no fertilizer inputs are usually provided; in contrast, the cotton usually receives N–P–K and cattle manure. Planting is done on ridges with adjacent furrows, which have the dual advantage of conserving water and retaining fertilizer. The grain yields are variable and tend to decline over the years. The farmers compensate for the low yields by increasing the area under cultivation; to prepare the land, they use animal traction and apply cattle manure.

The smallholders keep herds of 25–200 cattle, and these animals provide meat, milk, and traction. In addition, farmers also keep small ruminants (usually up to 20 or more), which usually satisfy the financial, social, and religious needs of the people. The herds depend on natural pasture during the wet season, then mainly on crop residues at the beginning of the dry season. These are supplemented with cottonseed cake (produced locally by the cotton industry) in the late dry season. Although produced locally, the cottonseed cake is reportedly still inadequate to support the growing cattle population in southern Mali. For instance, the cottonseed cake produced by the cotton mills in Koutiala and Koulikoro meets about 10–30% of the demand in southern Mali. Part of this cottonseed cake enters the commercial circuit and leaves the area for other regions in the country. Some farmers have been encouraged by extension workers to exploit *Stylosanthes* pastures for late dry-season supplementation of their cattle and small ruminants and to improve the nutritional status of their traction animals before commencement of land preparation. In the past, the use of improved pastures to feed animals was very rare in southern Mali.

The farmers usually establish *Stylosanthes* as sole crops, with guidance from farming-systems research scientists and extension agents. The land is mainly prepared by traction animals, and scarified seeds are broadcast at the rate of 10 kg ha^{-1}. Fertilizer (Phosphate naturel de Tilemsi™ [PNT]) is applied at the rate of 300 kg ha^{-1} at planting. Some farmers cut the legume and carry this fodder to the animals, whereas others use the improved pastures for grazing their animals.

Because of the legume's soil-improving characteristics, crops are usually introduced in *Stylosanthes* plots 3 years after establishment, to exploit the residual effect of the legume.

Land reclamation at the Dalabani seed-multiplication farm

The national seed-service farm was established at Dalabani (near Bougouni) by the Malian government to promote the production and distribution of high-quality seeds (cotton, rice soybean, cowpea, maize, sorghum, etc.) for crops grown by the cotton farmers in southern Mali. Continuous seed production commenced in 1975 but had to be stopped in 1992 because of the general decline in seed yield for all these crops. This was a result of soil degradation caused by lack of rest periods and failure to use amendments, such as cattle manure. Cover crops were then introduced, mainly to restore the fertility of the degraded soil on the farm. The usual seed-production activities of the farm were transferred to private-contract farmers, and the farm was planted with *Stylosanthes* spp. *Aeschynomene*, *Panicum*, etc. Fifty hectares of the land was specifically planted to *Stylosanthes*, and 22 ha of this was dedicated to seed-multiplication plots. The initial seed stock was purchased from the defunct Badikaha seed farm in northern Côte d'Ivoire, at a price of 4 000 XOF kg^{-1}.

Seeds harvested from the farm are usually sold to farmers and NGOs through the regional offices of the Compagnie malienne de développement des textiles (CMDT, Malian textiles development company). The yield varies from 200 to 300 kg ha^{-1}, and the *Stylosanthes* residue is fed to traction animals. The farm in Mali is able to produce *Stylosanthes* seeds for any organization in West Africa, provided the order is received in advance.

There is clear evidence (a high density of nitrophilous grasses) that the previously degraded soil has been rejuvenated, and the farm manager is now planning to go back to crop-seed production, in rotation with *Stylosanthes*-seed production. About 200 farmers visit the farm each year. These observers reckon that the idea of revitalizing the farm through cover crops is wise, and some of them promised to try it on their farms.

Animal evaluation

Research in Mali is currently focused on agronomic evaluation; however, farmers are evidently using *Stylosanthes* to promote dairy production and the performance of traction animals, and the legume seems to be having positive effects on both enterprises. In the CMDT zone around Koutiala, farmers allow work oxen to graze *Stylosanthes* before or after 2–3 h work.

Agronomic evaluation

In effect, it is the responsibility of the Institute of Rural Economy (IRE), and more specifically, the Division of Research for Rural Production Systems (DRRPS), to carry out the research and extension programs with a multidisciplinary team of scientists in three zones: the CMDT zone around Sikasso, Koutiala, and San; the CMDT zone at Bougouni; and Operation High Valley (OHV) zone, around Banamba, Koulikoro, Kati, Kangaba, and Bamako. All these extension bodies have been collaborating with other organizations, such as the Agro-ecological Project, the battle against erosion project (PLAE), and CMDT, to evaluate *Stylosanthes* in the farming systems of southern Mali. Some of these activities are summarized below.

In 1986, some herbaceous legumes, including *Stylosanthes*, were established in three villages (Tominian, Koutiala, and Fonsébougou); PNT was applied at three levels (0, 300, and 600 kg ha^{-1}). Some combinations of herbaceous legumes used were *B. ruziziensis* + *S. hamata* and *Cenchrus ciliaris* + *S. hamata*; pure *S. hamata* and natural vegetation were also in the trials.

Table 15. Effect of two types of fallows on the quantity and quality of fodder produced in the Operation High Valley zone.

Type of fallow	Biomass (t ha^{-1})	Cellulose (%)	N (%)	P (%)
Stylosanthes hamata	6.3	41	0.8	0.05
Natural fallow	4.1	42	0.6	0.06
Level of significance (*P*)	0.05	NS	NS	NS
CV	34	18	34	19

Source: DRRPS (1990).
Note: CV, coefficient of variation; NS, not significant.

In the OHV zone, 11 villages have had improved *Stylosanthes* fallows since 1989. After 2 years, the improved fallow produced more DM (6.3 t ha^{-1}) than the natural fallow (4.1 t ha^{-1}), but the forage value was more or less the same, and the N content improved only slightly (Table 15) (DRRPS 1990).

Between 1987 and 1988, ILCA carried out feasibility studies on fodder banks at three sites: Madina (4 ha), Diassa (4 ha), and Sotuba (near Bamako; 6 ha) (ILCA 1989). The banks, which consisted of *Stylosanthes* fallows, were meant to secure supplementary feed for livestock during the dry season. At each site, the land was plowed, fertilized with SSP (120 kg ha^{-1}), and seeded with *S. hamata* (10 kg ha^{-1}). After 2 years of establishment, *Stylosanthes*-based pastures yielded up to 10 200 kg ha^{-1} (71% stylo) at Sotuba, 5 500 kg ha^{-1} (87% stylo) at Madina, and 6 129 kg ha^{-1} (25% stylo) at Diassa (Table 16). The establishment of the fodder bank was preceded by several tests meant to identify species adaptable

Table 16. Characteristics of *Stylosanthes* fodder banks at three sites in the subhumid zone of Mali, 1988.

Parameter	Madina (sandy site)	Diassa (clay site)	Sotuba (sandy site)
Rainfall (mm)	1 069	1 069	1 088
Density (plants m^{-2})	1 492	820	1 570
Height (cm)	83	88	72
Biomass (kg DM ha^{-1})	5 540	6 129	10 200
Stylosanthes (%)	87	25	71
Grasses (%)	7	54	18
Broadleaf weeds (%)	6	21	11

Source: ILCA (1989).
Note: DM, dry matter.

Table 17. DM production of *Stylosanthes* in the peri-urban zone of Bamako.

	Rainfall (mm)		Biomass (kg DM ha^{-1})	
Village [a]	1990	1991	1990	1991
Falan	812	943	2 877	8 635
Sansankoroba	816	938	1 985	5 200
Bancoumana	774	888	2 580	6 200

Source: International Livestock Centre for Africa (unpublished).
Note: DM, dry matter.
[a] Data for Tienfala were not available.

to different sites in southern Mali. *Stylosanthes guianensis* was the most productive, followed by *Stylosanthes scabra* and then *S. hamata*. However, the first two species were susceptible to anthracnose and were therefore abandoned in favour of *S. hamata*.

In a peri-urban dairy program, jointly conducted by ILCA and IRE to improve milk production in Bamako, fodder banks consisting of *Stylosanthes* were established in four villages (Falan, Sanankoroba, Bancoumana, and Tienfala). The DM productivity was disappointing at all four sites in the first year, as a result of late seeding. However, in the second year, the yield was appreciable at all the locations (Table 17).

Crop production

DRRPS conducted on-farm trials on the effect of *Stylosanthes* and *Brachiaria* on soil fertility and the grain yield of subsequent cereals in the CMDT zone. The cover crops were planted either as sole crops or in combination in 1988. After 3 years, the plots were sown to sorghum. Soil analysis showed that after the fallow period, soil fertility had improved in the *Stylosanthes* plots, as was evident from better C–N ratios. For instance, the C–N ratio changed from a range of 22–25 to one of 8–12, signifying an improvement (Diarra and de Leeuw 1994). Grain yield of sorghum from soils preceded by the legume was also clearly better than that from non-*Stylosanthes* plots (Table 18) (DRRPS 1990).

Economic evaluation

A simple economic analysis of data from an SHZ site in Mali suggested that peasants' adoption of *Stylosanthes* generates a net income of 55 480 XOF ha^{-1} (Table 19). Fomba and Bosma (1994) concluded that the surplus cereal produced as a result of soil improvement does not guarantee the financial attractiveness of the

Table 18. Residual effect of established *Stylosanthes* on the yield of sorghum at Fonsénbougou, Mali.

Treatment	Grain yield (kg ha^{-1})
Stylosanthes + *Brachiaria*	995
Stylosanthes + *Brachiaria* (alternate rows)	979
Pure *Brachiaria*	848
Pure *Stylosanthes*	953
Natural fallow	518

Source: DRRPS (1990).

system and that extension schemes should focus on the optimal use of fodder by livestock in addition to crop yield. In Mali, as in Nigeria, the analysis indicated that fencing constitutes the highest expense (about 41%) in the package. Where the cotton industry is thriving, it may be more profitable to follow up an improved fallow with a cash crop, such as cotton, rather than with a food crop.

Similarly, an economic analysis based on linear programing confirmed that the adoption of *S. hamata* by farmers in southern Mali increased their incomes, provided a reliable market exists for animal products (Kébé 1994). In this evaluation the *Stylosanthes* system produced more animals (1029 tropical livestock nnits [TLUs] as opposed to 759 TLU) and more manure. The extra revenue generated from the sale of meat also provided the necessary capital to purchase inputs required for maize production. This analysis considered inputs such as land, labour, ox-plow, and cart; animal products and crops were considered the outputs.

Adoption of *Stylosanthes*

In southern Mali, the testing and diffusion of *Stylosanthes* owes much to the efforts of research and extension agents, in addition to those of DRRPS and CMDT, which actually have the national mandate for this. A summary of these efforts is given below to illustrate the potential for adoption of this legume.

Stylosanthes was introduced in 1974 to supply fodder and to reactivate degraded soils in Mali, mainly in the cotton-growing belt of the south. As already indicated, in 1986, *Stylosanthes* was tested in Tominian, Koutialia, and Fonsébougou. ILCA established three fodder banks at Madina, Diassa, and Sotuba between 1987 and 1988. In 1989, OHV introduced improved *Stylosanthes* in 11 villages, and in 1990, the peri-urban dairy team around Bamako established *Stylosanthes* in four villages (Falan, Sanankoroba, Bancoumana, and Tienfala).

Table 19. Partial budget analysis of a fodder plot in humid zones, with barbed-wire fencing and use of fodder after cutting.

	Amount (XOF)
Expenses	
Fencing	60 720
Seeds (12 kg)	18 000
PNT (600 kg)	18 000
Land preparation	10 000
Planting (1 d ha^{-1})	600
Weeding (2 d ha^{-1})	1 200
Cutting, transport, and storage	40 000
Total expenses	148 520
Income	
Fodder, over 3 years (11.2 t ha^{-1}; 20% losses)	168 000
Additional cereal production from fenced forage plot, as compared with unfenced plot	36 000
Gross margin	204 000
Net income	+55 480

Source: Fomba and Bosma (1994).
Note: PNT, Phosphate naturel de Tilemsi™; XOF, CFA franc; in 1998, 610.65 XOF = 1 United States dollar (USD). For the economic evaluation, the following prices were considered:

- *Stylosanthes* straw (= price of feed), 15 XOF kg^{-1};
- Cutting, transport, and storage, 5 XOF kg^{-1};
- Cereals, 60 XOF kg^{-1};
- Barbed-wire fencing, 360 XOF m^{-1}; local wood for posts and installation (wire strainers included), 100 XOF m^{-1} (total cost, 184 000 XOF ha^{-1});
- Equipment (writing off and including depreciation over 20 years; 11%), 20 240 XOF $year^{-1}$; total cost over 3 years, 60 720 XOF ha^{-1} (wire fencing, 188 400 XOF ha^{-1}); and
- Maintenance of fence, 10 000 XOF $year^{-1}$.

Promoting the technology, PLAE distributed 200 kg of *S. hamata* seed in 1991/92 to be used to establish sole pastures in 25 villages (Diarra and de Leeuw 1994). In the 1992/93 promotion, the same project distributed 1 000 kg of *Stylosanthes* seed in southern Mali.

Preextension *Stylosanthes* program

Faced with the constraints of maintaining soil productivity in southern Mali, DRRPS farming-systems scientists, in conjunction with CMDT extension agents, started testing *Stylosanthes* on farmers' fields in four villages (Kola, Karangana, Ségain, and Touroumadié) around Koutiala and Sikasso in 1989/90 (Fomba and Bosma 1994). The three principal objectives of this preextension phase were to evaluate the *Stylosanthes* system under farm conditions, determine the degree of adoption by farmers, and determine the support services required by the extension agents to successfully pass this message to farmers and fulfill their requirements, for instance, in the supply of seeds.

The introduction of *Stylosanthes* usually commences with a sensitization of farmers and the choice of voluntary farmers from each village. This is followed by a demonstration session on the establishment of *Stylosanthes* and live hedge enclosures to protect the legume; usually this session is organized by training agents. Subsequently, the sites are visited by other farmers from the village. The use of live fences is encouraged because wire fencing is very expensive. *Euphorbia balsamifera* and *Jatropha curcas* were used in this preextension program, as these species performed well in a previous program in the battle against erosion.

Stylosanthes seeds were unavailable in Mali to commence this extension program, but they were eventually acquired from NASRD (Côte d'Ivoire) at 4 000 XOF kg^{-1}. The same organization provided cuttings of *Euphorbia* free of charge.

After 3 years of activities, the preextension program ended with 49.3 ha covered. Of the original 310 participants, only 59 were still using the technology (Table 20). The dramatic drop in the number of participants could be related to the problems indicated by farmers in the Siwaa zone (see below).

During the evaluation, the farmers were asked to choose the three main problems they intended to combat using *Stylosanthes*. The problems the farmers cited generally depended on the particular situation of the village. For instance, restoration of soil fertility was perceived as an important issue in all the villages except Touroumadié, where land is always available (Table 21). Fodder production

Table 20. Trend in the adoption of *Stylosanthes* established in four villages in southern Mali, 1989–91.

	Number of farmers		Area occupied by final farmers (ha)	
Village	Initial	Final	Total	Avg. per farmer
Karangana	120	17	12.7	0.7
Kola	84	13	10.7	0.8
Ségain	58	11	15.5	1.4
Tourounmadié	18	18	10.4	0.5

Source: Fomba and Bosma (1994).
Note: Avg., average.

Table 21. Opinions of farmers on the order of importance of problems to be solved by using *Stylosanthes.*

		Importance (%)		
Village	Number of participants	Fertility	Erosion	Fodder
Karangana	32	47	0	53
Kola	23	30	56	14
Ségain	44	45	5	50
Touroumadié	22	9	45	45

Source: Fomba and Bosma (1994).

was also considered by all the villages to be important, except at Kola, where the farmers are busy combating soil erosion. At Touroumadié, because of the paddy fields, the problem of fodder should not be expected to be as acute as in any of the other villages, but the fact that the animals appreciate *Stylosanthes* explains the importance accorded to its production.

Transfer of *Stylosanthes* technology to farmers in the Siwaa zone by CMDT

The experience derived from the preextension exercise was very important for CMDT extension agents, who were already encouraging farmers in all the 25 CMDT sectors in the region to use *Stylosanthes*. The new program, which involved 45 farmers, was initiated in 1992 in the Siwaa zone, with the hope that the exercise would be extended in later years to other areas of southern Mali. The Siwaa zone covers two districts (Molobala and Koutiala) and six villages: four in Molobala and two in Koutiala. To stimulate *Stylosanthes*-seed production and to test the willingness of the farmers to pay for the seed, CMDT supplied it on the condition that the farmers would reimburse CMDT in the second year.

After 1 year, 49% of the farmers abandoned the program (Dembélé and de Vries 1993). Poor development of fodder during the first year and lack of follow-up by the trainers were two factors in the farmers' withdrawal from the scheme. Constraints that hindered the expansion of *Stylosanthes* in the Siwaa zone included lack of protection from roaming animals; ignorance of the types of species available; and lack of professional techniques for cutting, conservation, feeding, and seed collection.

Stylosanthes germination was good for 61% of the plots owned by the farmers who continued in the program but for only 27% of the plots owned by the farmers who withdrew. Also, management practices varied widely between the two groups. For instance, most of the farmers (72%) who opted out of the program planted the legume very late (October), whereas the majority of those (61%) who continued planted their *Stylosanthes* at the appropriate time (July). Fifty-nine percent of the farmers who abandoned their *Stylosanthes* plots paid no attention to fencing, but this was true of only 33% of those who continued. More live hedges were used by the latter (23%) than by the farmers who lost interest (9%).

Discussion

Main biophysical and socioeconomic constraints to adoption

Farmers in different countries have identified nine main problems that directly or indirectly influence their adoption of *Stylosanthes* (Table 22):

- Disease;
- Inadequate seed supply;
- Weed competition;
- Fencing;
- Land scarcity;
- Land tenure;
- Lack of capital;
- Labour requirements; and
- Fires.

Disease

The narrow genetic base for forage species in the Nigerian SHZ is a cause for concern, as it is limiting the uptake of the fodder-bank intervention in other agroecological zones and farming systems. Only three stylo cultivars (*S. hamata* cv. Verano, *S. guianensis* cv. Cook, and *S. guianensis* cv. Schofield) were initially identified for use in fodder banks. The situation has been made worse by the fact that two of these are susceptible to anthracnose. Reports that earlier introductions of *Stylosanthes* in Cameroon, Côte d'Ivoire, and Mali were susceptible to anthracnose scare off donors, policymakers, and potential adopters. Although *S. hamata* and *S. guianensis* cv. CIAT 184 are tolerant to anthracnose, new strains of the pathogen may develop and *S. guianensis* may lose its tolerance if it is improperly managed (especially in areas with high humidity), thus posing a serious threat to all *Stylosanthes*-based interventions.

Table 22. A comparison of *Stylosanthes*-adoption constraints and issues between countries: the main biophysical and socioeconomic constraints and key issues requiring policy intervention, promotional strategies, or further research.

Constraint–issue	Cameroon	Côte d'Ivoire	Mali	Nigeria
Disease	Anthracnose is a constraint to adoption, but the weak screening program needs to be strengthened	Anthracnose attack on *Stylosanthes* was a national disaster; intensive evaluations were developed to provide alternatives, such as *Stylosanthes–Panicum* mixtures, but more needs to be done on legume–legume mixtures	Anthracnose was reported; Mali needs to develop a sustainable cover-crop-evaluation program	Anthracnose was reported in *Stylosanthes*; intensive evaluation program was developed to find alternatives, but this needs to be expanded to include legume–legume mixtures
Inadequate seed supply	Shortage of seed has seriously affected uptake; Cameroon needs seed-production and seed-distribution enterprises	Closure of the national seed-production enterprise has created seed scarcity; Côte d'Ivoire needs more seed-multiplication and seed-distribution enterprises	Seed production and distribution are promoted by the government, but the high cost of this product warrants more seed-production efforts by all stakeholders	Low quantity and quality of seeds are a hindrance to adoption; more seed-multiplication and seed-distribution enterprises are required; research on cost-effective and sustainable seed-production techniques is also required
Weed competition	Competition from grasses is a problem; better management practices and legume–legume systems are advocated	Competition between *Stylosanthes* and associated *Panicum* and other weeds is reported; development of legume–legume systems could be a better alternative	Competition from grasses is not a serious problem, as *Stylosanthes* is established in cropped areas, where the species is well managed	Grass sometimes outcompetes desired *Stylosanthes* species in fodder banks; researchers need to identify more aggressive legumes or their mixtures

(continued)

Table 22 concluded.

Constraint–issue	Cameroon	Côte d'Ivoire	Mali	Nigeria
Fencing	Fencing is very expensive for fodder-bank adopters; cheap and suitable materials and establishment techniques need to be identified	Eco-farm Project recommends the use of *Gmelina* and barbed wire as fencing, but other suitable materials need to be identified to complement this system	Roaming animals have been the main deterrent to adoption; researchers need to identify suitable materials through evaluation trials	The need for expensive and labour-demanding fences to prevent roaming animals and uncontrolled grazing deters adoption; research should be encouraged to identify and establish both exotic and indigenous fencing material
Land scarcity	Farmers are reluctant to leave land in *Stylosanthes* fallow, owing to intensive cultivation; other systems, such as intercropping and sequential cropping, need to be developed	The land-scarcity problem is uncommon among the exploiters of *Stylosanthes*, as there is abundant land	High cropping intensity does not allow *Stylosanthes* to be incorporated as fallow crop in the same way as in Nigeria and Cameroon; other cropping practices should be identified	In intensively cultivated areas, farmers cannot leave land in *Stylosanthes* fallow for even 1 year; other cropping practices, such as intercropping or sequential cropping, need to be developed
Land tenure	Absence of secure land rights has affected diffusion of *Stylosanthes* among agropastoralists; favourable policies are required for adopters	Adopters of *Stylosanthes* in the Eco-farms Project have huge areas of land	Adopters of *Stylosanthes* are entitled to massive areas of land	Land-tenure issues are very serious constraints to adoption, especially by cattle owners; favourable land-use policies and more facilities for agropastoralists in grazing reserves are required

Lack of capital	Lack of loan schemes retards the adoption of *Stylosanthes*; low-interest loan schemes are required as incentives	Adoption of *Stylosanthes* is promoted by loans; farmers should be encouraged to target fodder banks to more lucrative enterprises	No loans are required for the promotion of fodder banks; the successful cotton industry provides capital for the required inputs	Incentives for fodder-bank adoption are provided through World Bank loan schemes; low-interest loan schemes are required; for sustainability, *Stylosanthes* should be targeted to more lucrative enterprises to generate sufficient income
Labour requirements	Labour is a serious bottleneck, and animal traction needs to be promoted	Côte d'Ivoire suffers a shortage of labour during the growing season, and animal traction is only well developed in the cotton belt; it needs to be better developed in other areas	There is shortage of labour, but ox-plows, carts, etc., are used by many farmers to alleviate this constraint; more research is required on the use of appropriate implements	Shortage of labour is acute, and animal traction is not widely used in central Nigeria; the technology needs to be introduced in these areas
Fires	Indiscriminate burning in rangelands is a very serious constraint to adoption of *Stylosanthes*; laws should be passed to deter this practice	Fires discourage farmers from adopting *Stylosanthes*; protective laws are required	Fires are not as serious in SHZ of Mali, where *Stylosanthes* is established in cropped areas as in Cameroon, Côte d'Ivoire, and Nigeria	Fires are a threat to further adoption of fodder banks; bush burning should be outlawed; fire breaks could also be constructed at the beginning of the dry season

Note: SHZ, subhumid zone.

Inadequate seed supply

The low quantity and poor quality of seed are major hindrances to the expansion of *Stylosanthes* in the SHZ of Nigeria. Seed production in the country is based on only one cultivar (Verano) because of the susceptibility of the other species to anthracnose. In Cameroon, a lack of seed prevents agropastoralists from establishing *Stylosanthes* for their herds. This is also a problem for extensionists who wanted to develop their own seed-multiplication plots for future use. In Côte d'Ivoire, seed production used to flourish but has ceased there, but Mali now has a successful national cover-crop seed-production program.

Weed competition

When *Stylosanthes* is established in association with grasses, such as *P. maximum,* but is not well managed, the legume will be suppressed, leading to a pasture that is dominated by grass and is lower in nutritional value. Also, aggressive and noxious weeds, notably *Imperata cylindrica* and *Sida acuta*, invade *Stylosanthes* pastures, sometimes completely displacing the desired legume.

Fencing

The *Stylosanthes* technology demands the use of fencing, which is very expensive (70% of the cost of a fodder bank in Nigeria), and local materials require additional labour, which some farmers cannot fit into their already busy schedule. This was a concern expressed by adopters in both Cameroon and Mali. *Stylosanthes* adopters suffer huge losses, in terms of both herbage productivity and subsequent crop yields, simply because they cannot afford appropriate fencing. This is not a concern expressed in Côte d'Ivoire, as the loan package there covers the cost of live fences of *Gmelina* and barbed wire.

Land scarcity

In intensively cultivated areas, farmers cannot leave land fallow for even 1 year, so they will find it difficult to include *Stylosanthes* fallows in their cropping systems unless they adopt other cropping practices, such as intercropping or sequential cropping. This concern is common in Cameroon, Côte d'Ivoire, and Nigeria but has not been expressed in Mali.

Land tenure

Where land rights are insecure, farmers are reluctant to make long-term commitments to land development. In many places in Nigeria, cattle owners do not have land rights; the land belongs to crop farmers, who have no interest in cattle production (although they do keep small ruminants) and are sometimes unwilling to give their unused fallow land to pastoralists for pasture development. This land-tenure constraint has affected the rate of adoption of fodder banks. The absence of secure land rights, the scarcity of land (as a result of intensive cultivation), and the open communal grazing system are some of the factors inhibiting diffusion of *Stylosanthes* to agropastoralists in Cameroon. However, land is not a restriction to fodder-bank adopters in either Côte d'Ivoire or Mali, as adopters in these countries own abundant land, sometimes up to 10 ha each.

Lack of capital

The diffusion of *Stylosanthes* technology to farmers through the Eco-farms Project came to a standstill because of a lack of capital. Also, the high interest rates and restrictions of the loan programs prevent farmers from exploiting these credit facilities. In Nigeria, when the World Bank withdrew its support for the loan scheme operating through the National Livestock Projects Department, the development of fodder banks in that country completely stopped. However, fodder banks are still promoted by other bodies, such as NGOs, and financially assisted extension programs, such as the Agricultural Development Projects. In Cameroon, the very weak initial use of fodder banks was partly due to lack of capital for research and extension. No loan scheme has been involved in the promotion of fodder banks in Mali, but the successful cotton industry provides capital for some farmers, thereby enabling them to buy the required inputs for the fodder banks.

Labour requirements

Each of the study countries was found to suffer an acute shortage of labour, as all available labour is required for subsistence cropping; Nigeria and Cameroon also suffer a shortage of agricultural mechanization, including animal traction. Additional labour is required to include *Stylosanthes* in the farming system, and this is scarcely available, especially to farmers with small families, or it is very expensive. In Côte d'Ivoire, farmers follow their traditional practice and concentrate on their crop fields during the growing season because of shortage of labour; they neglect the livestock enterprise, including the important task of managing legume-based pastures effectively.

Fires

Burning, especially during the dry season, is very common in most West African countries (especially Cameroon, Côte d'Ivoire, and Nigeria). Adopters are worried that *Stylosanthes* pastures reserved for the supplementation of cattle in the late dry season might be wiped out by fire at the most critical time; this makes the investment too risky.

Recommended policy interventions, promotional strategies, and further research

A critical point concerning the long-term sustainability of *Stylosanthes* is seed availability. Some countries, such as Côte d'Ivoire, import seed at a very high price, and others, such as Cameroon, do not have enough *Stylosanthes* seed to supply potential adopters. These constraints could be overcome if governments, private agencies, and farmers engaged in seed production enterprises, as is done in Mali and Nigeria, where *Stylosanthes* germplasm is available on the market in the same way as crop seed is. However, most of the seed farms are poorly managed in Nigeria. *Stylosanthes*-seed production is currently well handled by the national seed service in Mali; notwithstanding this, farmers should also be trained to produce and harvest their own seed. Appropriate advice on production and storage is needed by the farmers and these agencies. In Cameroon, national research and extension agencies, private companies, and even farmers should establish multiplication plots for *Stylosanthes* seed throughout the SHZ. Research to explore cost-effective and suitable techniques should be carried out concurrently.

The narrow genetic base of *Stylosanthes* species is also a problem, one that could be solved by implementing screening programs in a wide range of production domains and by identifying combinations of cover crops that complement each other. Over the years, ILCA has identified other promising species through its screening program. For instance, the best accessions in dry areas, such as Maiduguri (453 mm of rainfall), were *C. pascuorum*, *C. rotundifolia*, and *Lablab purpureus*. For high-rainfall areas, such as Jos and Makurdi (1 300 mm of rainfall), *S. scabra* and *C. brasilianum* were found to be the most successful. However, at Bauchi (780 mm rainfall), the best species was still *S. hamata* cv. Verano (Tarawali 1994). Similar screening programs are already under way in Cameroon and Côte d'Ivoire, and they are needed to complement the diffusion of fodder banks in Mali.

This evaluation was able to identify "best bets" such as *A. histrix*, which has very interesting features. This legume was found not only to produce high biomass in both dry and wet areas but also to suppress nematode and *Striga* infestation in crop fields (Weber et al. 1995).

The concept of legume–legume mixtures involving *Stylosanthes* and other cover crops should be developed, especially if year-round use of improved pastures is envisaged. Mixtures can also withstand drought, disease, fire, etc., better than sole cover crops. Better establishment techniques and cheap and better management practices are needed to guarantee a legume-dominant pasture. Probably the use of legume–legume mixtures, rather than sole legumes or legume–grass mixtures, should be explored through future research. Such studies have just started in Nigeria. They need to be initiated in Cameroon, Côte d'Ivoire, and Mali.

The persistent problem of anthracnose in the genus *Stylosanthes* could be overcome by setting up evaluation programs using other legumes for various agroecological zones and farming systems, in case there is a breakdown in the tolerance levels of *S. hamata* and *S. guianensis*. The country-wide evaluation undertaken by ILCA–ILRI and its national agricultural research system (NARS) partners in the Recherches en alimentation du bétail en Afrique occidentale et centrale (research on livestock nutrition in West and Central Africa) network is a step in the right direction. Recent reports indicate that this effort has slowed down in Mali, but the concept needs to be reactivated and even extended to new areas and countries.

Land tenure is a key policy issue in need of attention. The Nigerian government should create land-use policies favourable to the Fulani agropastoralists, whose main reason for not adopting *Stylosanthes* pasture is land-rights insecurity. The provision of grazing reserves for settling agropastoralists in Nigeria is a move in the right direction, but better facilities (schools, hospital, markets, boreholes, etc.) have to be provided to make these environments habitable and attractive. Such an approach is currently taken in Cameroon, where the government is settling agropastoralists on ranches.

Another approach employed by ILCA's farming-systems research team was to make *Stylosanthes* attractive to crop farmers who own land. Field days for demonstrating the benefits of legumes for crops and the use of *Stylosanthes* pastures for livestock were organized for both crop farmers and agropastoralists in central Nigeria. These demonstrations led the crop farmers to adopt the fodder-bank technology to improve the fertility of their continuously cultivated soils, as well as the quality of the feed they give their small ruminants (miniature fodder banks). The rationale is that once the crop farmers recognize *Stylosanthes* as a soil conditioner, they will be more likely to cooperate with agropastoralists who are seeking land to establish *Stylosanthes*.

Other factors seriously impeding the sustainability of *Stylosanthes* in West African farming systems are the shortage of labour and a lack of fencing materials to protect the legume against trespassing animals. To alleviate these constraints, the use of animal traction and carts in farm operations should be encouraged, to economize on manual labour, and there should be a complete integration of the crop and livestock sectors.

Adoption of animal traction seems to be weak in Cameroon and Nigeria. Feasibility studies on the introduction of animal traction in one of ILCA's case-study areas in central Nigeria stimulated a lot of interest from the local farmers, who used to hire carts and ox-plows from ILCA to carry out farm operations. The concept needs to be applied in other countries, and it requires further research on appropriate implements, weeding methods, feeding strategies, etc. In Côte d'Ivoire, complete integration of crop and livestock production should be recommended for all Eco-farms. The introduction of animal traction in these enterprises could reduce the labour constraint, encourage further integration, and increase total farm output. For instance, the soil-fertility improvements offered by *Stylosanthes* and manure from animals should be exploited for crop production. Conversely, residues from crops could be stored and fed to the animals during periods of feed scarcity.

Fencing *Stylosanthes* pastures or fallows represents 40–70% of the total cost of establishing a 4-ha leguminous pasture when imported metal posts and barbed wire are used. This is exorbitant. These costs could be avoided by using live fences, so research on the identification and establishment of suitable live fences should be pursued vigorously. The agroforestry divisions of national programs, such as CMDT, and the International Centre for Research in Agroforestry (ICRAF) should be able to recommend some promising species and better establishment methods. Alternatively, in countries where villagers are penalized by local custom and law if their animals damage crops, *Stylosanthes* could be protected, especially during the growing season, if farmers planted it within their crop fields. This innovation was demonstrated in southern Mali by a farmer who planted 2 ha of *Stylosanthes* in the middle of his cotton field; at the end of the growing season, he allowed his traction animals to graze the improved pasture. Another way of reducing the risk of damage to *Stylosanthes* by roaming village animals is to educate the community on the beneficial effects of the legume so that people give it the same respect and protection as they do other crops, which may also indirectly alleviate the problem of deliberate burning.

Using live fences — such as *Newbouldia*, *Ficus*, *Gmelina*, *Euphorbia*, citrus, and cashew — around farms is already in the culture of the farmers in all four countries. This suggests that the farmers may be willing to try fencing materials identified by researchers through the screening programs. Where animal traction is already well established (that is, in Côte d'Ivoire and Mali), fences are needed to prevent the animals from eating the *Stylosanthes* fields. Live fences should be promoted for this because they are cheaper than metal.

Indiscriminate burning of bush, especially during the dry season, should be banned through national legislation, and local strategies to implement controls should be developed. None of the four countries has so far adopted such a policy, which might deter the destruction of rangelands and make feed available for starving animals. Owners of *Stylosanthes* pastures should be encouraged to construct fire breaks at the onset of the dry season. This is a common practice in Côte d'Ivoire, Mali, and Nigeria for very large fodder banks (about 4 ha). Firebreaks are unnecessary in Cameroon for *Stylosanthes* plots used in intensively cultivated areas to promote dairy production.

Some of the *Stylosanthes* packages developed in certain countries are very capital intensive, and in most cases they are beyond the reach of small-scale farmers. Governments and development agencies could alleviate this problem by developing appropriate, low-interest loan schemes. A loan scheme sponsored by the Nigerian government and the World Bank promoted the diffusion of the *Stylosanthes* technology among the smallholders in the SHZ of Nigeria. Farmers in the Eco-farms project in Côte d'Ivoire now benefit from a funding scheme jointly provided by the Ivorian government, ADB, and GTZ. Such loan schemes are especially recommended for Cameroon and for all other West African countries where *Stylosanthes*-based technologies are capital intensive and peasants cannot afford the inputs.

Maximum benefits from *Stylosanthes*-based strategies to improve feed sources and soil can be realized in profitable enterprises, such as those with dairy herds or cash crops. Incidentally, research and extension activities for these enterprises are currently promoted in all four of these West African countries. In addition, the ILRI (formerly ILCA) has formed the Cattle, Meat and Milk Network to promote these enterprises, not only in West Africa but also on the continent as a whole.

Conclusions

Stylosanthes has the potential to improve feed sources, reclaim land, and control noxious weeds (especially *Striga*). These benefits are very important to both livestock and crop production in subhumid West Africa. Farmers can integrate the legume into their farming systems by growing *Stylosanthes* fallows or pastures in rotation or association with food or cash crops. Such a mixed-crop–livestock scenario could contribute to sustainable food production in West Africa. From this study, it can be seen that progress has been made in this direction, especially in the SHZs of Côte d'Ivoire, Mali, and Nigeria. Further testing and promotion seems warranted in Cameroon and SHZs of the region.

Information is available in both national and international research institutes to address the information gaps and assist in defining appropriate research and extension programs for farmers. For instance, ILRI–ILCA (de Leeuw et al. 1994; Tarawali et al. 1996) has undertaken extensive herbaceous-legume evaluations, including *Stylosanthes*-based mixtures, and animal evaluations. IITA and WARDA have information on the performance of cover crops (biomass, N accumulation, weed suppression, ecological adaptation, etc.) and soil management (Akobundu 1990; Tian et al. 1995; Sanginga, Ibewiro et al. 1996; Becker, personal communication, 1997[7]). ICRAF–Alley Farming Network for Tropical Africa (Atta-Krah 1987; Cobbina et al. 1990; Ladipo 1993; Kang et al. 1995) has many exotic and indigenous collections of trees that can be used as cheap fencing material. These institutes have several bases in West Africa. NGOs and NARS are also gaining experience that should be exchanged and acted on.

Acknowledgments

This study was made possible by financial support from the International Development Research Centre, for which the authors are grateful. Our sincere thanks also go to Dr Daniel Buckles for all his guidance and support during the development of the case study.

The contribution of the Nigerian government, the World Bank, and our NARS counterparts to the development and adoption of the *Stylosanthes* technology in Nigeria is very much acknowledged. The authors are very grateful to IRZ, Yaounde, Cameroon, and especially to J. Kounmenioc and former country representative of HPI, M. Nuwanyakpa, for all their useful suggestions. We thank E. Mill, M. Kaligha, and A. Touré of the GTZ–NASRD project, Côte d'Ivoire, for their enormous contributions to this research. We also thank Matthias Becker of WARDA for his suggestions and for facilitating the data collection in Côte d'Ivoire.

The authors acknowledge with thanks the management of CMDT and DRRPS for all the support provided in Mali. We also extend our gratitude to the CMDT regional directors and farmers for all their patience in responding to our inquiries and attending to us during field visits. Special thanks are due to M. Bengaly, Bertus Wennink, and Thea Hilhorst for their contributions to the discussions and for providing literature. The facilitating role of S. Debrah, Team Leader of the International Crops Research Institute for the Semi-Arid Tropics, Mali, was appreciated during the research in Mali.

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[7]M. Becker, WARDA, personal communication, 1997.

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Effets des engrais verts et des rotations de cultures sur la productivité des sols au Mali

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Résumé

Le Mali est l'un des pays de la zone soudano-sahélienne où la baisse générale de la fertilité des sols est l'une des principales contraintes qui limitent la production agricole et la stabilité de l'environnement. Une étude sur l'utilisation des engrais verts et des rotations légumineuses–céréales comme solutions de remplacement pour l'amélioration de la productivité des sols et le rendement du mil et du sorgho a été effectuée de 1990 à 1995 à la Station de recherche agronomique de Cinzana sur deux types de sol. Sur le sol ferrugineux tropical lessivé, caractérisé par une texture sablo-limoneuse, le mode de travail du sol n'a eu aucune influence significative sur le rendement grainier, quelle que soit la céréale ou l'année. Par contre, la rotation niébé–céréale et l'enfouissement de *Sesbania rostrata* et de *Dolichos lablab* comme engrais verts ont eu des effets significatifs positifs sur les rendements grainiers du sorgho et du mil. Sur le sol hydromorphe minéral à tendance vertique, caractérisé par une texture limono-argileuse, le mode de travail du sol a eu un effet significatif positif sur le rendement grainier du sorgho en 1991, premier cycle de rotation à la faveur du billonnage cloisonné. En 1995, troisième cycle de rotation, la rotation niébé–sorgho et l'enfouissement de *S. rostrata* et de *D. lablab* comme engrais verts ont eu des effets positifs significatifs, entraînant une augmentation de plus de 40 % du rendement grainier du sorgho par rapport au témoin monoculture de sorgho. Ces résultats permettent d'être optimiste quant à l'utilisation de *S. rostrata* et de *D. lablab* comme engrais verts pour la sécurisation du rendement du sorgho.

Abstract

As part of the effort to improve and maintain soil productivity in the Sudanosahelian region of Mali, a study on the combined long-term effects of legume–cereal rotations and green manures on soil fertility and crop yields was initiated in 1990 at the Cinzana research station. Cowpea–cereal (sorghum and millet) rotations were compared with incorporation of *Sesbania rostrata* and *Dolichos lablab* as green manure. Soil type, method of land preparation, and soil-moisture regime significantly affected crop yields under the various treatments. In the third rotation cycle, in 1995, the cowpea–sorghum

rotation and the *Sesbania* and *Dolichos* green manures improved sorghum grain yield by more than 48%. On hydromorphic soils or where tie ridges were used, the effects of cowpea–sorghum rotation on grain yields were similar to those of the green manures.

Introduction

Au Mali, la baisse générale de la fertilité des sols, l'insuffisance de techniques culturales appropriées et le faible pouvoir d'achat des agriculteurs sont des contraintes qui limitent le maintien et l'amélioration de la productivité dans toutes les zones agro-écologiques. L'estimation du bilan minéral effectuée ces dernières années par différents auteurs — Pieri (1989) et Veldkamp *et al.* (1991) fait ressortir un déficit global pour l'ensemble des éléments majeurs N, P et K dans les différents systèmes de culture pluviale. Les rendements moyens des principales cultures vivrières « sèches » sont estimés à 600 kg ha^{-1} pour le mil et à 800 kg ha^{-1} pour le sorgho. L'importance de la fumure minérale dans l'augmentation des rendements est évidente (IER 1987). Cependant, le prix élevé des engrais minéraux demeure le principal obstacle à l'application correcte des normes de fertilisation (100 kg ha^{-1} de phosphate d'ammoniaque et 50 kg ha^{-1} d'urée) recommandées par la recherche pour le mil et le sorgho. Moins de 20 % des superficies cultivées reçoivent environ 95 % des engrais minéraux importés. Ce sont des zones intensivement encadrées par les opérations de développement rural qui cultivent principalement le riz, le cotonnier et la canne à sucre. Les 5 % restants sont utilisés sur 80 % des superficies où sont cultivés le mil, le sorgho et l'arachide (Kieft *et al.* 1994).

La croissance démographique actuelle ne permet plus de compter sur la jachère de longue durée, qui autrefois permettait une certaine régénération du sol. Pour atteindre l'objectif du développement, à savoir un accroissement significatif de la production du mil et du sorgho, la recherche doit développer des techniques performantes. La stratégie de recherche devra tenir compte des conditions économiques de production et des possibilités réelles des paysans. Les rotations légumineuses–céréales et l'utilisation des engrais verts pourraient être des solutions de remplacement peu coûteuses pour le maintien et l'amélioration de la productivité des sols et du rendement des cultures. Les recherches ont montré que les légumineuses sont des cultures améliorantes qui peuvent enrichir le sol en N. Les résultats des travaux réalisés au Nigeria sur le niébé (Eaglesham *et al.* 1982) et au Malawi sur le dolic (MacColl 1989) montrent un effet résiduel positif de chacune de ces légumineuses équivalant à 36 kg N ha^{-1} pour la céréale suivante. Ceci représente environ 80 % de la dose recommandée de N pour la fertilisation minérale du mil et du sorgho au Mali. En riziculture, des résultats de recherche montrent que l'enfouissement de *Sesbania rostrata* comme engrais vert permet de doubler le rendement du riz (Allais 1988). On dispose de peu de résultats sur les cultures pluviales.

La présente étude a été initiée en 1990 par l'Institut d'économie rurale, qui est chargé de la recherche agricole au Mali, et le programme TropSoils de la Texas A&M University, aux États-Unis. Elle vise à mettre au point des techniques culturales susceptibles d'être adoptées par les paysans et capables d'améliorer la productivité des sols et le rendement des cultures grâce aux rotations céréales–légumineuses et à l'utilisation des engrais verts.

Matériel et méthodes

L'étude a été effectuée de 1990 à 1995 à la Station de recherche agronomique de Cinzana dans la région de Ségou, au Mali. La station est située dans le bassin versant des fleuves Niger et Bani, à 13°15′ Nord, 05°58′ Ouest et 281 m d'altitude. Le climat est du type soudano-sahélien avec une pluviométrie pluriannuelle moyenne de 650 mm.

Les recherches portaient sur deux types de sol. Une première analyse d'échantillons de sol a été effectuée au début de l'étude, en 1990. Le premier sol est un sol ferrugineux tropical lessivé, caractérisé par une texture sablo-limoneuse, un pH acide (5,3–5,6), une faible teneur en C organique (0,05–0,20 %), une très faible teneur en P assimilable (1,8–4,0 ppm), une capacité d'échange cationique médiocre (1,7–4,1 méq 100 g^{-1} de sol) et une très faible teneur en Ca échangeable (0,35–0,87 méq 100 g^{-1} de sol). Le second est un sol hydromorphe minéral à tendance vertique. Il est caractérisé par une texture limono-argileuse, une hydromorphie non fonctionnelle de profondeur, une faible teneur en P assimilable (1,1–6,2 ppm), un pH acide (5,5–6,0), une teneur en C organique faible à moyenne (0,27–0,67 %), une bonne teneur en Ca échangeable (3,6–5,8 méq 100 g^{-1} de sol) et une bonne capacité d'échange cationique (9,9–14,1 méq 100 g^{-1} de sol). Le dispositif expérimental utilisé est un split-plot à cinq répétitions ayant comme facteur principal le travail du sol à deux niveaux : billonnage simple et billonnage cloisonné ; et comme facteur secondaire quatre rotations de cultures : la monoculture de sorgho ou de mil avec exportation des pailles chaque année, la rotation niébé–sorgho ou mil, la rotation sesbania–sorgho ou mil et la rotation dolic–sorgho ou mil. Le *S. rostrata* et le *Dolichos lablab* sont enfouis comme engrais verts par un labour de fin de cycle. La fumure apportée au début des travaux (1990) est de 100 kg ha^{-1} de phosphate d'ammoniaque (18–46–0) et 50 kg ha^{-1} d'urée (23 N) pour le sorgho et le mil et de 65 kg ha^{-1} de Single Superphosphate™ (13,6 P – 6,5 S) pour les légumineuses. En 1995, une dose uniforme de 300 kg ha^{-1} de Phosphate naturel de Tilemsi™ (PNT) a été appliquée sur toutes les parcelles avant le semis.

Conditions de réalisation des travaux

Les pluies ont été suffisamment abondantes pendant les deux premières campagnes (1991 et 1993) pour couvrir les besoins en eau liés aux différentes phases du cycle de développement des cultures, quel que soit le traitement. En 1995, par contre, l'alimentation en eau du mil et du sorgho a été affectée pendant la phase remplissage-maturation des grains à cause de l'insuffisance des pluies. Le traitement rotation *Sesbania*–mil a été le plus affecté.

Résultats et discussion

Sur le sol ferrugineux tropical lessivé, le mode de travail du sol n'a eu aucune influence significative sur le rendement grainier, quelle que soit la céréale ou l'année (tableau 1). Par contre, la rotation des cultures et les engrais verts ont eu des effets positifs significatifs sur le rendement. En 1991, premier cycle de rotation, l'interaction mode de travail du sol × rotation des cultures a été significative à la faveur du billonnage cloisonné sous rotation niébé–sorgho et la monoculture de sorgho avec exportation des résidus tous les ans. Le cloisonnement des billons a permis d'obtenir sous ces traitements des augmentations de rendement grainier de plus de 40 % par rapport au billonnage simple.

En sol hydromorphe minéral, au premier cycle de rotation (1991), l'effet du mode de travail du sol a été significatif à la faveur du billonnage cloisonné, tandis que les rotations et les engrais verts n'ont eu aucune influence significative sur le rendement (tableau 2). Pendant les deux cycles suivants (1993 et 1995), il n'y a eu ni effet significatif du travail du sol ni interaction significative mode de travail du sol × rotation des cultures. En 1993, bien que statistiquement équivalentes au témoin, les rotations niébé–sorgho, *Sesbania*–sorgho et dolic–sorgho avec enfouissement de *Sesbania* et de dolic comme engrais verts ont eu des effets positifs sur le rendement grainier du sorgho. Les augmentations de rendement par rapport au témoin ont été de 12 % pour la rotation niébé–sorgho et de 18 % pour l'enfouissement de *S. rostrata* et de *D. lablab* comme engrais verts. En 1995, les rotations niébé–sorgho, *Sesbania*–sorgho et dolic–sorgho avec enfouissement de *Sesbania* et de dolic comme engrais verts ont été équivalentes entre elles et statistiquement meilleures que le témoin monoculture de sorgho (tableau 2). L'apport de 300 kg ha^{-1} de PNT avant le semis du sorgho a amélioré l'effet des rotations et des engrais verts sur le rendement du sorgho. Les augmentations du

Tableau 1. Effet des traitements sur le rendement grainier du sorgho et du mil en sol ferrugineux tropical lessivé, Cinzana, Mali, saisons 1991, 1993 et 1995.

		Effet sur le rendement (kg ha^{-1})		
	Travail du sol	Sorgho 1991	Mil 1993	Mil 1995
Traitement				
Céréale–céréale (paille exportée) [a]	Billon simple	650*b*	758	916
	Billon cloison	972*a*	932	851
	Moyenne	811	845*c*	884*b*
Niébé–céréale	Billon simple	661*b*	774	963
	Billon cloison	970*a*	1 269	1 091
	Moyenne	816	1 022*ab*	1 027*ab*
Sesbania–céréale	Billon simple	909*a*	997	976
	Billon cloison	982*a*	1 132	957
	Moyenne	946	1 065*a*	967*ab*
Dolic–céréale	Billon simple	996*a*	920	1 188
	Billon cloison	979*a*	1 069	1 064
	Moyenne	988	995*abc*	1 126*a*
Travail du sol (W)		NS	NS	NS
CV (%)		27,86	37,59	34,00
Rotation des cultures (C)		TS	S	S
CV (%)		13,84	18,62	21,11
W × C		S	NS	NS

Source : Kouyaté (1996).
Nota : CV, coefficient de variation ; NS, non significatif ; S, significatif ; TS, très significatif.
[a] Paille exportée chaque année.
a–c Les données de chaque colonne suivies de la même lettre ne diffèrent pas de façon significative au seuil $P = 0,05$.

rendement par rapport au témoin sont passées de 12 % à 44 % pour la rotation niébé–sorgho et de 18 % à 48 % pour l'enfouissement de *S. rostrata* et de *D. lablab* comme engrais verts. Malgré l'apport de phosphate naturel, le rendement grainier sous monoculture de sorgho a baissé d'environ 15 % de 1993 à 1995. Ces résultats montrent l'importance et l'intérêt de la rotation légumineuses–sorgho et de l'utilisation des engrais verts avec du PNT dans l'amélioration et la sécurisation du rendement du sorgho dans la zone agro-écologique concernée.

Les résultats futurs et les analyses de sol en fin d'étude permettront de se prononcer en faveur de telle ou telle rotation en fonction du type de sol.

Tableau 2. Effet des traitements sur le rendement grainier du sorgho en sol hydromorphe minéral, Cinzana, Mali, saisons 1991, 1993 et 1995.

		Effet sur le rendement (kg ha^{-1})		
	Travail du sol	Sorgho 1991	Sorgho 1993	Sorgho 1995
Traitement				
Sorgho–sorgho (paille exportée) [a]	Billon simple	2 127	1 574	1 426
	Billon cloison	2 384	1 629	1 355
	Moyenne	2 256	1 602*ab*	1 391*b*
Niébé–sorgho	Billon simple	2 081	1 874	2 117
	Billon cloison	2 308	1 708	1 890
	Moyenne	2 195	1 791*ab*	2 004*a*
Sesbania–sorgho	Billon simple	2 018	1 804	1 986
	Billon cloison	2 232	1 965	2 129
	Moyenne	2 125	1 885*a*	2 058*a*
Dolic–sorgho	Billon simple	1 952	1 951	2 093
	Billon cloison	2 216	1 818	2 029
	Moyenne	2 084	1 885*a*	2 061*a*
Travail du sol (W)		S	TS	TS
CV (%)		15,43	9,85	18,00
Rotation des cultures (C)		NS	TS	TS
CV (%)		13,58	12,36	10,60
W × C		NS	NS	NS

Source : Kouyaté (1996).
Nota : CV, coefficient de variation ; NS, non significatif ; S, significatif ; TS, très significatif.
[a] Paille exportée chaque année.
a,b Les données de chaque colonne suivies de la même lettre ne diffèrent pas de façon significative au seuil $P = 0,05$.

Conclusion

Dans le cadre de la gestion de la productivité des sols dans la zone concernée, les résultats obtenus montrent l'intérêt des rotations légumineuses–céréales et des engrais verts. Cependant, bien que N puisse être fourni par la rotation ou l'enfouissement des légumineuses, P peut limiter le développement et le rendement des cultures. Dans ces systèmes de culture à faibles intrants, l'apport du P est nécessaire pour soutenir la productivité du sol à long terme. Les résultats montrent l'effet bénéfique de l'utilisation de *S. rostrata* et de *D. lablab* comme engrais verts et de la rotation niébé–céréale en présence du PNT pour l'amélioration du rendement. Les résultats obtenus permettent d'être optimiste quant à l'emploi des engrais verts et aux rotations légumineuses–céréales comme solutions de remplacement susceptibles d'être adoptées par les paysans pour maintenir et améliorer la productivité des sols. Ils ont l'avantage de ne nécessiter aucun transport — contrairement au fumier — et ne posent aucun problème de disponibilité.

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Identification of cover crops for the semi-arid savanna zone of West Africa

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Abstract

Leguminous cover crops may be an appropriate component of sustainable food-production systems in the semi-arid savannas of West and Central Africa. A set of erect and spreading legumes was observed for adaptation to a semi-arid climate (700–900 mm annual rainfall), without fertilizer application, on three soil types in northern Cameroon. *Mucuna pruriens* generally reached 100% ground cover 60–90 d after planting, whereas *Canavalia ensiformis* rarely reached 100% ground cover. Two *C. ensiformis* accessions, one erect and one spreading, differed in their ability to cover the soil surface. Maximum foliage dry matter (DM) exceeded that of the locally adapted spreading cowpea in most cases. Foliage DM of *M. pruriens*, *C. ensiformis*, *Crotalaria ochroleuca*, and *Cajanus cajan* generally exceeded 4 t ha^{-1} at all but the most degraded site. At the degraded site, the erect *C. ensiformis* accession produced 5–7 t DM ha^{-1}. *Canavalia ensiformis* grew longer into the dry season and maintained higher moisture content, suggesting some drought resistance. Because of strong winds during the dry season and trampling during seed collection, foliage DM less than about 4 t ha^{-1} did not persist through the dry season. Uncontrolled cattle grazing was another threat to persistence of mulch through the dry season.

Résumé

Les cultures de couverture de légumineuses peuvent être un élément convenant aux systèmes de production alimentaire durable dans les savanes semi-arides de l'Afrique occidentale et de l'Afrique centrale. Un ensemble de légumineuses érigées et rampantes ont fait l'objet d'une étude afin d'être adaptées à un climat semi-aride (700–900 mm de précipitations annuelles) sur trois types de sol du nord du Cameroun sans application d'engrais. En général, la couverture de *Mucuna pruriens* atteint une maturité de 100 % dans les 60–90 jours après semis, alors que la couverture de *Canavalia ensiformis* atteint rarement 100 %. Deux obtentions de *C. ensiformis*, l'une dressée et l'autre étalée, n'ont pas la même capacité de couvrir le sol. Dans la plupart des cas, la culture sèche de feuillage maximale a dépassé celle des doliques étalées et adaptées à la région. La biomasse de *M. pruriens*, de *C. ensiformis*, de *Crotalaria ochroleuca* et de *Cajanus cajan* a

généralement dépassé 4 t ha^{-1} sur tous les terrains, sauf sur les plus dégradés. Sur un terrain dégradé, l'obtention de *C. ensiformis* dressés a produit de 5 à 7 t ha^{-1} de matière sèche. Les *C. ensiformis* ont poussé davantage pendant la saison sèche et ont maintenu une teneur en eau plus élevée, démontrant ainsi une certaine résistance à la sécheresse. La culture sèche de feuillage d'une densité inférieure à 4 t ha^{-1} n'a pas résisté aux vents forts de la saison sèche et aux dommages dus aux piétinements pendant la collection des semences. Le pâturage permanent des bovins a aussi été une menace à la persistance du paillis tout au long de la saison sèche.

Introduction

In the semi-arid zone, bare soil is susceptible to wind and water erosion, especially at the beginning of the rainy season. Live or dead vegetative cover can protect the soil surface from raindrop impact, runoff, and erosion. The mulch may also favour the activity of mesofauna, such as tunneling of termites, thereby increasing rainfall infiltration (Chase and Boudouresque 1989). Lal (1993) recommended mulch farming as a sustainable-management option for soil and water conservation in the semihumid zone, which he defined by the criterion of 800–1 000 mm annual rainfall. Sources of mulch could include crop residues or leguminous cover crops. Leguminous cover crops would not only protect the soil surface from erosion (Young 1989) and maintain the lower soil temperature (Budelman 1989) needed for soil biological activity, but also provide nutrients, particularly N. The mulch should ideally be in place when the first rains come at the beginning of the rainy season, if it is to protect the soil from erosion. From existing literature, it can be hypothesized that about 4 t ha^{-1} of dry matter (DM) is needed to protect the soil from erosion and to conserve soil water. This was observed in several studies in the forest savanna transition zone (De Vleeschauwer et al. 1980) and also in the northern Guinea savanna (Adeoye 1984).

Some leguminous cover crops have been adopted in West Africa but not in the semi-arid savanna zone. Herbaceous legumes with some adoption potential are *Mucuna pruriens* (CTA 1995), *Canavalia ensiformis* (NAS 1979; Udedible 1990), and *Crotalaria ochroleuca* (Wortmann et al. 1994).

In 1991, we initiated screening of multipurpose cover crops to identify species or accessions that not only cover the soil quickly during the rainy season but also accumulate substantial biomass and persist as live or dead cover during the dry season. We used a range of sites with different soil types.

Materials and methods

All trials were conducted in 1992 and 1993 in northern Cameroon, within 150 km of Maroua (lat. 10°30'N, long. 14°10'E), at Mouda (gravelly ferruginous Alfisol), Ndonkole (Vertisol), and Guetale (alluvial loam Inceptisol in the Mandara mountains). Annual rainfall in these environments was 700–900 mm. Soil properties varied from site to site (Table 1), with a high clay content at Ndonkole and a high level of available P at Guetale. Species screened included *M. pruriens*, *C. ensiformis* (one erect and one spreading type), *Cajanus cajan* (one early and one late type), and *C. ochroleuca*. A local spreading cowpea cultivar was used as a control in 1992.

In 1992, planting was done on 19 June at Guetale, 30 June at Ndonkole, and 1 July at Mouda. The experimental design was a randomized complete block, with two replications per site. Plot size was 6 m × 8 m, except at Ndonkole, where it was 5.5 m × 8 m. Interrow distance was 1 m for all species. Ground cover was estimated using a line-point transect method (Daughtry et al. 1995). A cord marked at 5-cm intervals was stretched diagonally across the plot and the proportion of points in line with vegetation was recorded. Biomass was sampled twice from 3.2 m^2, and a final sample was taken later from 12 m^2. Dates for ground-cover and DM determination depended on availability of transport to the sites. A subsample of the fresh biomass was oven-dried at 65°C for 48 h for DM determination.

In 1993, species or accessions were planted in a randomized complete-block design, with three replications, at Mouda (20 June), Ndonkole (21 June), and Guetale (22 June), near the plots used in 1992. Ground cover was determined at approximately 30, 60, and 90 d after planting (DAP), and DM was determined at 60, 120, and 180 DAP.

Table 1. Properties of soil (0- to 30-cm depth) at sites of cover-crop screening in northern Cameroon at the beginning of the experiment.

Property	Mouda (Alfisol)	Ndonkole (Vertisol)	Guetale (Inceptisol)
Organic C (%)	0.48	0.49	0.26
Available P, Bray-1 (ppm)	3.1	6.2	32.1
Sand (%)	57	34	49
Silt (%)	29	31	39
Clay (%)	14	35	12

The data for ground cover of *M. pruriens* and both *C. ensiformis* types were combined for the three sites in each year. Data for aboveground DM were subjected to analysis of variance, calculated separately for each year, each site, and each observation date. The maximum DM accumulation is presented; however, a combined analysis was not done over years because species and sampling times changed over the years.

Results and discussion

Cowpea often gave best early growth and ground cover; however, by the second month of growth, *Mucuna* covered the soil better than cowpea and thereby reduced soil temperature effectively during the growing season (data not shown). *Mucuna pruriens* attained 100% ground cover by 60–70 DAP in 1992 (Figure 1) and by 90 DAP in 1993 (Figure 2). In 1992 and 1993, the erect type of *C. ensiformis* gave consistently less ground cover than the spreading type. The spreading *C. ensiformis* gave consistently less ground cover than *M. pruriens* in 1992, but its ground coverage at the early-growth stage was slightly higher in 1993.

Maximum foliage DM yield is presented in Table 2. DM yields at Guetale were on average about 50% higher than those at Mouda and 30% higher than those at Ndonkole. This was probably due to the high level of available P at Guetale (see Table 1).

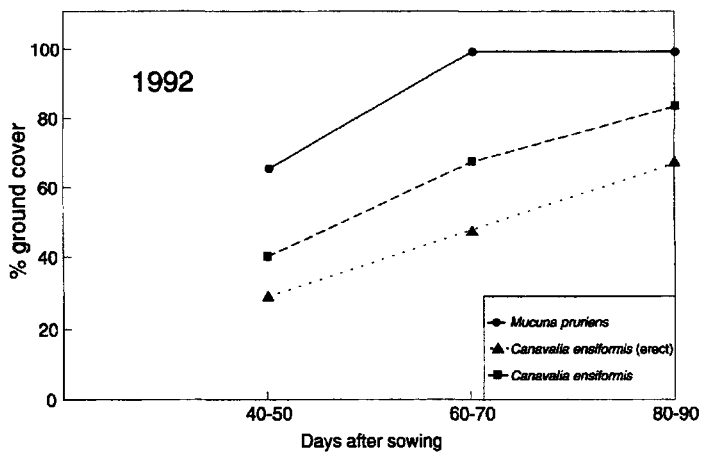

Figure 1. Percentage ground cover, 1992.

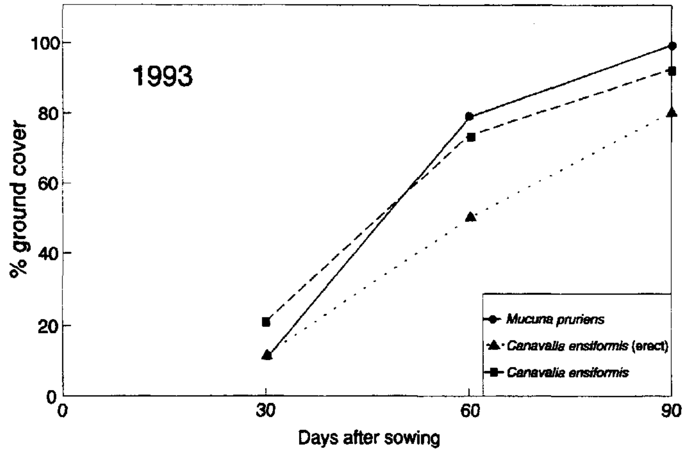

Figure 2. Percentage ground cover, 1993.

Table 2. Maximum foliage DM of legumes during 1992 and 1993 rainy seasons.

	DM (t ha^{-1})					
	Mouda		Ndonkole		Guetale	
	1992	1993	1992	1993	1992	1993
Cowpea	1.8	—	3.1	—	2.5	—
Mucuna pruriens	3.4	3.6	5.2	4.2	5.0	6.0
Canavalia ensiformis (erect)	3.9	2.7	5.0	1.9	6.2	9.3
C. ensiformis (spreading)	7.8	5.2	5.3	2.0	6.1	9.2
Cajanus cajan (early)	4.7	3.0	4.7	4.3	3.5	4.5
C. cajan (late)	7.0	—	5.7	—	5.1	—
Crotalaria ochroleuca	2.9	3.5	4.3	6.1	6.1	6.5
SE	0.97	0.67	1.07	0.73	0.64	0.92

Note: DM, dry matter; SE, standard error.

Foliage DM of cowpea was lowest at each site in 1992, averaging less than 2.5 t ha^{-1}. The cover-crop foliage yields were usually well more than 3.0 t ha^{-1}. Maximum *M. pruriens* DM averaged 4.5 t ha^{-1} in 1992 and 4.6 t ha^{-1} in 1993. Erect *C. ensiformis* DM averaged 5.0 t ha^{-1} in 1992 and 4.7 t ha^{-1} in 1993, which includes low yields at Mouda and Ndonkole. Spreading *C. ensiformis* averaged 6.4 t ha^{-1} in 1992 and 5.4 t ha^{-1} in 1993, which include a low yield at Ndonkole.

Cowpea leaves and stems generally blew away during the dry season because vegetative DM was rarely above 2.5 t ha^{-1}. Much of the biomass at Mouda (where all but spreading *C. ensiformis* produced less than 3.5 t ha^{-1}) was blown away by the dry-season winds. Many of the species persisted as mulch during the dry season (1993/94) at Guetale, where all species produced at least 4.5 t ha^{-1} of DM. It appears therefore that 3.5–4.5 t DM ha^{-1} is the minimum quantity of DM required to resist being blown away by the wind during the 8-month dry season of the semi-arid zone.

Mucuna DM accumulation has been reported in several agroecological zones of the tropics. DM is accumulated at rates of 7–12 t ha^{-1} in the humid zones of Honduras (Triomphe 1996) and Brazil (Smyth et al. 1991), 4.9–8.5 t ha^{-1} in the subhumid zone with bimodal rainfall pattern in Brazil (Lathwell 1990) and Nigeria (Sanginga et al. 1996), and 6–8 t ha^{-1} in the subhumid zone with monomodal rainfall pattern in Cameroon (Klein 1994). The accumulation of *Mucuna* DM in our trials was 3.4–6.0 t ha^{-1}, and the average was 4.6 t ha^{-1}, very near the threshold below which mulch cannot persist through the dry season, as discussed above.

The problem of persistence was exacerbated by grazing cattle. At Ndonkole, cattle came through the area in November and ate the dry and green vegetation in most of the plots. All species except *C. ensiformis* (both accessions) were eaten. Eventually, later on in the dry season, the *C. ensiformis* was also eaten. *Cajanus cajan* displayed a moderate regrowth after grazing by cattle.

Surface-soil crusting influenced establishment of some legumes. Small-seeded legumes were very much affected at Mouda in a preliminary trial in 1991. In 1993, establishment was generally lower at Mouda, with a gravelly Alfisol prone to crusting, and higher at Ndonkole, with a well-structured Vertisol. Small-seeded *C. ochroleuca* was most affected (data not shown).

In the semi-arid zone, drought resistance may be an important characteristic for a cover crop. *Canavalia ensiformis* generally continued to accumulate biomass after the end of the rains. The moisture content of *C. ensiformis* was usually much higher than that of *M. pruriens* during the early dry season (Table 3), suggesting that it still had active roots. Only *C. cajan* (late and early) and *C. ensiformis* (both varieties) still had green leaves by December. *Mucuna* reached senescence soon after the end of the rains. Late pigeon pea stayed green longest and in some cases survived the dry season. The biomass-yield potential of the early variety is lower than that of the late variety, but grain is more likely to be harvested from the early variety. Grain was harvested from the early variety but not from the late one at the Mouda site in 1992.

Table 3. Moisture content of aboveground foliage of *Mucuna* and *Canavalia* during early dry season.

	Moisture content (%)			
	Mouda		Guetale	
	1991, 122 DAP	1993, 178 DAP	1993, 120 DAP	1993, 180 DAP
Mucuna pruriens	35.5	4.0	46.4	22.4
Canavalia ensiformis	73.5	60.3	72.0	38.5
SE	3.48	0.01	0.10	0.02

Note: DAP, days after planting; SE, standard error.

Legume-planted fallows may not be adopted if the fallow species has no direct economic use (Greenland 1985). Because farmers are unlikely to grow a crop that produces no food for human consumption or any other obvious benefit, recommendations must be carefully formulated. It should be noted that the grain of *M. pruriens* and *C. ensiformis* can be used as food, but it needs to be processed and should constitute a small fraction of the human diet (Kay 1979). Future research on detoxification of these grains for human consumption should be encouraged. Other grain legumes that produce substantial biomass, such as *Lablab purpureus* should be tested.

For regeneration of degraded soils, a sole crop of *Mucuna* or *C. ensiformis* or a combination of the two species might be envisioned. These large-seeded species can break through a crusted, unplowed soil. They require very little or no weeding, and they provide the most rapid and complete cover. The major problem is that they must be protected from grazing and fire if their residues are to persist as mulch throughout the dry season. Intercropping with a drought-resistant cereal, such as millet, may increase the DM and the likelihood of persistence. Protection of mulch by fencing may be justified if the mulch proves to sustain crop production. An economic analysis will be required once the agronomic benefit of mulch is estimated.

Acknowledgments

All operations and data collection have been supervised by Mr Ngue, Institute of Agronomic Research, Cameroon. Partial funding for the trial came from the United States Agency for International Development through the National Cereal Research and Extension project.

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Gestion améliorée de la jachère par l'utilisation de légumineuses de couverture

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Résumé

Une expérimentation a été conduite en 1994–1995 à la Station de recherches agricoles de Farako-Ba. Il s'agissait d'introduire et d'évaluer les performances de croissance de sept légumineuses à travers la vigueur à la levée et le rythme de croissance, la couverture du sol, la hauteur ou la densité de végétation, la durée du cycle végétatif, la production de biomasse aérienne sèche et le pourcentage et l'accumulation de N. Les légumineuses utilisées étaient les suivantes : *Calopogonium mucunoïdes* Desv., *Mucuna pruriens* (L.) DC var. *utilis* (Wight) Burck., *Mucuna cochinchinensis*, *Pueraria phaseoloïdes* (Roxb.) Benth., *Lablab purpureus* (L.) Sweet, *Macroptilium atropurpureum* (DC) Urb. et *Cajanus cajan* (L.) Millsp.

Il ressort de l'étude les observations suivantes : (1) ces plantes ont un cycle végétatif variant entre 6 et 10 mois ; même après la période végétative, certaines d'entre elles, comme les « mucunes », présentent une litière abondante et sèche se formant en un enchevêtrement de lianes et de feuilles, constituant non seulement une protection du sol mais aussi un environnement favorable pour les micro-organismes ; (2) *Cajanus cajan* et les deux mucunes produisent la biomasse aérienne la plus importante avec un très bon taux de couverture ; (3) la teneur en N des légumineuses varie de 1,65 à 3,95 %, occasionnant une accumulation assez importante de N (61–650 kg ha^{-1}).

Ces légumineuses peuvent constituer une solution de remplacement intéressante pour résoudre le problème de baisse de la fertilité du sol et du rendement des cultures dans la zone ouest du Burkina Faso.

Abstract

Seven legumes — *Calopogonium mucunoïdes* Desv., *Mucuna pruriens* (L.) DC var. *utilis* (Wight) Burck., *Mucuna cochinchinensis*, *Pueraria phaseoloïdes* (Roxb.) Benth; *Lablab purpureus* (L.) Sweet., *Macroptilium atropurpureum* (DC) Urb. et *Cajanus cajan* (L.) Millsp. — were evaluated for performance (germination, growth-cycle soil coverage, height or vegetation density, aboveground-biomass production, and N accumulation). In general, germination was faster (97%) with large-grained legumes. All of the legumes

except siratro were characterized by slow initial growth and a very long growing cycle (6–10 months). These characteristics are important in the formulation of intercropping systems with cereals. Slow initial growth can constitute a problem because the legumes can become vulnerable to fast-growing weeds. *Mucuna*, calopo, and puero were free of insect pests, whereas *L. purpureus* was badly attacked by some unidentified pests. The legumes accumulated 2.7–8 t ha^{-1} of dry matter (DM). A total DM production of 19 t ha^{-1} was recorded for *Cajanus*. In 1994, an N accumulation of 61–231 kg ha^{-1} was observed for the legumes.

Introduction

Dans les zones d'Afrique soudano-guinéenne à forte densité de population, l'intensification des cultures, entraîne toujours une baisse du niveau de fertilité du sol (Dommergues et Ganry 1991 ; Sedogo 1991, 1993 ; Becker *et al.* 1995). Les effets négatifs les plus apparents attribuables à l'intensification sont la baisse du taux de matière organique (MO) (Hien *et al.* 1993), associée à la réduction de la quantité de N dans le sol (Traoré et Gigou 1991), et l'infestation des terres de culture par les mauvaises herbes. La croissance rapide de la population (plus de 3 % an^{-1}) mène à l'expansion des cultures, au déboisement et au surpâturage. La disparition du couvert végétal rend le sol vulnérable à l'érosion (Chopart 1984 ; Alegre et Cassel 1994). Les longs intervalles de jachère naturelle, nécessaires à la régénération de la fertilité du sol, ne peuvent plus être pratiqués (Nye et Greenland 1960 ; Sanchez 1976 ; Sedogo 1993 ; Le Roy 1995). Il faut trouver le moyen de combiner le recours intensif mais durable aux ressources disponibles localement (Burkina phosphate, dolomie, fumier, compost, engrais verts, jachères améliorées à base de légumineuses) et l'emploi parcimonieux d'intrants extérieurs afin de maîtriser l'érosion et de maintenir ou d'augmenter la productivité des sols (Raquet 1991).

Il faudrait élaborer un système d'agriculture équilibrée sur le plan écologique, combinant des mesures d'agencement des cultures (agroforesterie, culture multiple) et des mesures de fumure organique telles que l'utilisation de fumier provenant de bétail en étable, le compostage et l'ensemencement de jachères avec des légumineuses à croissance rapide, fixatrices de N. Ces jachères sont censées remplacer les jachères pâturées traditionnelles qui mettent longtemps à restaurer la fertilité du sol et dont l'efficacité reste faible (Pieri 1989 ; Raquet 1991 ; Roose 1993). En comparaison, elles sont de courte durée, étouffent efficacement les adventices (Johnson et Adesina 1993 ; Roose 1993), produisent bien plus de biomasse au cours de la première année (jusqu'à 20 t ha^{-1} de matière sèche [MS] de biomasse aérienne) (Pietrowick et Neuman 1987, cités par

Raquet 1991), limitent l'érosion, permettent de maintenir la biodiversité et améliorent la productivité du sol (Becker *et al.* 1996).

Certains auteurs trouvent des résultats mitigés par rapport aux jachères de courte durée. Selon Hien *et al.* (1993), les jachères améliorées à partir des légumineuses (*Stylosanthes*, dolique, etc.) ou naturelles à base de graminées à forte densité racinaire (*Andropogon*, *Pennisetum*, etc.) peuvent contribuer au maintien de la productivité face aux exigences de l'intensification des cultures lorsque le sol n'est pas en voie de dégradation poussée. Pieri (1989) montre à travers les travaux de l'Institut de recherches du coton et des textiles exotiques que des jachères, même courtes, réduisent le taux de pertes annuelles de MO. Le problème principal est de convaincre le paysan d'introduire ces jachères de courte durée dans son système de culture avant les baisses importantes de sa production végétale attribuables à la désaturation du complexe absorbant des sols. Cependant, la meilleure solution de replacement des systèmes de culture de ces zones écologiquement fragiles reste l'amélioration de la gestion des résidus culturaux et autres mesures de conservation du sol (par exemple, avec les plantes de couverture). Une telle gestion assurerait probablement la durabilité de la productivité en limitant l'érosion (Yost et Evans 1988), en améliorant les propriétés physiques et la fertilité du sol (Wilson *et al.* 1982 ; Lathwell 1990), et en réduisant la pression des adventices (Akobundu 1993 ; Balasubramanian et Blaise 1993).

L'objet de la présente communication est de présenter une approche visant à introduire les légumineuses de couverture dans les systèmes de culture des producteurs de la zone ouest du Burkina Faso. Cela se fait à travers le criblage de plusieurs espèces de légumineuses traditionnelles et exotiques (provenant des collections de germoplasmes du Centro Internacional de Agricultura Tropical, de l'International Rice Research Institute et de l'Institut international d'agriculture tropicale) afin de sélectionner celles qui auront la faveur des producteurs et qui s'adaptent aux conditions agro-pédoclimatiques de la zone.

Matériel et méthodes

Emplacement et caractéristiques du site

L'étude a été conduite en parcelles de cultures de la Station de recherches agricoles de Farako-Ba, située sur l'axe Bobo–Banfora, à 10 km au sud-ouest de Bobo Dioulasso (04° 20′ de longitude O., 11° 06′ de latitude N. et 405 m asl d'altitude). Le climat de la région est de type sub-soudanien (Guinko 1984), caractérisé par une période fraîche de novembre à février et une période chaude en mars et en avril. La longueur de la saison de pluies ou période de végétation active s'étend de 130 à 150 jours, avec une pluviométrie monomodale variant entre 950 et 1 100 mm. L'essentiel des précipitations s'étale de juin à septembre et se concrétise en nombre de jours de pluie variant de 50 à 70. Le sol appartient à la classe des sols à sesquioxydes de fer ± de manganèse et au sous-groupe des sols ferrugineux tropicaux lessivés indurés peu profonds (lixisols ferriques, phase pétroferrique). Les caractéristiques physico-chimiques figurent au tableau 1.

Évaluation des légumineuses

Dans cette expérimentation, sept légumineuses ont été utilisées : *Calopogonium mucunoïdes* Desv. (calopa), *Mucuna pruriens* (L.) DC var. *utilis* (Wight) Burck. et *Mucuna cochinchinensis* (« mucunes »), *Pueraria phaseoloïdes* (Roxb.) Benth. (puero), *Lablab purpureus* (L.) Sweet (dolique), *Macroptilium atropurpureum* (DC) Urb. (siratro) et *Cajanus cajan* (L.) Millsp. (pois cajan ou pois d'angole). Il s'agissait d'introduire et d'évaluer leur performance de croissance à travers le rythme de croissance et la durée du cycle végétatif, la couverture du sol, la hauteur ou la densité de végétation, la production de biomasse aérienne sèche et le pourcentage et l'accumulation de N.

Ces plantes ont été semées le 12 juillet 1994 et le 15 juin 1995. Les écartements utilisés étaient de 0,20 m entre les lignes pour toutes les cultures. La densité de semis était fonction du type de semence : 25–30 graines m^{-2} pour les légumineuses à petites graines (calopo, puero et siratro) et 10–15 graines m^{-2} pour celles à grosses graines (pois cajan, dolique, mucune). Les dimensions des parcelles élémentaires étaient de 8 m × 3 m (24 m^2). Pour chaque légumineuse, on utilisait trois répétitions.

Sur les légumineuses, le prélèvement de la biomasse a été effectué sur trois lignes de 3,3 m de long. Un sous-échantillon de 100 g de matière fraîche a été pris et mis à sécher à l'étuve 72 h à 70° C pour la détermination de MS. Cet échantillon est par la suite conservé dans un sachet en plastique bien fermé pour la détermination de la teneur en N par la méthode Kjeldahl. Les légumineuses ont été récoltées à une périodicité de 28 jours à partir du semis.

Résultats et discussion

Évaluation des légumineuses

Les données concernant le pourcentage de levée, l'indice de couverture et l'épaisseur de végétation (à différentes étapes du cycle végétatif) des légumineuses figurent dans les tableaux 2 et 3 pour 1994 et 1995 respectivement. On constate en général une très bonne levée pour les légumineuses à grosses graines (en moyenne 97 %) par rapport aux petites (55 %). Les semences de dolique et de

Tableau 1. Caractéristiques physico-chimiques du sol, Farako-Ba, saison humide, 1994.

Caractéristique	Horizon 0–20 cm	Horizon 20–40 cm
Analyse granulométrique		
Texture	SL	LS
Argile (%)	12,75	13,50
Limon fin (%)	8,75	4,75
Limon grossier (%)	11,13	54,69
Sable fin (%)	65,28	26,16
Sable grossier (%)	2,09	0,95
Matière organique		
Matière organique totale (%)	1,02	0,93
C total (%)	0,59	0,54
N total (%)	0,05	0,04
C–N	12,0	14,0
K		
Total (ppm)	974,0	1 678,0
Disponibilité (ppm)	89,0	49,0
P		
Total (ppm)	88,0	132,0
Assimilable (ppm)	3,38	2,86
Bases échangeables		
Ca^{2+} (méq 100 g^{-1} du sol)	1,43	1,53
Mg^{2+} (méq 100 g^{-1} du sol)	0,51	0,82
K^{+} (méq 100 g^{-1} du sol)	0,15	0,08
Na^{+} (méq 100 g^{-1} du sol)	0,06	0,08
Somme des bases, S (méq 100 g^{-1} du sol)	2,15	2,50
Capacité d'échange, T (méq 100 g^{-1} du sol)	3,83	3,86
Taux de saturation, S/T (%)	56,3	64,9
Réaction du sol		
pH eau	6,19	5,62
pH KCl	4,60	4,47
Al échangeable (méq 100 g^{-1} du sol)	<0,01	0,04
H échangeable (méq 100 g^{-1} du sol)	0,28	0,44

Nota : LS, limon sableux ; SL, sable limoneux.

Tableau 2. Pourcentage de levée, indice de couverture du sol et épaisseur de végétation des légumineuses, Farako-Ba, saison humide, 1994.

			Épaisseur (cm)		
	% levée	Couverture [a]	28 JAS	56 JAS	84 JAS
C. mucunoïdes	75	9	5,0	15,9	38,6
M. cochinchinensis	96	9	10,9	20,8	70,1
P. phaseoloïdes	95	7	12,3	2,8	62,7
M. pruriens	98	8	12,7	21,3	72,0
L. purpureus	98	7	11,8	26,3	68,0
C. cajan	95	7	21,3	71,3	172,5
M. atropurpureum	40	6	4,7	10,8	17,9

Nota : JAS, jours après le semis. Légumineuses : *Calopogonium mucunoïdes* Desv., *Mucuna cochinchinensis, Pueraria phaseoloïdes* (Roxb.) Benth., *Mucuna pruriens* (L.) DC var. *utilis* (Wight) Burck., *Lablab purpureus* (L.) Sweet, *Cajanus cajan* (L.) Millsp. et *Macroptilium atropurpureum* (DC) Urb.
[a] Évaluation visuelle : 1 = 10 %, 2 = 20 %, ... , 10 = 100 % de couverture.

Tableau 3. Pourcentage de levée, indice de couverture du sol et épaisseur de végétation des légumineuses, Farako-Ba, saison humide, 1995.

			Épaisseur (cm)		
	% levée	Couverture [a]	28 JAS	56 JAS	84 JAS
C. mucunoïdes	52	8	10,2	27,0	39,8
M. cochinchinensis	87	8	41,2	58,9	63,4
P. phaseoloïdes	43	5	9,8	20,8	43,6
M. pruriens	77	7	41,9	69,4	59,1
L. purpureus	98	6	25,6	52,2	43,4
C. cajan	95	7	31,3	118,2	133,0
M. atropurpureum	47	5	ND	ND	ND

Nota : JAS, jours après le semis ; ND, non déterminé. Légumineuses : *Calopogonium mucunoïdes* Desv., *Mucuna cochinchinensis, Pueraria phaseoloïdes* (Roxb.) Benth., *Mucuna pruriens* (L.) DC var. *utilis* (Wight) Burck., *Lablab purpureus* (L.) Sweet, *Cajanus cajan* (L.) Millsp. et *Macroptilium atropurpureum* (DC) Urb.
[a] Évaluation visuelle : 1 = 10 %, 2 = 20 %, ... , 10 = 100 % de couverture.

siratro ont été obtenues à Beguedo (CRPA du centre-est) auprès d'une coopérative de production de semences fourragères. Cela dénote une relative maîtrise de la production de semences.

L'indice de couverture est très bon dans l'ensemble, à l'exception du siratro. En ce qui concerne le rythme de croissance, on note dans l'ensemble un démarrage lent, mais le rythme devient plus rapide après le second mois de végétation, surtout en ce qui concerne le pois d'angole, légumineuse arbustive. Cette croissance initiale lente de ces légumineuses, avec un cycle très long (de 6 à 10 mois), pourrait être intéressante dans le cas d'une association avec des céréales : peu de compétitivité vis-à-vis de la céréale (eau et éléments minéraux) de toute façon largement compensée par son effet de couverture du sol (lutte contre les adventices et diminution de l'évaporation du sol), forte production de MS à l'hectare, complète couverture du sol et lente décomposition qui permettent de maintenir le sol couvert à plus de 70 % pendant plus de 4 mois à partir de son plein développement. Ces plantes sont restées vertes de juillet 1994 à janvier 1995, ne commençant la dégénérescence que plus tard pour toutes les espèces à l'exception du siratro dont le développement a été lent. Cette dernière est restée verte pendant plus de 11 mois. Dès les premières pluies d'avril 1995, le calopo, le siratro et le puero, dans une moindre mesure les mucunes et la dolique, ont germé naturellement. Les tableaux 4 et 5 présentent l'évolution de la biomasse aérienne sèche des légumineuses de couverture à différentes phases du cycle végétatif, respectivement pour 1994 et 1995.

Au cours de la première campagne de criblage, les plantes ont été suivies jusqu'à la fin de la période de jachère. La dolique, le siratro et le puero ont un développement initial plus lent que les mucunes et le pois cajan, couvrent le sol plus tard ; par conséquent, ils sont plus vulnérables dans la compétition avec les adventices à croissance rapide dans les premières semaines. Les feuilles de *L. purpureus* souffrent d'une forte infestation de ravageurs, alors que les mucunes,

Tableau 4. Évolution de la biomasse aérienne sèche de quelques légumineuses, Station de Farako-Ba, saison humide, 1994.

	Biomasse aérienne sèche (kg MS ha^{-1})					
	28 JAS	56 JAS	84 JAS	196 JAS	224 JAS	252 JAS
C. mucunoïdes	41	4 982	7 904	5 782	3 289	3 692
M. cochinchinensis	119	9 038	8 051	5 698	3 408	8 233
P. phaseoloïdes	12	1 419	2 961	2 927	3 076	3 005
M. pruriens	120	2 588	7 629	3 928	3 373	4 890
L. purpureus	131	2 425	3 104	3 939	4 059	5 681
C. cajan	225	5 588	9 333	ND	ND	6 435
M. atropurpureum	ND	ND	ND	1 941	3 278	2 732

Nota : JAS, jours après le semis ; MS, matière sèche ; ND, non déterminé. Légumineuses : *Calopogonium mucunoïdes* Desv., *Mucuna cochinchinensis*, *Pueraria phaseoloïdes* (Roxb.) Benth., *Mucuna pruriens* (L.) DC var. *utilis* (Wight) Burck., *Lablab purpureus* (L.) Sweet, *Cajanus cajan* (L.) Millsp. et *Macroptilium atropurpureum* (DC) Urb.

Tableau 5. Évolution de la biomasse aérienne sèche de quelques légumineuses, Station de Farako-Ba, saison humide, 1995.

	Biomasse aérienne sèche (kg MS ha^{-1})			
	28 JAS	56 JAS	84 JAS	112 JAS
C. mucunoïdes	209	2 147	9 135	7 904
M. cochinchinensis	891	6 618	9 135	8 050
P. phaseoloïdes	56	723	8 975	2 968
M. pruriens	1 056	4 750	9 861	7 629
L. purpureus	459	3 347	5 667	3 104
C. cajan	149	3 491	28 836	19 333
M. atropurpureum	357	993	1 115	ND

Nota : JAS, jours après le semis ; MS, matière sèche ; ND, non déterminé. Légumineuses : *Calopogonium mucunoïdes* Desv., *Mucuna cochinchinensis*, *Pueraria phaseoloïdes* (Roxb.) Benth., *Mucuna pruriens* (L.) DC var. *utilis* (Wight) Burck., *Lablab purpureus* (L.) Sweet, *Cajanus cajan* (L.) Millsp. et *Macroptilium atropurpureum* (DC) Urb.

le calopo et le puero présentent une croissance puissante et saine. La MS accumulée pour la plupart des légumineuses est importante (2,7–8 t ha^{-1} ; 19 t ha^{-1} pour le pois cajan). Ces données sont conformes à celles de nombreux auteurs dont Skerman (1982), qui trouve un rendement en MS variant de 10 à 35 t ha^{-1} en Australie pour le *C. cajan*. Le pourcentage et l'accumulation de N sont présentés au tableau 6.

En 1994, on note une accumulation de N de l'ordre de 61 (calopo) à 231 (*M. cochinchinensis*) kg ha^{-1}. Agboola et Fayemi (1972) et Mello (1978) (cités par Charpentier *et al.* 1991) trouvent respectivement de 370 à 450 kg N ha^{-1} pour *C. mucunoïdes* et 157 kg N ha^{-1} pour *M. pruriens* var. *utilis*. Skerman (1982) avance pour cette dernière un rendement de 331 kg N ha^{-1}, soit l'équivalent de 1 615 kg ha^{-1} de sulfate d'ammoniaque au Queensland septentrional (Australie). Pour la seconde année de criblage, on obtient de 66 (puero) à 650 (*Cajanus*) kg N ha^{-1}. Ces apports de N sont considérables et contribuent, si la gestion des résidus de légumineuses est bien efficace, à une meilleure disponibilité en N du sol pour les cultures.

Conclusion et perspectives

Ces deux années de criblage ont donné d'appréciables renseignements sur le comportement de ces légumineuses de couverture dans les conditions agropédoclimatiques de la station de Farako-Ba. La litière en place et l'accumulation de N en fin de jachère est appréciable.

Tableau 6. Biomasse aérienne sèche, pourcentage et accumulation de N des légumineuses, Station de Farako-Ba, saison humide, 1994 et 1995.

	Biomasse aérienne sèche (kg MS ha^{-1})		Teneur en N (%)		Accumulation de N (kg ha^{-1})	
	1994	1995	1994	1995	1994	1995
C. mucunoïdes	3 692	7 904	1,65	2,21	61	175
M. cochinchinensis	8 233	8 050	2,80	3,05	231	246
P. phaseoloïdes	3 005	2 968	1,92	2,21	58	66
M. pruriens	4 890	7 629	1,69	2,78	83	212
L. purpureus	5 681	3 104	2,03	3,71	115	115
C. cajan	6 435	19 333	2,53	3,36	163	650
M. atropurpureum	2 732	ND	2,43	3,95	66	ND
Jachère naturelle	ND	3 290	ND	0,12	ND	4,0

Nota : MS, matière sèche ; ND, non déterminé. Légumineuses : *Calopogonium mucunoïdes* Desv., *Mucuna cochinchinensis, Pueraria phaseoloïdes* (Roxb.) Benth., *Mucuna pruriens* (L.) DC var. *utilis* (Wight) Burck., *Lablab purpureus* (L.) Sweet, *Cajanus cajan* (L.) Millsp. et *Macroptilium atropurpureum* (DC) Urb.

Actuellement, des études sont entreprises en conditions paysannes afin de faire participer davantage les agriculteurs au développement de ces méthodes culturales, gage de réussite du transfert de technologie. De même, des expérimentations sur les possibilités d'associer les cultures vivrières (mil, maïs, sorgho) et les plantes de couverture, simultanément ou en culture relayée, sont en cours, comme celles portant sur une gestion rationnelle des résidus de légumineuses.

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Abstracts and short reports / Résumés et abrégés

On-farm trials of *Mucuna* spp. in Ghana

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Résumé

La présente recherche a été effectuée dans la zone de transition entre 1993 et 1995 afin de déterminer l'effet du *Mucuna* sur le chiendent et sur le rendement du maïs. En 1993, une étude a démontré que les cultures en lignes jumelées de maïs, séparées de 50 cm sur 40 cm et largement espacées entre elles par environ 150 cm, ne réduisent pas nécessairement de beaucoup le rendement du maïs. Les résultats des études menées à l'aide de collections locales de *Mucuna* ont indiqué une différence considérable entre elles dans leur précocité de maturité et leur production de biomasse. En général, les rendements de maïs suivant une culture de *Mucuna* ont plus que doublé si on les compare aux rendements lorsque le maïs a suivi la culture de doliques ou de maïs dans les parcelles tracées par les agriculteurs. Le contrôle du chiendent à l'aide du *Mucuna* dans les champs gérés par les agriculteurs a également été efficace dans l'ensemble, sauf dans les cas où la sécheresse a empêché la production de *Mucuna*. Les nombreux feux de brousse qui ont détruit le paillis de *Mucuna* accumulé constituent le principal obstacle à l'adoption du *Mucuna* dans le pays. Une bande de dolique (6 m de long) a été plantée autour des champs de *Mucuna* au cours de la saison secondaire de 1995. La bande a servi de cloison de recoupement et a protégé certains des champs de *Mucuna* contre le feu.

Introduction

The transition zone of Ghana produces the bulk of maize and other food crops for the country. Farmers in this zone face serious problems with weeds and low soil fertility. Research was conducted in the transition zone between 1993 and 1995 to determine the effect of *Mucuna* on spear grass and yield of maize.

A study, conducted in 1993, showed that maize yield is not significantly reduced by having paired rows of maize spaced at 50 cm × 40 cm and the paired rows separated by a wide spacing of about 150 cm. Crop management was easier when *Mucuna* was intercropped in the wide spacing between these paired rows than when the *Mucuna* was intercropped in conventional maize rows.

An informal survey conducted in the transition and forest zones of Ghana indicated that *Mucuna* is often consumed in soups and stews by people in these zones. The *Mucuna* commonly grown in the country for food has black, ash, mottled, or yellow seeds.

Studies conducted with local types of *Mucuna* indicated that they differed significantly in days to maturity and biomass production. The latest maturing and most aggressive *Mucuna* had mottled seeds and matured in about 190 d, whereas the earliest maturing *Mucuna* had yellow seeds and matured in 130 d. Biomass production and weed control by the *Mucuna* with mottled seeds were similar to those by an exotic *Mucuna* from Benin. The highest grain yield of *Mucuna* (1 087 kg ha^{-1}) was obtained from the *Mucuna* from Benin, whereas the lowest (370 kg ha^{-1}) was obtained from the mottled type. Lima beans and *Canavalia ensiformis* were also included in this study. Both of these legumes appeared to mature very late and to have a very poor canopy, and the lima beans bore no fruit.

Farmer-managed Mucuna fields

Many farmers in the transition zone in Ghana have been using *Mucuna* with maize since work started on *Mucuna* in this country. In general, yields of maize following *Mucuna* have been more than double those following cowpea or maize in farmer-managed plots. *Mucuna* has also on the whole effectively controlled spear grass on the farmer-managed fields, except when drought prevented maximum biomass production by the *Mucuna*.

Constraints

The adoption of *Mucuna* in Ghana has been limited by the numerous bush fires that destroy the accumulated *Mucuna* mulch. It has also been observed that bush fires in the study area do not spread through fields where groundnuts, soybean, or cowpea had been planted during the preceding minor season. This is because such fields tend to have little crop residue. Based on this observation, a 6-m strip of cowpea was planted around *Mucuna* fields in the minor season of 1995. The strip served as a fire barrier and protected some *Mucuna* fields from burning.

Using polythene bags to control the growth of *Mucuna* vines

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Résumé

Une plante de couverture de type *Mucuna* utilisée dans un système de cultures intercalaires peut causer des ravages en recouvrant la culture constituante, en lui faisant de l'ombre et en l'étouffant. Une expérience a été réalisée en 1997 à la station expérimentale du Crops Research Institute à Ejura, au Ghana, afin de voir si l'on pouvait empêcher les lianes de *Mucuna* de grimper en créant des obstacles avec des sacs en polythène. Des piquets recouverts de sacs en forme de cône (1) noirs et non perforés, (2) transparents et non perforés ou (3) transparents et perforés ont été plantés dans le *Mucuna*. Le traitement de contrôle s'est fait avec des piquets sans sac. Tous les sacs ont effectivement empêché le *Mucuna* d'atteindre le haut des piquets jusqu'à 96 jours après qu'ils ont été plantés. Cent vingt jours après qu'ils ont été plantés, le *Mucuna* de contrôle formait une voute d'un diamètre de 90 cm en haut des piquets. Les sacs faisaient obstacle en « piégeant » les lianes qui grimpaient le long des piquets. Bien que cette méthode soit probablement peu économique pour des cultures de récolte annuelle comme le maïs, elle est prometteuse pour les cultures de plantations.

Introduction

Velvetbean (*Mucuna* spp.) is one of the most widely used cover crops in the tropics. Its benefits include fixation of atmospheric N (Osei-Bonsu and Asibuo 1997), improvement of the soil's physical properties (Hulugalle et al. 1986), and weed control (Versteeg and Koudokpon 1990). *Mucuna* is a vigorous, climbing annual legume (Wilmot-Dear 1984), and it can become a pest in an intercropping system by climbing and shading the component crop and reducing the yield (Osei-Bonsu and Asibuo 1997). If *Mucuna* is intercropped with short-season crops such as maize, *Mucuna* planting can be delayed to allow the crop to be harvested before the *Mucuna* attains maximum growth and causes damage. This strategy cannot, however, be used with perennial crops, such as mangoes and oranges. With a perennial crop, *Mucuna* vines would have to be constantly pruned to prevent them from climbing, but pruning is tedious and time consuming.

It was hypothesized that a barrier, such as a polythene bag, could prevent *Mucuna* from climbing, either by diverting its direction of growth or by trapping it. The direction of growth would be diverted if *Mucuna* "detected" the bag (through the mechanism of tropism) and bent away from it. If conditions in the bag, such as temperature, darkness, and relative humidity (RH), were unfavourable, detection would occur. *Mucuna* vines could, on the other hand, be trapped by the bag if they failed to detect it in the absence of the unfavourable conditions mentioned above. Based on this hypothesis, we conducted a study to determine whether *Mucuna* vines could be physically prevented from climbing if polythene bags were used as a barrier.

Materials and methods

The study was conducted at the Crops Research Experimental Station, Ejura, Ghana, in 1997. The study area falls within the forest–savannah transition zone, with a bimodal rainfall pattern. The major season begins in April and ends in July, and the minor season begins in September and ends in mid-November. Mean total rainfall for the major season is 1 200 mm; for the minor season, 800 mm. The experimental treatments were *Mucuna* staked with poles fitted with (1) black unperforated (black), (2) transparent, unperforated (transparent), or (3) transparent, perforated (perforated) polythene bags. Poles without bags were used as the control. The experimental design was a randomized complete block, replicated three times. Each plot had three poles spaced 3 m apart. Each bag, with open ends, was fitted to form a conical structure around a pole: the vertex of the cone (bag) was tightly tied to the pole with twine, and the base of the cone remained open. With this arrangement, vines had entry into the bags through the bases but no exit through the vertexes (Figure 1).

The polythene material used was about as thick as ordinary paper. Holes for the perforated bags were made with a penknife and were about 1 cm long and 3 cm apart. *Mucuna pruriens* var. *utilis* was planted on 20 May at a spacing of 80 cm × 40 cm and was staked 10 d after emergence. The central pole of each plot was used for data collection. Temperature and RH were measured (the latter with a hygrometer) within the bags and also at 120 cm above the ground for the control. Photosynthetically active radiation (PAR) was measured with a Sunfleck Ceptometer™ (Decagon Devices Inc., Pullman, WA, USA), and fractional light interception (FLI) was calculated with the following formula:

$$f = (A - B) \times 100/A$$

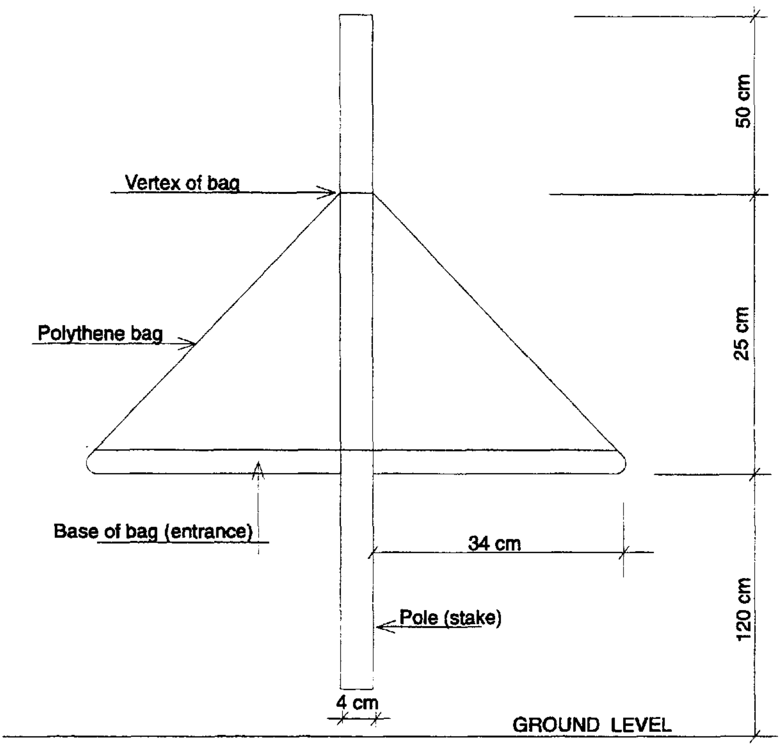

Figure 1. A pole fitted with a polythene bag. Note: Not to scale.

where *f* is FLI; *A* is ambient PAR; and *B* is canopy PAR (Monteith 1977).

PAR for FLI at 0 d after staking (DAS) was measured at the base of the bags immediately after staking, but subsequent PAR was measured above the vertex.

For biomass assessment at 160 DAS (at full-podding stage), the *Mucuna* vines on each pole were cut into three parts: bottom (from ground level to 120-cm height); middle (120–145 cm height); and top (above 145-cm height). The biomass was oven dried for 72 h at 105°C and then weighed.

Results and discussion

Temperature and RH within the bags and around the control poles at the start of the experiment did not differ significantly (data not shown). However, FLI did differ significantly ($p < 0.01$) and was highest for the black bag (32%) and lowest (2%) for the control (Table 1).

Table 1. RH and FLI within *Mucuna* canopy and polythene bags.

Treatment	RH (%)	FLI (%)			
		0 DAS	60 DAS	120 DAS	160 DAS
Transparent	73.5	20	2	4	59
Perforated	70.8	21	4	5	38
Black	72.5	32	3	4	58
Control	69.3	2	46	56	98
CV (%)	1.1	10.9	9.3	8.4	9.3
$LSD_{(0.05)}$	2.4	7	3	3	2

Note: CV, coefficient of variation; DAS, days after staking; FLI, fractional light interception; LSD, least-significant difference; RH, relative humidity.

Mucuna vines were first observed climbing the poles 17 DAS, irrespective of treatment. By 32 DAS the vines in the control group had reached the top of the poles, and by 120 DAS they had formed a canopy 90 cm wide on top of these poles. Although the number of vines at the base of the poles did not differ significantly at 120 DAS (Table 2), no vine reached the top of the poles with bags during this period. FLI of the *Mucuna* canopy on top of the poles in the control group was 46% at 60 DAS and 56% at 120 DAS; the highest FLI for the other treatments at 120 DAS was only 5% (see Table 1). Absence of foliage on top of the poles with bags explains the low FLI recorded in these treatments. All the vines that climbed the poles with bags entered the bags and were trapped at the vertex, as hypothesized.

Table 2. Number of vines at 120 DAS and DW of biomass at 160 DAS per pole.

	Number of vines		DW of biomass (g)			
Treatment	Bottom	Top	Bottom	Middle	Top	Total
Transparent	78	—	550	225	150	925
Perforated	84	—	701	373	125	1 202
Black	81	—	500	175	126	801
Control	87	73	875	400	349	1 625
CV (%)	7.5	—	18.5	14.9	15.8	12.4
$LSD_{0.05}$	NS	—	NS	150	100	451

Note: CV, coefficient of variation; DAS, days after staking; LSD, least-significant difference; NS, not signifucant. Totals are rounded.

Inside the bags, development and growth of new leaves occurred, but we observed that growth occurred at a lower rate in the black and transparent bags than in the perforated ones. As the quantity of biomass increased in the bags, drops of water appeared and remained inside the black and transparent bags, which might have caused the increased RH recorded in Table 1. With time, the tips of the vines and leaves began to burn and rot, probably as a result of the high humidity. Of the vines that entered the bags, virtually none reemerged, and about 60% were wilted by the end of the experiment.

The vines reached the top of the poles with bags in the same period (between 128 and 132 DAS) by climbing over the bags. This became possible when *Mucuna* foliage formed around the poles up to the base of the bags and blocked the entrance.

Vines from different directions tended to bend toward an upright-growing vine or vines (in one observation, we counted up to 68 vines intertwined). Consequently, once a vine had climbed over a bag, many more also climbed over the bag, using the first vine for support.

Understanding the mechanism underlying this process of bending (which is likely to be linked with tropism) may help researchers find a solution to the problem of climbing and shading.

The quantities of biomass that accumulated at the bottom, middle, and top of the poles at 160 DAS are presented in Table 2. Statistically, the dry weight (DW) of the biomass did not differ among treatments at the bottom of the poles but did differ at the middle and top (see Table 2). The least biomass was formed at the middle of the poles with black and transparent bags, indicating suppressed growth in these bags. Shade (in the black bag) and poor aeration might have contributed to the suppressed growth. Vines in the control group accumulated 349 g DW of biomass on top of the poles, whereas those in the treatments with bags accumulated a maximum of 150 g DW.

The total biomass accumulated per pole was lowest (801 g DW) with the black bags and highest (1624 g DW) for the control. There were no significant differences among bag treatments, but these groups accumulated a significantly lower total biomass per pole than the control group (see Table 2).

At 160 DAS, FLI of the *Mucuna* canopy on top of the poles reached 98% in the control group, whereas that for the other treatments ranged between 38 and 59% (see Table 1).

Conclusions

The study showed that *Mucuna* vines can be prevented from climbing if a barrier is placed against the direction of their growth. Although this method is unlikely to be economical for *Mucuna* intercropped with annual crops such as maize, it holds promise for use with plantation crops. Further studies are required to determine the effect of the bags on crop growth and to determine the optimum size of bags that would prevent any climbing whatsoever.

Acknowledgment

The authors gratefully acknowledge the International Institute of Tropical Agriculture, Ibadan, Nigeria, for financial support for this research.

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The use of cover plants with plantation tree crops in Ghana

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Résumé

Les couvertures de sol aident à diminuer les risques d'érosion du sol dans les cultures arbustives, particulièrement avant la fermeture du couvert arbustif. Parmi les différentes espèces de couverture de sol testées avec le cacao au Ghana, celles qui ont eu le plus de succès sont *Centrosema pubescens*, *Pueraria phaseoloïdes* et *Flemingia congesta*. Ces couvertures de sol ont été aussi efficaces pour le désherbage et l'amélioration de la fertilité des sols épuisés par des cultures de plantations. L'arrivée du mouton de la race djallonké dans les plantations a évité l'encombrement des cultures arbustives en fournissant de surcroît l'occasion de produire de la viande. Après 20 ans de pâturage, *Centrosema* et *Pueraria* ont pratiquement été remplacés par une grande variété d'espèces spontanées.

Introduction

The cultivation of plantation tree crops — such as oil palm, citrus, cashew, coconut, rubber, papaw, and cola — carries a high risk of soil erosion until the tree-crop canopy closes. Several cover crops have therefore been tested with plantation tree crops in Ghana. The most successful cover crops include *Centrosema pubescens*, *Pueraria phaseoloïdes*, and *Flemingia congesta*.

Cocoa itself covers the soil properly, so its requirement for a cover crop is less crucial. Nevertheless, some cover-crop work has been done with cocoa. In experiment 1, a number of shrubby cover plants were tested for their ability to recondition forest soils exhausted by cropping; cocoa was used as a test crop, and natural bush fallow was used as a control (given a cocoa yield index of 100). In experiment 2, creeping covers were tested in cocoa, and in experiment 3, mixed creeping and erect cover plants were tried in cocoa. Results of the three experiments are shown in Table 1.

Most of the cover crops were hard seeded and required treatment before planting. The seed was steeped in concentrated H_2SO_4 for 10 min, rinsed in water,

Table 1. Performance of various covers in cocoa.

Experiment 1 (rejuvenation of exhaustively cropped soils)		Experiment 2 (creeping cover in cocoa)		Experiment 3 (mixed creeping and erect cover in cocoa)	
Cover	Score (%)	Cover	Score (%)	Cover	Score (%)
Natural regrowth	100	Natural regrowth	100	Natural regrowth	100
Flemingia congesta	588	*Calopogonium mucunoïdes*	207	*Indigofera sumatosa*	241
Pennisetum purpureum	341	*Pueraria phaseoloïdes*	183	*Tephrosia* spp. (mixed)	218
Leucaea ieucocephala	170	*Mimosa invisa*	100	*Desmodium asperum*	195
Cajanus cajan	154	*Centrosema pubescens*	158	*Indigofera spicata*	183
Tithonia diversifolia	42			*Cassia tora*	158
				M. invisa	156
				Crotolaria longithyrsa	144
				T. diversifolia	18

Source: Adapted from annual reports of the Kade Agricultural Research Station, University of Ghana, Legon, Ghana.

Table 2. Chemical composition of cover plants grazed by sheep on a tree-crop plantation.

	% of DM					ppm of DM		
Genus	N	P	K	Ca	Mg	Zn	Cu	Mn
Pueraria	3.5	0.21	2.0	0.51	0.23	26.0	11.3	360
Centrosema	3.2	0.20	2.3	0.45	0.15	29.3	11.3	320
Panicum	2.4	0.19	2.8	0.28	0.16	20.0	2.0	187

Note: DM, dry matter.

and planted immediately. Alternatively, it was soaked in warm water (75°C) for 15 min. Broadcasting untreated seed immediately after burning the bush has also worked well on some oil-palm estates.

Livestock integration with tree crops

Cover crops are invariably so vigorous that they have to be slashed to prevent them from choking the tree crops. However, many cover crops are nutritious (Table 2) and palatable to animals. Sheep were therefore introduced to graze them and to convert their threat into an opportunity to produce meat. Under research-station conditions, forest-type sheep (Djallonke) reached 25–30 kg in 2 months, compared with 15–25 kg in the savanna zone. Lamb mortality was 5–6% on station and 24% on farm, whereas the national average for scavenging flocks is 40%.

After 20 years of being grazed, the *Calopogonium* has disappeared and *Centrosema* and *Pueraria* have been reduced drastically in the plantations, having been displaced by a wide range of volunteer species. Some of these invaders, which were introduced in screening trials for effective cover crops, have become cosmopolitan on the station. Among these are *Mimosa pudica*, *Axonopus compressus*, *Brachiaria lata*, *Oplismemus burmanii*, *Desmodium sooparius*, *Panicum maximum*, *Synedrella modiflora*, *Byrsocarpus coccineus*, *Lantana camara*, and *Oxalis corniculata*. *Chromolaena odorata*, which entered Ghana in about 1960, has adapted very well to the climate and is widespread on the plantations.

Green-manure crops for sustainable agriculture in the inland valleys of northern Ghana

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Résumé

Les études sur les légumineuses pouvant être introduites dans les systèmes de culture dans les vallées au nord du Ghana ont commencé au milieu des années 1980. Bien que les légumineuses à graines comme le niébé, l'arachide et le soja produisent une biomasse et une quantité de N plus élevées que celles des plantes de couverture telles que *Calopogonium*, les paysans ne sont pas disposés à les utiliser comme engrais verts au détriment de la production des graines. Cependant, les variétés de 60 jours de niébé intéressent les paysans parce qu'elles servent à la fois d'engrais verts et de production de graines. Les légumineuses utilisées comme cultures de relais avec le riz n'intéressent pas les paysans parce qu'un semis précoce de la légumineuse dans le riz empêche la croissance de ce dernier tandis que, semée tardivement, la légumineuse souffre et ne s'établit pas. L'utilisation des légumineuses comme jachère antérieure à la culture de riz donne de meilleurs résultats. Une culture de niébé précédant la culture de riz, par exemple, accroît le nombre de talles productives et le rendement grainier.

Introduction

Northern Ghana, comprising the Upper East, Upper West, and Northern administrative divisions, lies between lat. 8° and 11°05'N and between long. 0°30'E and 3°W and covers 9.97×10^6 ha. Rainfall in the area has a unimodal pattern, from April to October, with the peak in September, and totals 1 000 – 1 100 mm. In the first 2 or 3 months, the rainfall is too erratic for farmers to cultivate a staple food crop.

Subsistence agriculture is the predominant occupation, and the crops are sorghum, millet, rice, maize, legumes (groundnuts, cowpea, and soybean), and cotton. The lack of appropriate land-management and -conservation practices has resulted in severe degradation of the environment: a changing vegetation cover, further decreases in soil fertility, increased soil compaction and erosion, disturbed hydrological regimes, and high weed infestation. The consequence of this in the past few decades has been a falling agricultural-productivity index (kilograms crop yield per capita).

Materials and methods

Relay cropping of rice with *Calopogonium*

In this trial, *Calopogonium* was interseeded into rice 1 and 2 months after the rice was planted and 2 weeks before the rice was harvested, with a no-interseeding control. The experiment had a randomized complete-block design, replicated four times. Yield data and growth habits of both crops were used to assess treatments.

Calopogonium as an improved fallow legume

In the improved-fallow study, treatments were 1, 2, and 3 years of *Calopogonium* fallow and weedy fallow, with different levels of fertilizer, in a split-plot design. Type of fallow was the main plot, and levels of fertilization were the subplots. Continuous rice cropping was the control treatment. Weed infestation and grain yield were recorded, and an economic analysis of the different systems was undertaken. This work, located at an on-farm site at Yepeligu and an on-station site at Nyankpala, is ongoing.

Results

Relay cropping of rice with *Calopogonium*

When *Calopogonium* was seeded 1 month after the rice, it competed with the rice; when it was seeded 2 months after the rice, it germinated poorly, probably as a result of shading, high soil-water levels, and low soil temperature. A good crop of *Calopogonium* could not be established when planted 2 weeks before the rice harvest.

Improved-fallow study

Annual dry-matter yield of *Calopogonium* measured in November–December ranged from 5 to 8 t ha^{-1}. This biomass dried up during the dry season and formed a carpet. At the beginning of the rains, in April, *Calopogonium* seeds that dropped on the ground in the fallow plots germinated to form a regenerated fallow, in contrast to the bush-fallow and continuous-rice fields. Biomass incorporated from this regenerated fallow in June ranged from 1 to 3 t ha^{-1} and contained about 2% N. A 3-year *Calopogonium* fallow significantly increased soil organic matter and cation exchange capacity. Fertilizer application had no effect on these properties. However, differences were not significant after 1 year of fallow.

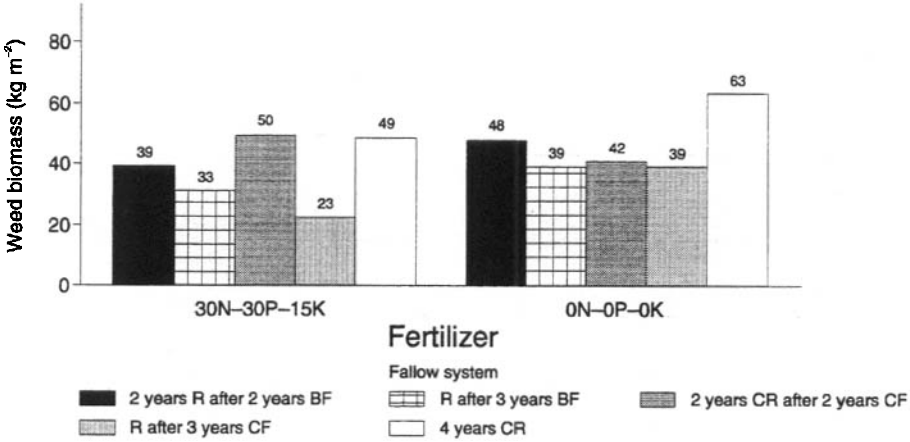

Figure 1. Effect of fallow and fertilizer on weed biomass at 28 d after planting, Yepeligu. Note: BF, bush fallow; CF, *Calopogonium* fallow; CR, continuous rice; R, rice.

Rice fields preceded by 3 years of *Calopogonium* had a significant reduction in weed biomass. This effect was highly significant with the application of fertilizer (Figure 1). Both 1 and 3 years of *Calopogonium* fallow resulted in significantly higher rice-grain yields per hectare than bush fallow did. A partial budget analysis of the systems at both sites showed that *Calopogonium* fallow was the most profitable system (Table 1).

Table 1. Partial budget analysis of rice produced in different fallow systems, Yepeligu, 1995.

Treatment [a] (years)	Fertilizer (kg ha^{-1})	Grain yield (kg ha^{-1})	Incremental benefit (GHC ha^{-1})	Incremental cost (GHC ha^{-1})	Profit (GHC ha^{-1})
2 CR after 2 CF	0	1 093	−75 000	1 976	−76 976
	30	1 602	124 345	56 563	67 782
R after 3 BF	0	1 200	20 379	4 940	25 319
	30	1 659	138 957	1 976	84 370
2 CR after 2 CF	0	1 268	38 095	1 976	36 119
	30	2 330	286 680	56 563	230 117
R after 3 CF	0	1 580	117 791	4 940	112 551
	30	2 664	373 000	54 587	318 421
4 CR	30	2 246	290 896	59 527	231 369

Note: In 1998, 2 292 Ghanaian cedis (GHC) = 1 United States dollar (USD).
[a] Continous rice without fertilizer was the control. BF, bush fallow; CF, continuous fallow; CR, continuous rice; R, rice.

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L'association culturale sorgho–niébé pour prévenir le ruissellement et l'érosion dans le Sahel au Burkina Faso

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Abstract

In the Central Plateau region of Burkina Faso, intensity of rainfall is a principal factor inducing soil erosion and rapid degradation of the structure of the topsoil. Field trials investigating the effectiveness of some leguminous species (*Mucuna pruriens*, *Canavalia ensiformis*, *Crotalaria retusa*, *Calopogonium mucunoides*, *Pueraria phaseoloides*, *Cajanus cajan*, and one *Arachis* sp.) in controlling runoff and soil erosion were conducted at the Institut d'étude et de recherches agricoles (INERA, agricultural study and research institute) station at Saria. In three-year multilocation trials carried out by INERA – SemiArid Food Grain Research and Development, cowpea cv. IAR 7/18045 rapidly covered the ground, within 30 d, giving adequate protection against soil erosion. *Mucuna pruriens* gave 100% protection within 45 d. In third place was *C. ensiformis*, with 50% coverage. The other species gave ≤30% coverage. Of the species tested, cowpea was the most attractive to farmers, because it produced edible grains. Because of drought, *Mucuna* was unable to produce seeds (annual rainfall rarely exceeds 900 mm). The grains from *Canavalia* are not consumable. These results prompted field trials investigating the effectiveness of *Sorghum*–cowpea intercropping in controlling runoff and soil erosion. With this combination, runoff was 20–30% less than with *Sorghum* grown as a sole crop and 5–10% less than with cowpea grown as a sole crop. Soil erosion was 80% less than with *Sorghum* alone and 45–55% less than with cowpea alone. Total farm productivity under *Sorghum*–cowpea intercropping was double that under sole crops of either *Sorghum* or cowpea.

Introduction

Dans le Plateau central du Burkina Faso, la situation pluviométrique très aléatoire est aggravée par un ruissellement important (42% de pluie en moyenne par an) et des pertes en terre considérables (4–8 t ha^{-1} an^{-1}) malgré une pente relativement faible (inférieure à 3%) (Roose 1981). Suite à des travaux de recherche menés à la station de Saria (Nicou *et al.* 1990 ; Guillobez et Zougmoré 1994), il est ressorti que l'intensité des pluies, principal facteur du phénomène de ruissellement, entraîne une dégradation rapide de la structure des sols en surface. On assiste alors à une baisse rapide du régime d'infiltration et ainsi au déclenchement du ruissellement (Casenave et Valentin 1989). L'une des solutions pratiques consiste en une meilleure protection de la surface du sol. Des expérimentations sur le paillage (« mulching ») ont été effectuées et les résultats obtenus montrent un effet réducteur très net sur le ruissellement.

Mais face aux problèmes liés à la gestion des résidus culturaux dans cette zone (Lompo 1993), l'une des voies possibles est l'utilisation de légumineuses à fort développement végétatif comme plante de couverture. En outre, l'association de culture, traditionnellement pratiquée par les paysans, pourrait être plus facilement acceptée en vulgarisation. Cette technique permettrait de limiter le ruissellement des eaux de pluie et d'améliorer la teneur en N et en matière organique (MO) du sol. L'objet de la présente étude est d'évaluer l'effet d'une association culturale sorgho-niébé sur le ruissellement et l'érosion à l'échelle de la parcelle

Matériel et méthods

L'étude a été menée pendant 3 ans (de 1993 à 1995) sur les cinq parcelles aménagées depuis 1971 à la station de Saria pour les mesures du ruissellement et de l'érosion. Chacune des parcelles est bordée de lames de tôle pour empêcher l'introduction d'eau extérieure ou la fuite de l'eau qui ruisselle dans la parcelle. En aval se trouve un système de bassin de réception et de fosses munies de cuves pour recueillir les eaux et les transports solides. La pente du milieu est de 0,7 % et les dimensions parcellaires sont de 72 m^2 (16 m × 4,5 m) pour la parcelle PW et 96 m^2 (16 m × 6 m) pour les quatre autres. Les traitements sont les suivants :

Parcelle	Traitement
PW	Semis direct de sorgho, deux sarclages
P1	Semis direct de sorgho, paillage de surface, deux sarclages
P2	Labour aux bœufs, semis de sorgho et de niébé, deux sarclages
P3	Labour aux bœufs, semis de sorgho, deux sarclages
P4	Labour aux bœufs, semis de niébé, deux sarclages

Le sol est de type ferrugineux tropical lessivé dont la carapace se situe à 50 cm de profondeur. Les teneurs en MO, N, K échangeable et P assimilable sont très basses. La capacité d'échange cationique est médiocre (2–4 me 100 g^{-1}) et le taux de saturation diminue de 70 % en surface à 30–50 % en profondeur parallèlement au pH 5,3–4,9 (Roose 1981).

Les mesures et observations sont réalisées systématiquement après chaque pluie supérieure à 10 mm. Les paramètres suivants ont été suivis :

- *quantité d'eau ruisselée et quantité de terre érodée* — après chaque pluie ayant occasionné un ruissellement, la hauteur d'eau totale ruisselée et la terre déplacée par le ruissellement sont quantifiées ;

- *rendements culturaux* — le poids des grains et des pailles est mesuré à la récolte ;

- *Variétés utilisées* — sorgho, ICSB 1049 ; niébé, IAR 7/180-4-5.

Résultats

Ruissellement et érosion

Les mesures de ruissellement réalisées pendant les trois années (figure 1) ont donné les résultats suivants : après le travail du sol (labour, grattage manuel), le ruissellement n'a lieu qu'après un cumul de pluie de l'ordre de 60 mm. Les meilleures conditions d'infiltration du sol créees par cette intervention expliquent que le sol absorbe toute la quantité d'eau des deux ou trois premières pluies. Le classement par ordre de ruissellement croissant est le suivant : 1-P1, paillage de surface ; 2-P2, association sorgho–niébé ; 3-P4, niébé seul ; 4-PW, sorgho seul après grattage ; 5-P3, sorgho seul après labour.

L'étude des pertes en terre est effectuée de façon similaire à celle du ruissellement, c'est-à-dire en comparant les parcelles entre elles à l'aide d'un graphique normé en somme des pluies et somme des terres érodées (figure 2). La quantité de terre déplacée la plus importante est obtenue sur la parcelle labourée puis cultivée en sorgho. En 1994, les mesures ont donné 16,4 t ha^{-1} sur cette parcelle ; 6,5 t ha^{-1} sur P4 ; 5,9 t ha^{-1} sur PW ; 2,9 t ha^{-1} sur P2 ; 1,4 t ha^{-1} sur F1. Les valeurs obtenues en 1993 et 1994 sont du même ordre de grandeur que celles précédemment énumérées. Le travail du sol (labour, sarclo-binage) semble favoriser l'arasement du sol. Des résultats similaires avaient été obtenus par Guillobez *et al.* (1995) qui ont trouvé que lors de pluies importantes, les pertes en terre deviennent considérables si le sol est fréquemment travaillé.

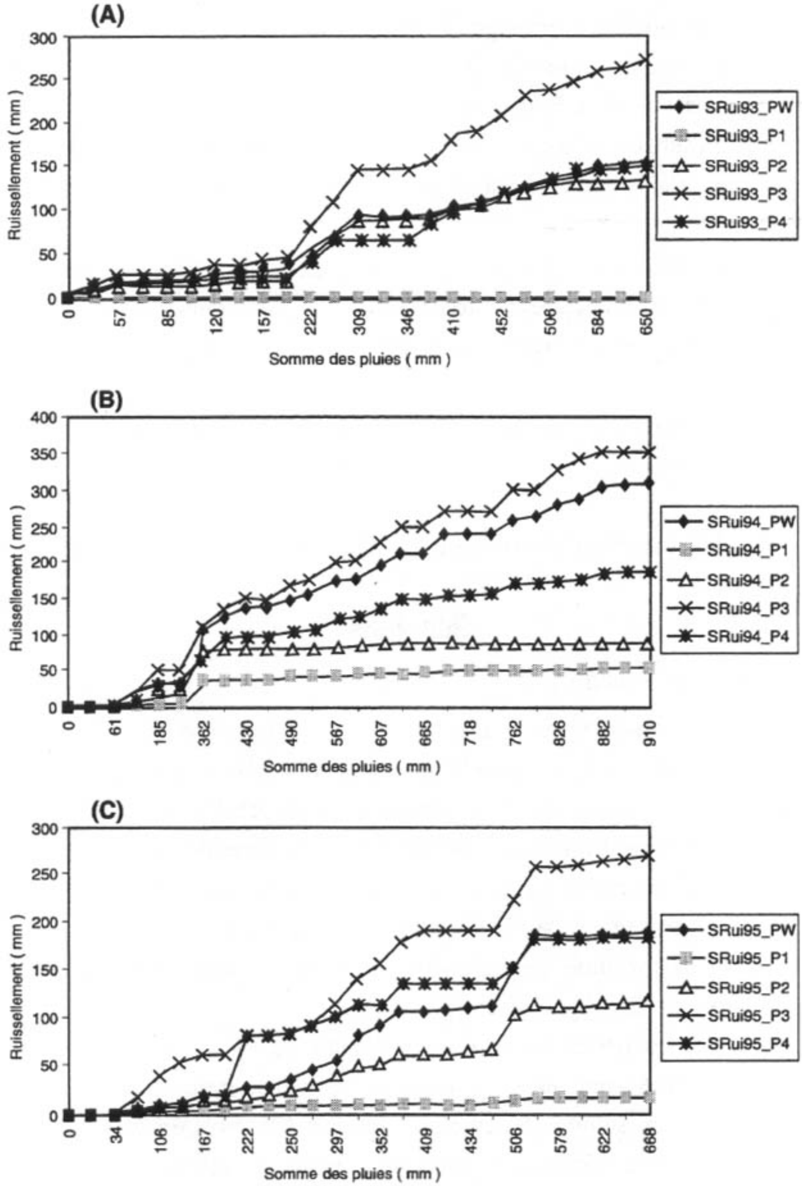

Figure 1. Volume annuel d'eau de ruissellement à Saria, Burkina Faso. (A) 1993 ; (B) 1994 ; (C) 1995. Traitement : PW, semis direct de sorgho, deux sarclages ; P1, semis direct de sorgho, paillage de surface, deux sarclages ; P2, labour aux bœufs, semis de sorgho et de niébé, deux sarclages ; P3, labour aux bœufs, semis de sorgho, deux sarclages ; P4, labour aux bœufs, semis de niébé, deux sarclages.

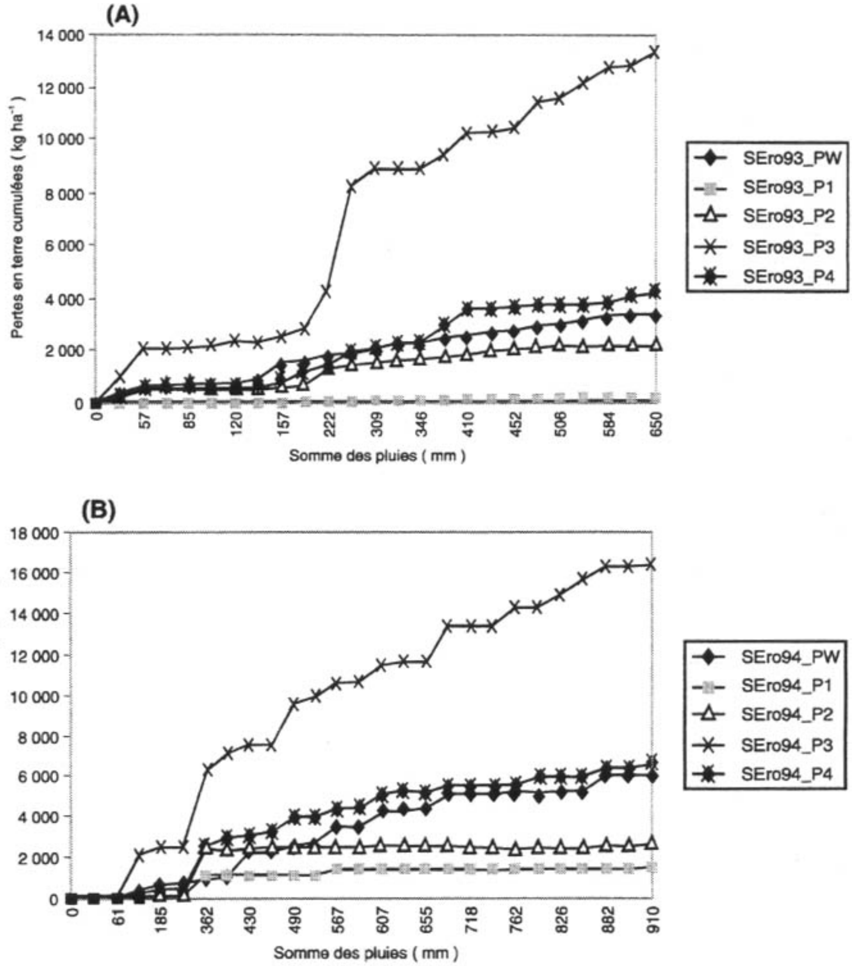

Figure 2. Érosion des sols (quantité de terre déplacée par an) à Saria, Burkina Faso. (A) 1993 ; (B) 1994. Traitement : PW, semis direct de sorgho, deux sarclages ; P1, semis direct de sorgho, paillage de surface, deux sarclages ; P2, labour aux bœufs, semis de sorgho et de niébé, deux sarclages ; P3, labour aux bœufs, semis de sorgho, deux sarclages ; P4, labour aux bœufs, semis de niébé, deux sarclages.

Rendements culturaux

La production obtenue à la récolte a confirmé l'efficacité du niébé en association. En effet, le LER (« low equivalent ratio ») calculé pour les rendements de 1994 a été de 0,9 pour le niébé, 0,8 pour le sorgho et 1,7 pour l'association. Ce système d'association est donc bénéfique et la production totale est plus importante qu'en situation de culture pure (figure 3). Des travaux réalisés par l'IITA–SAFGRAD

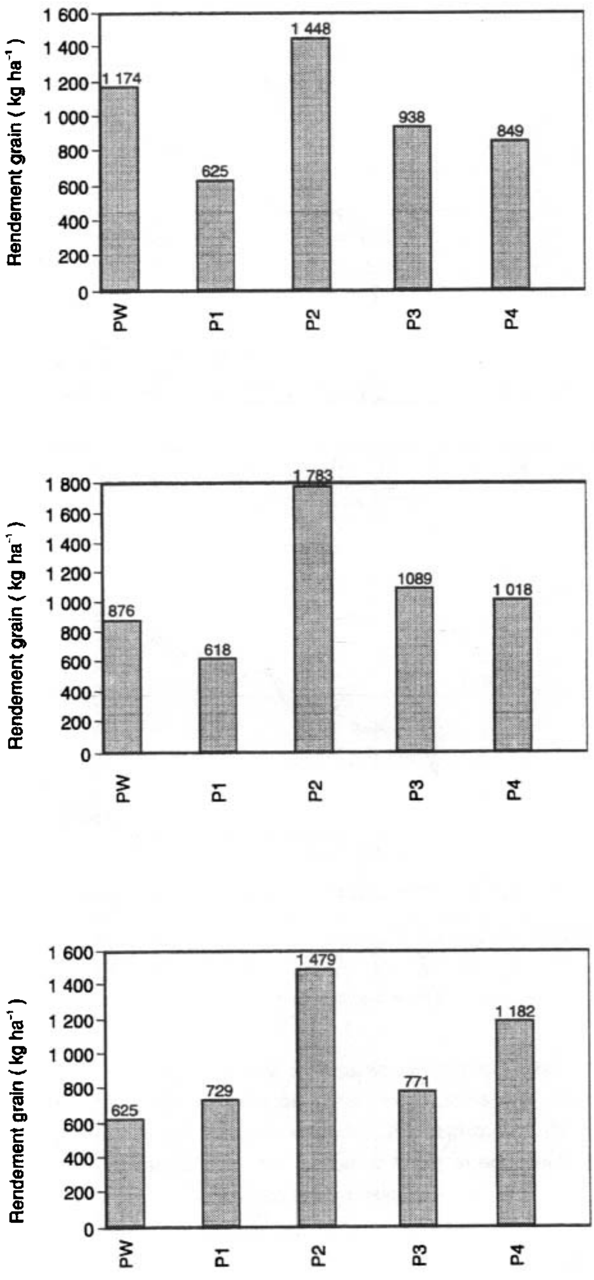

Figure 3. Rendement annuel des cultures à Saria, Burkina Faso. (A) 1993 ; (B) 1994 ; (C) 1995. Traitement : PW, semis direct de sorgho, deux sarclages ; P1, semis direct de sorgho, paillage de surface, deux sarclages ; P2, labour aux bœufs, semis de sorgho et de niébé, deux sarclages ; P3, labour aux bœufs, semis de sorgho, deux sarclages ; P4, labour aux bœufs, semis de niébé, deux sarclages.

(1988) ont abouti à des résultats similaires où il a été expliqué que la couverture du sol assurée par la culture de niébé maintenait l'humidité du sol pendant plus longtemps. Ainsi, les cultures en place arrivent à résister pendant les nombreuses poches de sécheresse.

Discussion

Le niveau de couverture du sol serait un facteur déterminant dans la réduction du ruissellement. Des résultats similaires ont été obtenus par Perez (1994) au Sénégal avec une culture d'arachide en association avec le mil. Il a trouvé que l'arachide protège le sol en fin de cycle si le développement foliaire a été régulier mais que la croissance végétative du mil ne semble pas avoir une action déterminante sur les écoulements tout au long du cycle.

Pour l'ensemble du cycle cultural (du semis à la récolte), la protection du sol par l'association semble plus efficace que celle assurée par le niébé seul. En effet, l'association a l'avantage d'avoir sur une même superficie, une ligne de sorgho et une ligne de niébé alors qu'il n'existe qu'une seule ligne de niébé dans le cas de la culture pure de niébé — c'est-à-dire que le taux de couverture du sol (surtout pendant la période de croissance) est plus important en association qu'en culture pure.

Ainsi, comme l'ont souligné Roose *et al.* (1992), la protection de la surface assurée par une litière (mulch de paille) ou un couvert végétal bien développé permet de diminuer les pertes par ruissellement et de ralentir l'évolution des croûtes. Il faudrait donc favoriser l'implantation rapide des cultures et le développement d'une biomasse apte à intercepter efficacement la pluie. Cela impose d'associer étroitement les techniques de gestion de l'eau et de maintien de la fertilité des sols.

L'érosion des sols étant intimement liée au processus de ruissellement, l'importance des pertes par parcelle est tributaire de la quantité d'eau ruisselée. Ainsi, les déplacements de terre sont plus faibles sur la parcelle recouverte d'un mulch de paille (P1). L'association culturale s'est montrée plus efficace que les cultures pures en entraînant une réduction de l'érosion de 80 % par rapport au sorgho seul et de 45 à 55 % par rapport au niébé seul. En réduisant la vitesse des écoulements, la protection de la surface du sol permet une limitation des déplacements solides, notamment des particules grossières (Roose 1981).

On pourrait conclure que l'association culturale sorgho–niébé est une méthode efficace contre le ruissellement et l'érosion au niveau de la petite échelle. La production s'est avérée également intéressante (>1 t ha^{-1} de grains), ce qui constitue dans cette partie du pays, un atout certain pour une large utilisation de cette technique. Une évaluation des avantages qu'apporte la légumineuse en terme d'apport d'éléments minéraux (fixation symbiotique de N de l'air, apport de MO, etc.) à la céréale, ainsi que la recherche d'un système de culture alliant potentiel existant et technicité en milieu paysan, permettront de mieux rentabiliser une telle technique.

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Système de cultures avec légumineuses au Cameroun

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Abstract

The project was carried out in a low-lying area of the subhumid savannah in northern Cameroon. Sustainable production of cereal crops (maize and sorghum) in this area is constrained by irregular and insufficient rainfall; soil erosion from runoff; lack of elemental nutrients (N, P, S, Mg, Zn); low levels of soil organic matter; weeds (*Striga*, *Commelina*); and the high cost of inputs. In light of these constraints, we experimented with an improved fallow, extending over 2 years, using several species of leguminous ground cover (*Mucuna pruriens*, *Stylosanthes hamata*, *Calopogonium mucunoïdes*, and *Canavalia ensiformis*); and a supplementary improved fallow, extending over 3 years, using *C. ensiformis*, *S. hamata*, and *C. mucunoïdes*. These two tests were conducted on very sandy ferruginous tropical soils derived from quartz sandstone.

Introduction

Les activités sont menées dans le nord du Cameroun, en zone de savane subhumide de basse altitude où les principales contraintes à la production des céréales (maïs et sorgho) sont les suivantes : pluies irrégulières et insuffisantes, problème de ruissellement des eaux de pluie et d'érosion du sol, carences en éléments nutritifs (N, P, S, Mg, Zn) et faible niveau de matière organique dans les sols, problème de plantes adventices (*Striga*, *Commelina*), problème du coût relativement élevé des intrants, etc.

Compte tenu de ces contraintes à la production durable du maïs et du sorgho, nous avons utilisé les légumineuses de couverture améliorantes du sol, et mis au point, entre autres une jachère améliorée étalée sur 2 ans avec les espèces suivantes de légumineuses de couverture du sol : *Mucuna pruriens*, *Stylosanthes hamata*, *Calopogonium mucunoïdes* et *Canavalia ensiformis*, ainsi qu'une jachère intercalaire améliorée étalée sur 3 ans utilisant les espèces suivantes : *C. ensiformis*, *S. hamata* et *C. mucunoïdes*. Ces deux tests ont été effectués sur des sols ferrugineux tropicaux très sableux, issus des grès quartzeux.

Tableau 1. Production de maïs avec jachère améliorée.

	Rendement (t ha^{-1})	
	Sans engrais	Avec engrais
Jachère naturelle	1,22	2,45
Canavalia ensiformis	1,48	2,88
Mucuna pruriens	1,67	2,69
Stylosanthes hamata	2,30	3,68
Calopogonium mucunoïdes	1,52	2,73

Jachère améliorée

La première année (1992), quatre espèces de légumineuses améliorantes du sol ont été mises en place : *C. ensiformis, S. hamata, M. pruriens* et *C. mucunoïdes.* Une étude de la matière sèche (MS) à l'hectare a donné les résultats suivants : *C. ensiformis*, 8,38 t MS ha^{-1} ; *S. hamata*, 11,28 t MS ha^{-1} ; *M. pruriens*, 5,02 t MS ha^{-1} ; et *C. mucunoïdes*, 7,41 t MS ha^{-1} (4 mois environ après le semis). Les indices de couverture du sol (1 = faible couverture, ... , 10 = couverture maximum) ont donné les résultats suivants, 119 jours après le semis : *C. ensiformis*, 8 ; *S. hamata*, 7 ; *M. pruriens*, 9 ; et *C. mucunoïdes*, 8.

La deuxième année (1993), une étude de l'effet résiduel a été faite : chaque traitement a été divisé en deux sous-parcelles, dont une a été laissée en jachère pour une étude de l'efficacité de repousse des légumineuses et l'autre a été plantée en maïs avec deux niveaux de fertilisation : sans engrais et avec engrais (100 kg N–P–K ha^{-1}); avec un témoin maïs sur jachère naturelle précédent (tableau 1).

Jachère intercalaire améliorée

La première année (1991), trois espèces de légumineuses améliorantes du sol ont été utilisées pour effectuer ce test : *C. ensiformis, S. hamata* et *C. mucunoïdes* (table 2). Le maïs a été planté avec ces légumineuses. Un témoin maïs–maïs a été utilisé pour le contrôle. Les légumineuses ont été plantées 3 semaines après le maïs, à raison d'une ligne de légumineuse pour deux lignes de maïs.

La deuxième année (1992), les légumineuses ayant repoussé toutes seules dès les premières pluies, chaque traitement a été divisé en deux sous-parcelles (table 3) dont une a été laissée en jachère pour une étude de contrôle de mauvaises herbes et l'autre a eu deux niveaux de fertilisation (sans engrais et avec

Tableau 2. Production de maïs avec jachère intercalaire améliorée, première année.

	Sans engrais		Avec engrais	
	(t ha^{-1})	(%)	(t ha^{-1})	(%)
Maïs	1,17	100	3,20	100
Canavalia ensiformis	2,14	182	4,44	138
Calopogonium mucunoïdes	2,17	185	4,00	125
Stylosanthes hamata	2,25	192	4,40	137

Tableau 3. Production de maïs avec jachère intercalaire améliorée, deuxiéme année.

	Sans engrais		Avec engrais	
	(t ha^{-1})	(%)	(t ha^{-1})	(%)
Jachère naturelle	1,59	100	4,08	100
Calopogonium mucunoïdes	3,80	238	5,51	135
Stylosanthes hamata	3,42	215	5,13	125

engrais). Le système de culture minimale a été utilisé avec traitement d'herbicide (Gramoxone^{MC}). *Canavalia ensiformis* n'a pas pu repousser seule la deuxième année.

La troisième année (1993), la partie laissée en jachère l'année précédente a eu deux niveaux de fertilisation (sans engrais et avec engrais). Sans engrais, le traitement avec légumineuses a donné une augmentation de 2,21 t ha^{-1} (+138 %) en rendement grain maïs, soit une valeur potentielle de 110 500 francs CFA au marché par rapport au maïs–jachère naturelle (en 1998, 612,11 francs CFA [XAF] = 1 dollar américain [USD]) .

Les paysans ont apprécié la jachère intercalaire améliorée, mais il existe un problème de contrôle des animaux en divagation après les récoltes qui risque de détruire les légumineuses. Les espèces de légumineuses *Calopogonium* et *Stylosanthes* peuvent très bien contrôler les mauvais herbes.

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Développement de technologies agro-forestières et de maintien de la fertilité du sol au Bas-Bénin

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Abstract

This paper describes the main features of a participatory technology-development project in which farmers adapt and assess a range of technologies for sustaining soil productivity in southern Benin. First results confirm that not all farmers are interested in the same type of technologies. Present and prospective microeconomic assessment of the technologies indicates that their ranking depends on the cropping systems of the sites and on farmers' circumstances, especially concerning land tenure. There is a need to offer farmers a wide range of soil-improving techniques.

Introduction

Le projet constitue le volet sociologique et micro-économique du programme spécial de recherche SFB 308 au Bénin, programme dont le but est de contribuer au développement de systèmes de culture durables en zones semi-humides (Bas-Bénin) à semi-arides (ouest du Niger). L'objectif spécifique de ce volet est de développer, en collaboration avec des paysans, des technologies agro-forestières et de maintien de la fertilité des sols sur terres de barre et sur socle cristallin et d'en évaluer conjointement le rendement. Le programme a démarré ses activités en 1994 dans six sites pilotes.

Une diversité de problèmes et de sites

Nombreuses sont les publications qui font état des difficultés à développer des technologies dans des environnements pauvres, à haut risque et de grande diversité. C'est pourquoi d'emblée, le programme de recherche a opté pour une stratégie laissant une grande marge de manœuvre aux paysans dans le choix, le test et l'adaptation de technologies, et favorisant les échanges d'expériences entre paysans ainsi qu'entre paysans et intervenants (des chercheurs dans la plupart des cas).

Différents principes de production et de restitution de biomasse proposés au test et à l'évaluation de volontaires

Depuis la création du programme en 1994, les activités suivantes ont été menées :

- Sur la base des expériences antérieures dans la sous-région, on a recensé une gamme de technologies qui visent toutes à produire et à restituer de la matière organique fraîche aux sols cultivés et qui représentent différents principes de production et de restitution de biomasse. La gamme comprend des plantes de couverture (*Mucuna pruriens* var. *utilis* et var. *cochinchinensis*) et engrais verts annuels (*Cajanus cajan*) qui viennent alors remplacer la jachère spontanée dans la rotation, des jachères pérennes rendues plus productives en enrichissant la végétation spontanée ou en plantant des espèces à croissance rapide (*Acacia auriculiformis*) et des « jachères simultanées » conduites en blocs, bordures ou couloirs dans les parcelles de culture (*Senna siamea*, *Gliricidia sepium*, *Leucaena leucocephala*).

- Six sites représentatifs de l'hétérogénéité en matière de fertilité ont été choisis (trois sur terres de barre dans l'Atlantique et le sud du Zou, trois sur socle cristallin dans le centre et le nord du Zou) et les technologies de la gamme *a priori* adaptées ont été identifiées sur chaque site sur la base d'un diagnostic agronomique conduit avec les villageois.

- Les technologies ont été présentées aux villageois (par dessins et discussions, par visites d'essais en place ailleurs), et les paysans intéressés ont choisi les technologies à tester. Ce processus de choix est répété chaque année.

- L'équipe de recherche aide les volontaires à mettre en place une parcelle de test avec la technologie de leur choix et une parcelle témoin avec la pratique courante de chacun.

Une combinaison de méthodes conventionnelles de la recherche-système et de méthodes participatives

L'évaluation des technologies s'appuie sur différents types de méthodes :

- Des visites des parcelles de test lors de « journées paysannes » permettent aux participants, aux non-participants, aux chercheurs et aux agents de développement de la région d'échanger leur point de vue sur les technologies. Ces journées constituent des moments clés car les travaux en atelier permettent de faire des propositions contribuant à adapter les technologies aux environnements variés (en particulier sur les sites difficiles), à les rendre plus faisables, et à discuter des facteurs institutionnels mettant en cause le processus de régénération des terres (tenures foncières, contrôle de feux de brousse, etc.). De plus, c'est au cours de ces journées que les participants s'approprient la démarche de recherche et améliorent leur statut social au sein du village. Ces visites ont trouvé des prolongements dans d'autres activités comme des voyages d'étude dans d'autres régions, des concours de chant sur le thème du maintien de la fertilité, etc.

- Des entretiens individuels permettent une évaluation systématique des opinions de chaque participant sur les technologies qu'ils testent.

- Des enquêtes systématiques des parcelles de test et de les parcelles témoins permettent de calculer les marges brutes de la terre, la demande en travail et les revenus du travail de chaque technologie, de la phase d'installation à la phase de croisière.

Par ailleurs, à plus grande échelle, des études sont menées à l'échelle des unités de production et du village dans chaque site et dans quelques sites voisins non touchés par le projet. Ces études combinent les recherches exploratoires et participatives (méthode accélérée de recherche participative) et les enquêtes standardisées à grand échantillon d'unités de production. Elles permettent d'apprécier les dynamiques socio-économiques en cours (développement et intensification de l'agriculture, ou développement d'activités extra-agricoles, voire mouvements d'émigration). La pertinence et la faisabilité des techniques proposées pour différentes catégories socio-économiques qui sont alors repérées peuvent être discutées avec les personnes visées, mais aussi évaluées avec les outils d'analyse des systèmes d'exploitation. Les phénomènes sociaux et institutionnels favorisant ou limitant l'échange de connaissances et la participation à un processus de recherche collective sont en partie cernés. Enfin, la modélisation d'unités domestiques typiques constituera un outil d'évaluation prospective de ces technologies. À cette modélisation de l'impact économique des technologies s'ajoute une évaluation (approximative) de leur impact sur les bilans minéraux.

Résultats

Des choix et des évaluations de technologies diversifiées

Les premiers résultats (Doppler et Floquet 1996) montrent que l'intérêt pour les différentes technologies varie fortement selon les sites, les ressources et modes de tenure foncière, la valeur du bois et l'importance de l'*Imperata cylindrica*. Dans les régions de terre de barre, les technologies à base de *M. pruriens* var. *cochinchinensis* ou var. *utilis* se sont taillé une bonne place, qu'elles partagent avec les jachères plantées à *Acacia auriculiformis*, tandis que plus au nord, le manque de terre n'est pas aussi important et le problème des feux de brousse reste à résoudre (figure 1).

Vus à l'échelle de la rotation, les systèmes à pois mascate ont l'avantage de ne pas demander de travail supplémentaire, au contraire. Le rendement économique de ces systèmes après 2 ans est convenable et devrait s'améliorer grâce à des effets cumulatifs sur les rendements (déjà significatifs à l'heure actuelle ; voir la figure 2) et grâce à l'acquisition de savoir-faire par les paysans.

Néanmoins, à court terme, dans les systèmes de culture très intensive tels qu'on les retrouve sur les terres de barre très dégradées du plateau d'Abomey (systèmes permanents à arachide et à niébé), l'introduction du pois mascate dans la rotation fait tout d'abord baisser la productivité des terres, d'autant qu'il est nécessaire — et les paysans eux-mêmes l'ont proposé — de l'installer en culture

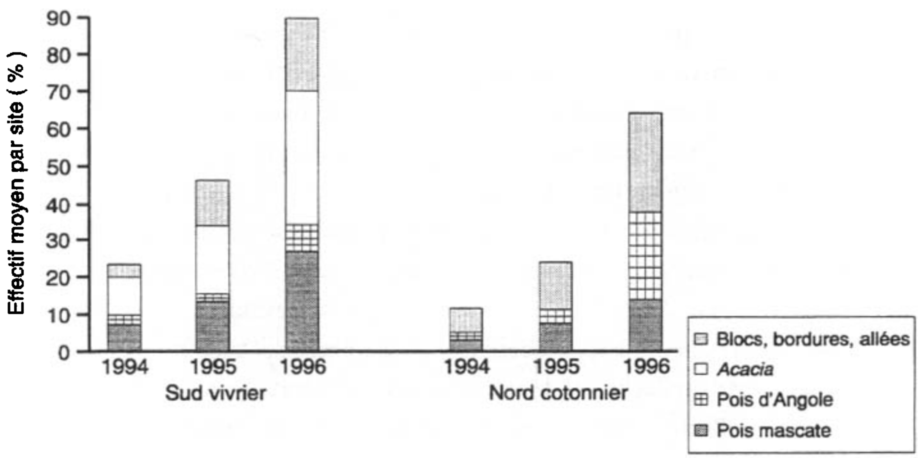

Figure 1. Effectif des participants selon les technologies choisies en 1994, 1995 et 1996 dans le sud vivrier et le centre cotonnier.

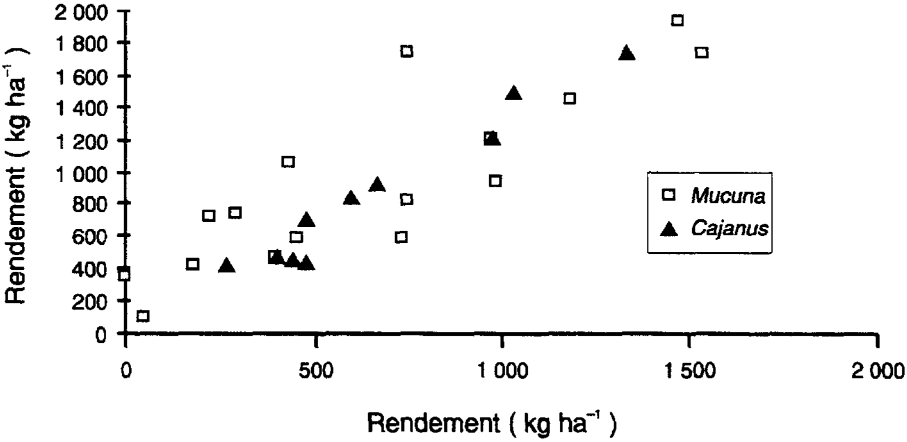

Figure 2. Rendements des parcelles paillées avec des résidus de *Mucuna* ou des émondes de *Cajanus* comparés à ceux des parcelles témoin (effet en première saison [1995] d'engrais verts semés en 1994). *Mucuna* : $y = 1,26x$; *Cajanus* : $y = 1,30x$.

pure et non en relais afin d'obtenir une quantité significative de biomasse (figure 3). Pour améliorer le niveau de productivité des terres à court terme sur ce type de terres, il faudrait pouvoir combiner les plantes de couverture avec la fumure minérale, mais les paysans des zones non cotonnières se heurtent à de grandes difficultés d'accès et de financement des engrais minéraux. Dans les systèmes plus extensifs où la jachère arbustive est encore pratiquée, le pois mascate, en venant remplacer cette jachère pluriannuelle, permet au contraire une amélioration de la productivité des terres à l'échelle de l'ensemble du système.

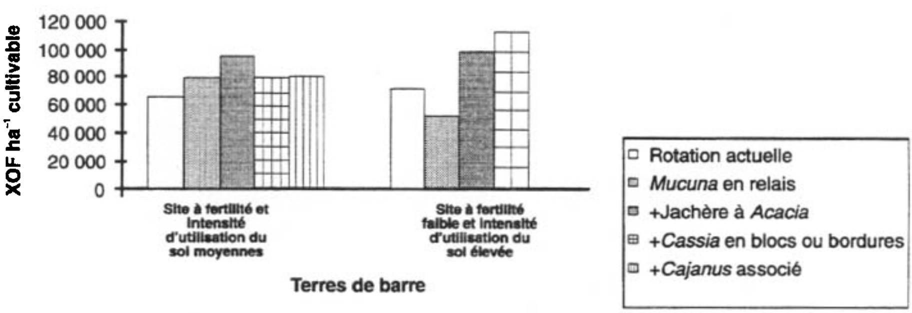

Figure 3. Marge brute à l'échelle du système de culture sur deux sites de terres de barre (scénarios). Nota : En 1998, 610,65 francs CFA (XOF) = 1 dollar américain (USD).

Pourquoi une recherche-action sur une technologie *a priori* établie ?

La démarche engagée peut surprendre puisqu'elle consiste à reprendre, dans un processus de recherche conjointe, des technologies qui sont déjà « passées en vulgarisation ». En fait, l'expérience montre que le passage par une phase d'expérimentation et d'adaptation est quasi obligatoire pour les paysans et que, sans appui, ils abandonnent la technologie à la première difficulté. Bien sûr, les voisins bénéficieront des efforts des premiers, surtout s'ils ont eu la possibilité d'en prendre connaissance. De plus, cette phase de test doit se poursuivre jusqu'à l'introduction des technologies à une échelle significative dans les systèmes de culture. Enfin, l'adoption des technologies pose de nouveaux problèmes institutionnels et organisationnels au niveau des villages, et il est utile d'aider une série de villages à résoudre ces problèmes pour créer une base d'expériences à laquelle d'autres villages pourront se référer. Tous ces processus sont déterminants pour une adoption des technologies qui soit un acquis après le départ de l'équipe. Ceci pose des questions clés sur les approches adaptées de « diffusion » d'innovations complexes et de passage à une échelle plus grande.

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Dynamique de la culture du *Mucuna pruriens* dans la commune rurale de Gakpé, au Bénin

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Abstract

The expansion of *Mucuna pruriens* in the rural community of Gakpé, Ouidah division, Benin, was studied between 1991 and 1996. The number of farmers showing interest in *Mucuna* increased from 8 in 1991 to 318 in 1996. In the first 3 years, all recipients of *Mucuna* seeds planted the crop. In the later years, only a small proportion (2–3%) of farmers who received seeds failed to plant them. Farmers who hesitated to use *Mucuna* said it was because *Mucuna* takes usable land out of production during the second (minor) rainy season. An offer to purchase *Mucuna* seeds from the farmers helped to compensate for this loss of income.

The progression in the number of users of the *Mucuna* technology in the community of Gakpé indicates that any simple technology that addresses constraints identifiied by the farmers can be readily adopted. *Mucuna* simultaneously solved two problems for the farmers: elimination of *Imperata* weed and improvement of soil fertility.

Introduction

Au cours d'une étude sur les problèmes liés à l'atteinte de la sécurité alimentaire affectuée en 1990, les populations de la commune rurale de Gakpé, dans la circonscription urbaine de Ouidah, au Bénin, avaient signalé, entre autres contraintes, l'infertilité des sols et l'envahissement des terres par l'*Imperata cylindrica*. Pour tenter de résoudre ces différents problèmes, le Centre régional pour le développement et la santé (CREDESA) a introduit dans cette commune la culture du *Mucuna pruriens*. Versteeg et Koudokpon (1990) ont fait remarquer que le *Mucuna* n'élimine pas complètement le chiendent.

L'étude décrite ci-après avait pour but de suivre le mouvement de la culture du *Mucuna* dans la commune de Gakpé.

Méthodes

L'étude a été effectuée dans la commune rurale de Gakpé, dans la circonscription urbaine de Ouidah. Cette commune est située entre la commune de Savi et la sous-préfecture de Tori-Bossito. L'étude a duré 6 ans (1991–1996), et la population cible était les paysans ayant abandonné des terres colonisées par le chiendent (*I. cylindrica*).

L'étude comprenait quatre étapes :

1. *Persuasion* — Cette phase consistait à obtenir l'accord de principe des paysans qui s'étaient plaints de la présence de chiendent sur leur parcelle afin d'effectuer l'étude.

2. *Installation* — Avec l'approbation du technicien de développement rural, le paysan a sélectionné et délimité la partie où aurait lieu l'essai en tenant compte de l'accessibilité, de la luminosité et de la densité de chiendent au mètre carré (au moins 150 touffes).

3. *Suivi* — Un contrat de surveillance et de suivi de l'essai a été établi entre le paysan et le technicien. Les grandes lignes de ce contrat portaient sur les points suivants : exécution des pratiques culturales ; surveillance de la parcelle pour éviter la consommation par les ruminants ; observations et commentaires sur l'évolution de l'essai ; organisation de visites pour les pairs ; récolte des graines ; redistribution des graines ; autovulgarisation.

4. *Recensement* — Cette phase consistait à recenser au début de chaque campagne agricole les nouveaux bénéficiaires de semences et la source d'approvisionnement. De même, des visites sur les nouveaux sites ont été organisées afin de vérifier si ces nouveaux bénéficiaires avaient effectué le semis et respecté l'exécution des pratiques culturales.

Résultats et discussion

L'expérience a débuté en 1991 avec huit paysans « délégués à l'innovation » de la commune qui ont abandonné des superficies de terre à cause de la présence de chiendent. Les parcelles retenues ont au moins 150 touffes de chiendent au mètre carré et une superficie de 800 m^2 égale à 2 *kantins* (l'unité de mesure traditionnelle).

Au début des campagnes qui ont suivi, nous nous sommes approchés de ces paysans pour établir la liste de ceux qui leur avaient pris des semences. Nous

Tableau 1. Évolution des bénéficiaires et proportion des pratiquants du *Mucuna*.

	1991	1992	1993	1994	1995	1996
Paysans ayant obtenu du *Mucuna* (*n*)	8	37	98	159	280	318
Paysans ayant pratiqué le semis (*n*)	8	37	96	157	276	309
Proportion de pratiquants (%)	100	100	97,9	98,7	98,5	97.1

avons également enregistré le nombre de paysans qui se sont adressés directement au CREDESA ou au Centre d'action régionale pour le développement rural, institutions travaillant à l'introduction du *Mucuna* dans la région. Après cet enregistrement, le CREDESA a vérifié auprès des nouveaux bénéficiaires de semences si le semis avait été fait. Cette opération a été répétée jusqu'en 1996. Les sources d'approvisionnement en semences étaient variées — différents paysans de la localité et agents de développement — ce qui fait que le système de suivi et de monitoring des techniciens agricoles a connu quelques difficultés.

Le tableau 1 montre une nette croissance du nombre de bénéficiaires et pratiquants entre 1991 et 1996. En effet, le nombre de bénéficiaires est passé de 8 en 1991 à 318 en 1996 et celui des pratiquants, de 8 à 309. Cela montre l'importance croissante qu'accordent les populations à la culture du *M. pruriens*. Par ailleurs, une comparaison du nombre de bénéficiaires et de pratiquants sur les différentes années (1991–1996) montre que la plupart des bénéficiaires pratiquent la culture du *Mucuna*. Toutefois, il faut remarquer un décalage entre ces nombres qui, à partir de 1994, commencent à chuter légèrement. Mais ce décalage est très négligeable. Notons qu'avant la campagne 1992–1993, certains paysans hésitaient car ils doutaient de l'efficacité du *Mucuna*. La croissance du nombre de bénéficiaires est surtout attribuable à la découverte par les paysans du pouvoir fertilisant du *Mucuna* qui raccourcit la durée de la jachère traditionnelle, qui est passée d'une dizaine d'années à seulement 1 an (Bunch 1990).

L'hésitation observée aux deux premières campagnes est peut-être attribuable au fait que le *Mucuna* occupe les champs une saison sans être exploité. Sur les 200 à 600 kg de graines récoltées par hectare, une faible proportion sert de semences.

Références

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Expérience du Projet de développement de l'élevage dans le Borgou-Est sur les plantes de couverture

K. Yaï

Projet de développement de l'élevage dans le Borgou-Est, Bénin

Abstract

The Projet de développement de l'élevage dans le Borgou-Est (eastern Borgou animal-breeding project) is concerned with finding solutions to the serious problem of insufficient forage in eastern Borgou, in the Republic of Benin. Among the herbaceous legumes studied, *Mucuna pruriens* var. *cochinchinensis* is the most accepted by farmers engaged in both crop and animal production. Farmers' interest in *Mucuna* is based on the observed benefits: improvement of soil fertility; control of noxious weeds, such as *Imperata* and *Striga*; and adaptability to intercropping with maize and sorghum (which improves land-use efficiency). The introduction of *Mucuna* in eastern Borgou is a timely solution to diverse farm problems. This legume is particularly favourable for crop–animal integration.

Résumé

Le Projet de développement de l'élevage dans le Borgou-Est (PDEBE) est financé par le Programme des Nations Unies pour le développement et le Fonds d'équipement des Nations Unies. Le PDEBE vise essentiellement à lever les contraintes qui jusque-là ralentissent le vrai démarrage de l'élevage dans sa zone d'intervention (Borgou-Est : Ségbana, Kalalé, Nikki, Pèrèrè et Tchaourou-Est). Au nombre de ces contraintes, on peut citer le manque d'eau pour l'abreuvement des animaux en saison sèche, le manque ou l'exploitation irrationnelle du pâturage et la fréquence des maladies du bétail, corollaire du taux de mortalité élevé constaté au niveau du cheptel de la zone. Si certaines contraintes ont pu avoir des solutions assez remarquables et efficaces, les essais se poursuivent dans le but de trouver une solution au manque et à l'exploitation irrationnelle du pâturage, surtout en saison sèche. Les essais de la culture du *Mucuna* au niveau des agro-éleveurs sont assez concluants et aujourd'hui, la quasi-totalité des éleveurs et agro-éleveurs de la zone d'intervention du PDEBE ont adopté cette culture même si c'est encore sur de petites superficies. Les objectifs principaux sont les suivants : (1) évaluer, variété par variété, la quantité de fourrage à l'hectare ; (2) situer la période de mise à terre pour l'obtention d'une grande productivité en tenant compte des conditions climatiques de la localité ; (3) tester le niveau d'appétabilité du fourrage ; et (4) étudier les autres propriétés du *Mucuna*.

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Influence des dates de semis de *Mucuna* sur le rendement du maïs au Bénin

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Abstract

Various planting dates for *Mucuna* in maize–*Mucuna* intercrops were tested to determine the competition between maize and *Mucuna*; the advantages of an early *Mucuna* planting date; and the response of *Mucuna* to successive pruning. The study revealed a strong competition between the two crops when they are seeded the same day. *Mucuna* plants die when they are pruned 15 cm above the ground. *Mucuna* seeded 42 d after maize planting provides the best results for intercropping.

Introduction

Les terres de barre au sud du Bénin sont dégradées et peu fertiles. La pression démographique est forte, atteignant dans certains endroits des densités supérieures à 200 habitants km^{-2}. Aussi la présence du chiendent (*Imperata cylindrica*) limite-t-elle sérieusement l'utilisation de ces terres, qui sont même parfois abandonnées par les paysans incapables de le contrôler.

L'introduction du pois mascate (*Mucuna* spp.) capable d'étouffer le chiendent et de l'éradiquer a permis aux paysans de retrouver leurs terres non seulement sans chiendent, mais aussi avec les effets améliorants de la légumineuse : augmentation de la matière organique (MO) et accumulation de N symbiotique dans le sol. Dans l'association maïs–*Mucuna*, le *Mucuna* est semé 42 jours après un maïs de 90 jours. Une fois le maïs récolté, le *Mucuna* s'installe seul en deuxième saison afin de boucler son cycle de 180 jours.

L'objectif du présent essai est d'étudier la compétition entre le maïs et le *Mucuna* à partir de différentes dates de semis, de statuer sur l'opportunité de semis plus précoce du *Mucuna*, et de voir la possibilité d'utiliser la biomasse pour améliorer le rendement de la culture en petite saison.

Matériel et méthodes

L'essai a été réalisé en 1995 et en 1996 sur le site expérimental du Centre national d'agro-pédologie, avec un sol de type ferrallitique faiblement désaturé développé sur les formations sédimentaires du Continental Terminal et présentant une texture sablo-limoneuse avec 9,7 % d'argile, 5,7 % de limon et 85,2 % de sable. La teneur en MO (1,14 %) est faible, tout comme teneurs en K (0,15 méq 100 g^{-1} de sol) et en P assimilable (3 ppm selon BRAY 1). Le taux de N (0,057 %) à pH 6,2 faiblement acide est médiocre. Le rapport C–N, de 11,5, est bon.

Un dispositif en blocs randomisés a été choisi : quatre traitements par blocs et quatre répétitions. Les parcelles accueillant chaque traitement mesuraient 42 m^2 (10 m × 4,2 m). Les quatre traitements sont les suivants :

Parcelle	Traitement
T1	Maïs–*Mucuna* ; *Mucuna* semé en même temps que le maïs
T2	Maïs–*Mucuna* ; *Mucuna* semé 14 jours après le maïs
T3	Maïs–*Mucuna* ; *Mucuna* semé 28 jours après le maïs
T4	Maïs–*Mucuna* ; *Mucuna* semé 42 jours après le maïs

La fertilisation minérale apportée a été de 74–46–28 de N–P–K sous forme de N–P–K (14–23–14) et d'urée. La variété de maïs utilisée est le DMR-ESRW d'un cycle de 90 jours. L'écartement était de 80 cm × 40 cm et le semis s'est fait à deux plants par poquet, sans démariage, donnant une densité de population de 62 500 plants ha^{-1}. La variété de pois mascate utilisée est le *Mucuna utilis* var. *pruriens* (un *Mucuna* noir); elle a été semée entre les lignes de maïs, à un écartement de 0,80 × 0,80 à raison de deux graines par poquet. Le recépage du *Mucuna* a eu lieu 73, 106, 135, 166 et 196 jours après le semis du maïs. La hauteur de coupe était à 15 cm du sol sur la moitié de la parcelle (5 m × 4,2 m). La biomasse récoltée a été pesée et le taux de regénération des plantes a été mesuré. Des échantillons foliaires de *Mucuna* ont été prélevés pour les analyses chimiques au laboratoire. Les éléments chimiques ci-après ont été déterminés par les méthodes d'analyse suivantes : N, méthode Kjeldahl ; P, méthode colorimétrique après une minéralisation par voie sèche ; K, Ca et Mg, spectrophotométrie d'absorption atomatique après une minéralisation par voie sèche.

Tableau 1. Teneurs en N, P et K contenues dans la biomasse du *Mucuna* à la récolte du maïs.

Traitement	N (%)	P (%)	K (%)
T1	3,13	0,15	0,86
T2	3,29	0,22	1,05
T3	3,08	0,17	0,91
T4	3,10	0,14	0,73

Résultats et discussion

Le rendement du maïs augmente de T1 à T4, tandis que la biomasse (matière sèche, MS) recépée à la première coupe diminue. La biomasse (MS) du *Mucuna* recépée le 73e jour après le semis du maïs a influencé négativement ($r = -0{,}93$) le rendement du mais grains obtenu pendant les deux années d'essai. Ceci est attribuable à la forte compétition entre les deux cultures mises en association.

L'élément dominant dans la biomasse du *Mucuna* (tableau 1) est N, suivi du K et, enfin, du P. Des doses plus faibles de N, P et K ont été obtenues par Kanninkpo (1992), mais les doses d'engrais appliquées au maïs étaient plus faibles. L'analyse de la variance des teneurs en N, P et K contenues dans la biomasse à la récolte du maïs ne montre aucune différence significative. En conséquence, les dates de semis n'ont pas influencé les teneurs en nutriments du *Mucuna*.

Le nombre de plants régénérés et recépés augmente de T1 à T4 et diminue en fonction du temps après la première coupe. La hauteur de recépage et la pluviométrie seraient à l'origine du faible taux de régénération obtenu. La biomasse du *Mucuna* a influencé négativement le rendement du maïs, conséquence de la forte concurrence entre les deux cultures mises en association. Les dates de semis du *Mucuna* n'ont pas eu d'effet sur les teneurs en N, P et K dosées dans la biomasse du *Mucuna* à la récolte du maïs. Plus le *Mucuna* est âgé, moins il supporte le recépage.

Référence

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Relation symbiotique entre *Mucuna* et *Rhizobium*, département du Mono au Bénin

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Abstract

On-station and on-farm studies were carried out to investigate the extent to which establishment and N contribution of *Mucuna* depend on symbiotic properties such as effective nodulation and mycorrhizal infection. The studies showed that (1) nodulation and mycorrhizal-infection rates varied widely between and within farmers' fields; (2) the nodule number per plant ranged from 0 to 135; (3) the mycorrhizal-infection rate varied between 2 and 31%; and (4) unlike the nodulation rate, the mycorrhizal-infection rate was significantly related to shoot weight. Research is needed to assess abiotic and biotic factors affecting *Mucuna–Rhizobium* symbiosis.

Résumé

On a procédé à des études en ferme et en station afin de savoir dans quelle mesure l'implantation et la contribution en N du *Mucuna* dépendaient des propriétés symbiotiques telles que la nodosité et l'infection mycorrhizienne. Les résultats ont démontré (1) une grande variation du taux de nodosité et d'infection mycorrhizienne entre les champs des agriculteurs ou à l'intérieur de ceux-ci ; (2) une nodosité par plante allant de 0 à 135 ; (3) un taux d'infection mycorrhizienne variant entre 2 et 31 % ; et (4) contrairement au taux de nodosité, une relation significative entre le taux d'infection mycorrhizienne et le poids des parties épigées. Une recherche serait utile pour évaluer les facteurs abiotiques et biotiques qui ont un effet sur la symbiose *Mucuna–Rhizobium*.

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Expérience agronomique avec *Mucuna*, RAMR[1], département du Mono au Benin

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Abstract

Mucuna technology has continued to improve in Benin since its introduction there in 1987. Experience showed that 1 year of *Mucuna* fallow was not enough to adequately improve the fertility of some badly degraded soils. Experiments were therefore initiated to study the effects of two 4-year land-use systems: 2 years of maize–*Mucuna* intercropping followed by 2 years of sole-maize crop; and 2 years of *Mucuna* fallow followed by 2 years of sole-maize crop. A residual effect of 2 years of *Mucuna* fallow was a significant improvement in maize-grain yields for two seasons, without further intervention of *Mucuna* fallow. Soil-fertility improvement from cowpea was significantly inferior to that from *Mucuna*.

Résumé

L'amélioration de la technologie liée au *Mucuna* se poursuit depuis son introduction au Bénin en 1987. L'expérience a montré qu'une période de jachère avec le *Mucuna* n'améliorait pas la fertilité dans certains cas de sols très dégradés. On a alors étudié les effets d'un système d'utilisation des terres sur une période de 4 ans, soit 2 ans de culture intercalaire de *Mucuna* et de maïs, suivis de 2 ans de culture de maïs seulement, une fois la fertilité du sol modifiée. Le rendement des productions de maïs était plus élevé pendant la deuxième culture intercalaire de *Mucuna* et de maïs. Comparativement au *Mucuna*, le pois d'angola a nettement moins contribué à l'amélioration de la fertilité des sols.

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[1]Recherche appliquée en milieu réel (applied research in practice — a research project of the Benin Ministry of Rural Development).

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Recherche sur les plantes de couverture et les fertilisants

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Abstract

Attempts to capitalize on the spectacular results obtained with *Mucuna* by the Recherche appliquée en milieu réel (RAMR, applied research in practice),[1] Mono Province, Benin, were dampened by the inability of the farmers to respect the optimum planting dates for *Mucuna*; drought, which reduced biomass production; and damage by animals and bush fires. Farmers who put a high premium on *Mucuna* forage failed to appreciate the suggestion that they incorporate *Mucuna* biomass into the soil with the last rains. Since 1994 three other legumes — *Aeschynomene histrix, Canavalia ensiformis*, and *Stylosanthes hamata* — have been investigated, in addition to *Mucuna*. The objective of RAMR's current research on cover crops is to determine the optimum amount of chemical fertilizer to use with crops after cover-crop fallows of various durations.

Résumé

Les tentatives de tirer parti des résultats spectaculaires obtenus avec le *Mucuna* par la Recherche appliquée en milieu réel, département du Mono ont été freinées par les éléments suivants : (1) la difficulté des agriculteurs à respecter les dates de plantation optimales du *Mucuna* ; (2) la sécheresse qui a réduit la production de biomasse ; et (3) les dommages causés par les animaux et les feux de brousse. Les agriculteurs n'ont pas adhéré à l'idée d'ajouter une biomasse de *Mucuna* après les dernières pluies, étant donné qu'ils ont une prime d'option de vente élevée sur les plantes fourragères du *Mucuna*. Depuis 1994, trois autres légumineuses — l'*Aeschynomene histrix*, la *Canavalia ensiformis* et le *Stylosanthes hamata* — sont à l'étude en même temps que le *Mucuna*. L'objectif du projet de recherche actuel sur les cultures de couverture est de déterminer la quantité optimale d'engrais nécessaire après les différentes périodes de jachère d'*Aeschynomene* et de *Canavalia*.

[1]A research project of the Benin Ministry of Rural Development.

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Selecting green-manure legumes for relay and intercropping systems with maize on sandy soils in Zimbabwe[1]

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Résumé

La présente expérience avait pour buts de trouver l'engrais vert approprié qui peut être remplacé sans trop diminuer le rendement céréalier du maïs, de déterminer la date de plantation favorable aux cultures d'engrais vert et de déterminer en quoi les légumineuses servant d'engrais contribuent à l'état nutritif et au rendement céréalier du maïs qui en résulte. L'étude a eu lieu pendant les saisons de croissance 1994–1995 et 1995–1996. Au cours de la saison 1996–1997, le maïs a poussé après qu'aient été plantées des légumineuses servant d'engrais vert. On a fait l'expérience sur des sols de sable à grains moyens aux stations expérimentales de Mlezu et de Makoholi, ainsi que dans les régions des communautés de Chiwundura et de Chihota. Pendant la saison 1995–1996, aucune implantation d'engrais vert valable n'a été effectuée en raison de la sécheresse. Toutefois, pendant la saison 1995–1996, trois cultures d'engrais vert de légumineuses ont présenté un meilleur rendement que les autres, soit les pois mascate (*Mucuna pruriens*), les *Crotalaria juncea* et les doliques.

Dans une situation de relais, on a constaté que le meilleur moment pour effectuer la plantation de légumineuses servant d'engrais vert se situe 4 semaines après l'apparition du maïs. Ce moment coïncide également avec la période de désherbage du maïs. Les engrais verts de légumineuses n'ont jamais nui au rendement céréalier du maïs. Toutefois, les pois mascate qui ont été plantés 4 semaines après l'apparition du maïs ont étouffé le maïs enchevêtré qui n'a pu résister à la verse.

Introduction

Supplementing inorganic fertilizers with legume green manuring may add nutrients, like N, S, and P, to the soil. Green manuring may also help maintain or build soil organic matter (OM), which will in turn help improve the soil's structure,

[1]Paper presented at the International Workshop on Green-Manure Cover Crop Systems for Smallholders in Tropical and Subtropical Regions, 6–12 April 1997, Chapeco, Brazil.

pore size, water-holding capacity, and inorganic-fertilizer-use efficiency (through increased cation exchange capacity). Green manuring was common in Zimbabwe in the 1920s. Rattery and Ellis (1952) reported that green manuring was used to maintain soil fertility and maize yield. Green manuring was widely practiced on commercial farms with soils whose physical structure was better than that of communal-area soils; hence, the benefit of legume green manuring was mainly the addition of N, symbiotically fixed by the legumes. Green manuring involved growing a crop mainly of legumes during the summer, to be plowed under at flowering time. The opportunity cost of committing land, inputs, and labour to a green-manure crop was high, so with the introduction of chemical fertilizers, green manuring largely disappeared.

Communal farmers also adopted the use of chemical fertilizers, but not as a complete package: they rarely lime their fields or rotate maize production with other grain legumes. They often apply less than the recommended fertilizer levels because of financial constraints (Muza et al. 1998). Crop residues are not incorporated into the soil, because they are vital as stock feed. This has led to nutrient mining and depletion in the communal areas (Grant 1970, 1981; Mashiringwani 1983).

Green manuring may still have a place in soil-fertility management in the communal areas of Zimbabwe, mainly on sandy soils with low OM contents and poor physical structure. By relaying maize and a green-manure crop, farmers can make the green-manure crop fit into their cropping systems without displacing the major summer crops.

Hence, the objective of this study was to identify legumes that can be relayed with maize. The legume must not reduce maize-grain yield if it is to be acceptable to farmers. It should also benefit from agronomic management targeting maize, such as fertilization and weeding.

Materials and methods

The experiment was carried out at four sites: the Mlezu and Makoholi research stations and the Chihota and Chiwundura communal areas. Details about the sites are shown in Table 1. At Mlezu and Makoholi, land was plowed the winter before the experiment and disced in October. Communal-area sites were plowed at the onset of rains in mid-November. In Chihota, maize was planted in mid-November; at the other sites, in late November.

Table 1. Experimental-site description.

Study site	Annual rainfall (mm)
Chihota	1 000
Chiwundura	800
Mlezu (on station)	800
Makoholi (on station)	650

Note: Soils at all sites were medium-grain sands.

The maize was planted 30 cm apart in rows 90 cm apart. Projected density was 37 000 plants ha^{-1}. The sites were fertilized according to recommendations for maize production in those areas: Chihota received compound D (8 : 14 : 7 N–P–K) at a rate of 350 kg ha^{-1}; Chiwundura and Mlezu, at 250 kg ha^{-1}; and Makoholi, at 250 kg ha^{-1}. Fertilizer rate depended on rainfall: sites in high-rainfall areas received more fertilizer. At 6 weeks after maize emergence, ammonium nitrate was applied as a top dressing at all sites at the rate of 60 kg ha^{-1}. The fertilizer was applied to the maize rows only. Thiodin powder was applied in the maize funnel to control stalk borer. The experiment had a split-plot design, with planting date of green-manure legume as the main-plot factor and the legume type as the subplot factor. The gross plots were 32.4 m^2, and the net plots were 14.4 m^2. The trial had three replications.

Legume planting dates were 4, 6, and 8 weeks after maize planting. The green-manure legumes were velvetbean, sunhemp, cowpea, *Dolichos*, *Tephrosia*, and pigeon pea. All the legumes were planted in rows between maize rows, except sunhemp, which was broadcast and worked in between the maize rows at a rate of 45 kg ha^{-1}. Sole-maize plots were planted as controls. After maize harvesting, legume aboveground biomass was incorporated into the soil. Before the legume was incorporated, the total aboveground biomass of the green-manure legumes was determined from four subsamples, harvested from 1 m × 1 m quadrats in each subplot.

Results and discussions

The 1994/95 growing season suffered a drought, and all the legumes and field crops failed in a large area of Zimbabwe. However, the 1995/96 season had normal rains, and most legumes established stands and produced a considerable biomass.

Legume green-manure crops planted 4 weeks after 50% maize emergence had the highest aboveground biomass. However, legume aboveground biomass declined with later planting dates (Tables 2–5). Velvetbean had the highest aboveground biomass at all sites expect Mlezu, where sunhemp had the highest aboveground biomass (Table 4).

Table 2. Effect of planting date on legume aboveground biomass and N, Chihota communal area, 1995/96 season.

	Planting date				
	4 weeks		6 weeks		8 weeks
Legume	Biomass (kg ha^{-1})	N (kg ha^{-1})	Biomass (kg ha^{-1})	N (kg ha^{-1})	Biomass (kg ha^{-1})
Velvetbean	4 473	87	178		0
Sunhemp	2 467	74	1 097	33	294
Cowpea	1 039	22	336		0
Dolichos	218		0		318
Tephrosia	669		0		0
Pigeon pea	395		0		0

Note: Soils at all sites were granitic sands, with 4.3% clay, 0.34% organic C, and pH of 4.3 ($CaCl_2$).

Table 3. Effect of planting date on legume aboveground biomass and N, Chiwundura communal area, 1995/96 season.

	Planting date			
	4 weeks		6 weeks	8 weeks
Legume	Biomass (kg ha^{-1})	N (kg ha^{-1})	Biomass (kg ha^{-1})	Biomass (kg ha^{-1})
Velvetbean	10 556	207	463	249
Sunhemp	2 256	67	162	76
Cowpea	1 081	23	307	301
Dolichos	860		83	98
Tephrosia	23		131	488
Pigeon pea	359		153	79

Note: Soils at all sites were granitic sands, with 5% clay, 0.19% organic C, and pH of 5.7 ($CaCl_2$).

Table 4. Effect of planting date on legume aboveground biomass and N, Mlezu research station, 1995/96 season.

	Planting date					
	4 weeks		6 weeks		8 weeks	
Legume	Biomass (kg ha^{-1})	N (kg ha^{-1})	Biomass (kg ha^{-1})	N (kg ha^{-1})	Biomass (kg ha^{-1})	N (kg ha^{-1})
Velvetbean	3 148	62	1 788	35	445	
Sunhemp	9 554	287	301		159	
Cowpea	4 699	62	821		805	
Dolichos	2 875		29		67	
Tephrosia	0		920		160	
Pigeon pea	538		2 233	48	1 030	22

Note: Soils at all sites were granitic sands, with 5% clay, 0.3% organic C, and pH of 4.3 ($CaCl_2$).

Table 5. Effect of planting date on legume aboveground biomass and N, Makoholi research station, 1995/96 season.

	Planting date			
	4 weeks		6 weeks	8 weeks
Legume	Biomass (kg ha^{-1})	N (kg ha^{-1})	Biomass (kg ha^{-1})	Biomass (kg ha^{-1})
Velvetbean	660	13	220	50
Sunhemp	170	5	10	0
Cowpea	130	2	83	7
Dolichos	140		0	0
Tephrosia	0		0	0
Pigeon pea	0		0	0

Note: Soils at all sites were granitic sands, with 3% clay, O.3% organic C, and pH of 4.5 ($CaCl_2$).

Based on aboveground-biomass production, promising green-manure legumes on sandy soils of Zimbabwe are velvetbean, sunhemp, and cowpea. *Dolichos* lacked vigorous growth, except at Mlezu. Stand establishment was very poor for *Tephrosia* and pigeon pea. Because pigeon pea's initial growth is very slow, it should be planted at the same time as maize.

Table 6. N and P in velvetbean, sunhemp, and cowpea aboveground biomass and roots.

	N (%)		P (%)	
Legume	Aboveground biomass	Roots	Aboveground biomass	Roots
Velvetbean	1.96	1.36	0.13	0.17
Sunhemp	3.00	0.84	0.12	0.04
Cowpea	2.16	1.52	0.18	0.14

Table 7. Effect of legume green manure on maize-grain yields.

	Yield (kg ha^{-1})			
	Chihota	Mlezu	Chiwundura	Makoholi
Legume				
Velvetbean	1 478	8 383	4 228	2 071
Sunhemp	1 645	6 046	3 943	2 321
Cowpeas	1 668	7 146	3 960	2 522
Dolichos	1 709	8 086	3 870	2 333
Pigeon pea	1 692	7 961	4 147	2 295
Tephrosia	1 506	7 672	4 290	2 318
Sole maize	1 559	7 923	4 343	2 496
Mean	1 608	7 602	4 112	2 336
Significance	NS	NS	NS	NS

Note: NS, not significant.

The aboveground biomass and roots of velvetbean, sunhemp, and cowpea were analyzed for N and P. The results are shown in Table 6. Sunhemp aboveground biomass had the highest N content, and velvetbean had the lowest. Planting legumes between maize rows did not affect maize-grain yield, as shown in Table 7.

Conclusions

Relay cropping maize and green-manure legumes had no effect on maize-grain yields in the 1995/96 season, which was generally a wet season in Zimbabwe. The best planting time for a relayed green-manure legume was 4 weeks after 50% maize emergence.

Acknowledgments

I thank Mr Pashapa and his technical team, who helped run these trials. I also thank the Government of Zimbabwe, Ministry of Agriculture, and the Rockefeller Foundation for jointly funding this work. Last, but not least, I thank the International Maize and Wheat Improvement Center, Mexico, for funding to attend the International Workshop on Green Manure-Cover Crop Systems for Smallholders in Tropical and Subtropical Regions, in Chapeco, Santa Catarina, Brazil.

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Expérience de la Compagnie malienne de développement des textiles dans la réalisation des soles fourragères pluriannuelles

E. Dembélé

Compagnie malienne de développement des textiles, Mali

Abstract

The Compagnie malienne de développement des textiles (Malian textiles development company) is an agroindustrial firm concerned with integrated rural development based on cotton production in the Sudan savanna of Mali, where annual rainfall is 700–1 300 mm. Most of the cotton producers are agropastoralists, so the company focuses on the production of an abundant supply of good-quality forage, as well as on soil-fertility improvement and erosion control. *Stylosanthes hamata* and *Aeschynomene histrix* are perennial cover crops that have attracted the attention of the farmers. Although all the farmers appreciate the cover crops for production of an abundant supply of good-quality forage, only a third acknowledge soil-fertility improvement as an incentive for growing them. Optimum time of planting the cover crops (mid-June to end of July) is critical for forage production. However, farmers are busy with other farm operations during this period, and this clash, along with ravaging animals, may constitute a major constraint to adoption of cover crops.

Résumé

La Compagnie malienne de développement des textiles (CMDT) est une entreprise agro-industrielle chargée de la mise en œuvre du développement rural qui s'articule autour des systèmes de production cotonniers. Les producteurs de coton sont essentiellement des agropasteurs qui reçoivent un encadrement technique de la CMDT. Les objectifs des soles fourragères pluriannuelles, comme *Stylosanthes hamata* et *Aeschynomene histrix*, sont d'obtenir une quantité importante de fourrage de bonne qualité pour l'alimentation des animaux surtout en saison sèche, d'améliorer la fertilité du sol à court terme, et de permettre une meilleure couverture du sol et d'atténuer en conséquence l'érosion hydrique et éolienne. La restauration de la fertilité du sol est perçue par 34 % des exploitants, et seulement 4 % des exploitants ont perçu une amélioration dans la lutte anti-érosive. La divagation des animaux est à l'origine de l'abandon de 59 % des soles fourragères. Aussi, 59 % des exploitations ont semé en retard.

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Expérience de l'ESPGRN[1]–Sikasso sur la dolique comme plante fourragère et plante de couverture au Mali-Sud

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Abstract

In response to farmers' increasing complaints about insufficient animal feed in south Mali, trials on *Dolichos lablab* were carried out between 1991 and 1994. *Dolichos* showed good adaptation to maize intercropping. When *Dolichos* was planted between maize stands 15–21 d after maize planting, average forage (*Dolichos*–maize) yield ranged between 5 and 6 t ha^{-1}. Maize-yield reduction was less than 200 kg grain ha^{-1}. Farmers found the system very attractive because the loss of income from 200 kg of maize grain was far less than the cost of procuring 1 000 kg of animal feed in the dry season. Although the residual effects of *Dolichos*–maize intercropping on soil fertility were superior to those of maize planted alone, the primary reason for farmer adoption was increased forage, rather than green-manure production. The leaves, flowers, and pods of *Dolichos* are very susceptible to insect pests. Availability of seeds, therefore, constitutes a major constraint on adoption of the system. Farmers have discovered, however, that *Dolichos* planted around cotton fields produces good-quality seeds because it suffers from fewer insect attacks.

Introduction

La zone Mali-Sud est comprise entre les isohyètes 800 mm au nord et 1 200 mm au sud. Elle est la zone cotonnière par excellence depuis plus de 40 ans. Outre le coton, le sorgho, le maïs et le mil occupent une place importante dans le système de culture. La pression sur les terres de culture et les pâturages est la raison principale de la dégradation physique (érosion) et chimique des sols. La teneur en N et K est respectivement de −5 et −7 kg ha^{-1} an^{-1}. Des pH compris entre 5 et 4 ont été observés. Cela a ainsi entraîné une diminution de la quantité et de la

[1]Équipe Programme systèmes de production et gestion des ressources naturelles (production systems and natural resources management team).

qualité du fourrage en saison sèche. C'est dans ce cadre que l'Équipe Systèmes de production et guestion des ressources naturelles – Sikasso a voulu intensifier la production fourragère tout en protégeant le sol contre la dégradation. Ainsi, des légumineuses fourragères telles que le niébé, le *Mucuna*, le *Stylosanthes* et la dolique (*Dolichos lablab*) ont été introduites dans la zone. Certaines de ces légumineuses, comme le niébé, ont eu une faible adoption en raison de leur insertion difficile dans le calendrier agricole du paysan.

Ces dernières années, l'accent a surtout été mis sur la dolique, qui présente l'avantage très certain de bien couvrir le sol. Cette couverture intervient au moment où le sol devrait être exposé (après la récolte du maïs) au soleil et aux grandes pluies, le protégeant ainsi de l'érosion par ruissellement et par lixiviation. Le système racinaire pivotant et dense de la dolique permet une meilleure exploitation du sol et une augmentation du taux de matière organique du sol. La dolique perd ses feuilles vers la fin de septembre et reprend de la vigeur à la mi-octobre. Ces feuilles qui tombent en période encore humide se décomposent et forment un humus non négligeable qui peut compenser une partie des exportations faites par la plante.

Les recherches sur la dolique, qui ont été effectuées entre 1991 et 1994, avaient comme objectifs de produire du fourrage en quantité et en qualité et de diminuer l'érosion hydrique. Afin de favoriser son intégration dans le système de production de la zone d'étude, la dolique a été associée au maïs. Cette pratique offre certains avantages : économies de terres cultivables et de main-d'œuvre ; augmentation globale du fourrage grâce aux tiges de maïs liées par la dolique ; meilleure gestion du calendrier agricole (possibilités de réaliser la récolte après celle du coton) ; et meilleure protection du sol contre l'érosion après la récolte du maïs.

La culture qui était introduite dans la zone a été testée dans un premier temps afin d'en évaluer l'adaptabilité au milieu et les caractéristiques en tant que fourrage. Par la suite, les aspects agronomiques (mode et date d'association, fertilisation, effets sur le sol et la production de semences) ont été étudiés.

Résultats

Le rendement de fourrage dolique–maïs se situait en moyenne entre 3 et 6 t ha^{-1}. Les résultats variaient cependant selon la campagne et le site. En année d'excès d'eau, la dolique se comporte mal. Le rendement est plus intéressant sur les sols limoneux à limono-argileux. Sur beaucoup de sites, une couverture totale du sol a été observée après la récolte du maïs. Le coût de production de cette culture, estimé à 12 francs CFA kg^{-1}, était inférieur à celui du fourrage niébé ou mil

(15 francs CFA kg^{-1}) et au prix de l'aliment pour bétail concentré (24 francs CFA kg^{-1}) (en 1998, 610,65 francs CFA [XOF] = 1 dollar américain [USD]). Après la première année de test, les paysans ont beaucoup apprécié le fourrage dolique associé aux tiges de maïs.

Mode et date d'association

Après une campagne de test, le mode le plus approprié était l'association de la dolique sur la même ligne que le maïs en « interpoquet » afin de faciliter les travaux d'entretien mécanique. Pour des interlignes de 0,80 cm et selon l'écartement des poquets, la dolique était associée après chaque poquet de maïs (>60 cm) ou après chaque deux poquets (<60 cm).

La date optimale d'association variait de 15 à 21 jours après le maïs, ou lorsque les plants de maïs avaient de quatre à six feuilles. L'incidence de la dolique sur le maïs est faible, voire négligeable, selon le point de vue des paysans. En moyenne, le manque à gagner est de 200 kg ha^{-1} de maïs graine qui, selon le paysan, est insignifiant devant le gain de 1 000 kg ha^{-1} supplémentaire de fourrage de qualité. Les paysans estiment que le prix des 200 kg ha^{-1} de maïs ne suffit pas pour payer l'équivalent de 1 000 kg ha^{-1} d'aliment pour bétail.

Fertilisation

Deux campagnes agricoles ont été mises à profit pour étudier trois doses d'engrais sur l'association :

Parcelle	Traitement
D1	50 kg complexe céréale (15–15–15 N–P–K) + 75 kg d'urée (46 % N)
D2	D1 + 200 kg phosphate naturel (28 % P_2O_5, 35 % CaO)
D3	2D1 = 100 kg complexe céréale + 150 kg d'urée

Les résultats ont montré que la dose forte de fumure minérale (D3) donne le meilleur rendement (fourrage et maïs graine) mais que la pratique incluant le phosphate naturel semble la plus économique et la plus durable pour le système du paysan. Dans les années de bonne pluviométrie, le phosphate naturel améliore la production fourragère de dolique.

Les observations sur les effets à long terme du maïs–dolique ont montré que le système n'épuise pas le sol. Les mesures de rendement et les observations des paysans ont montré que les anciennes parcelles de dolique se comportent mieux par rapport aux parcelles de maïs pur.

Production paysanne de semences de dolique

La longueur du cycle de la variété de dolique utilisée et sa sensibilité aux attaques constituent les contraintes pour la production de semences chez les paysans. La divagation des animaux intervient avant la maturation des graines de dolique en plein champ ; la dolique est aussi très attaquée par les insectes.

C'est dans ce cadre que plusieurs techniques de production ont été testées : la production dans les jardins ; la production sur les arbres ; la production sur les arbres à l'intérieur des champs de coton et sur les diguettes anti-érosives au bord des parcelles de coton ; et le triage progressif des graines mûres dans les parcelles associées. Dans tous les cas, les parcelles situées à proximité des champs de coton ont été très peu attaquées et ont permis de produire des quantités modestes de graines de dolique.

Sesbania fallows for increased maize production in Zambia

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International Centre for Research in Agroforestry

Résumé

Des études conduites dans l'est de la Zambie à partir de 1987 ont révélé qu'une courte durée de jachère améliorée avec le *Sesbania sesban* constitue une alternative agroforestière préférable à la jachère naturelle pour accroître la fertilité des sols dégradés. La rotation du *S. sesban* pendant 2–3 ans a doublé ou triplé le rendement par rapport au système de culture sans engrais. En outre, les jachères à base de *Sesbania* produisent de 10 à 35 t de bois de chauffage ha^{-1} après 1–3 ans. Les jachères améliorées de *Sesbania* sont plus appropriées pour les paysans pauvres pour connaître les avantages des fertilisants. Il apparaît que les jachères améliorées avec *Sesbania* constituent une réponse à l'appel à une agriculture durable qui peut nourrir une population sans cesse croissante, sans causer trop de dommages à l'environnement.

The backdrop

More than 90% of Zambia's staple food, maize, is grown by small-scale farmers. The country's food security rests with these producers and is threatened when such farmers are not given the means to deal with problems of severe land degradation and, by consequence, declining food production and soil fertility; high population growth; shorter fallow periods; high cost of fertilizers; erratic rainfall; and scarcity of fuelwood. Also, the biodiversity of the Miombo woodlands is threatened by agricultural expansion. Each of these problems is related to, and even exacerbates, the others.

Finding a solution in *Sesbania* trees

Sesbania sesban is widespread in southern, Central, and eastern Africa. It is widely distributed along major lakes, rivers, streams, and marshes. After trying many different tree species and provenances, researchers with the Zambia – International Centre for Research in Agroforestry (ICRAF) Agroforestry Research

Project in Chipata selected *S. sesban* as a potential species for short-rotation fallows, as it is fast growing, vigorous, and easy to propagate and to remove from the soil; produces high-quality biomass; nodulates easily; and fixes N. The ICRAF researchers found that growing *Sesbania* in depleted fields or on fallow lands for 2 or 3 years and then introducing a hybrid maize crop after the fallow period produced exciting and encouraging results. Without N fertilizers, maize yields were 2.3 t ha^{-1} after 1 year of *Sesbania* fallow; 5.6 t ha^{-1}, after 2 years; and 6.0 t ha^{-1}, after 3 years. Continuous maize crops gave only 1.5 t ha^{-1}.

Sesbania fallows also produced 10–35 t of fuelwood ha^{-1} after 1–3 years. Such on-farm production of fuelwood eases the burden of labour carried by women and children, as well as reducing the pressure on natural woodlands.

When the *Sesbania* trees are removed (usually by hand), roots are left in the soil: 1.2 t ha^{-1} of root mass after 1 year; 1.7 t ha^{-1}, after 2 years. Most (90%) of the roots were in the top 50 cm of the soil, and as they slowly decayed they provided nutrients to crops. A few roots reached the water table, at a depth of 7.5 m, where they could access nutrients and water.

A cost–benefit analysis showed that *Sesbania* fallows are more profitable than continuous cropping, even allowing for the land taken out of maize production. In a farm setting, on severely depleted soils, maize yields increased from 0.15 t ha^{-1} to 4.0 t ha^{-1} after 2 years of *Sesbania* fallow. However, for wide evaluation on farms, nursery-raised, inoculated, bare-rooted seedlings, rather than potted ones, must be used to reduce establishment costs.

There is considerable enthusiasm among farmers in Chipata, Katete, and Chadiza, where 200 farmers established *Sesbania* fallows from bare-rooted seedlings in the 1994/95 season. Currently, more then 1 000 farmers in eastern Zambia alone are participating in an evaluation of improved fallows. Trials at 100 sites with various soil and climatic conditions will show researchers what biophysical conditions — rainfall, soil fertility, and soil composition — are needed to grow *S. sesban*. On-farm nurseries have been set up at farmer training centres and in farmers' fields to supply seedlings to farmers who wish to try the technology. Furthermore, several farmers have established their own farmer-designed trials with *Sesbania* in fallow fields. This indicates that the technology is poised to take off.

Acknowledgments

We gratefully acknowledge the Swedish Agency for Research Co-operation with Developing Countries for the continued funding of the Zambia–ICRAF Agroforestry Research Project in Chipata, Zambia, and the International Development Research Centre, Canada, for covering the travel and related costs of presenting this work at the cover-crops symposium in Cotonou, Benin. We also thank Damary Odanga for preparing a poster for the symposium and Alice Aduol for typing the manuscript.

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Epilogue: Achieving sustainability in the use of cover crops

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Résuné

Les expériences que font les agriculteurs et les chercheurs avec les plantes de couverture montrent que ces plantes répondent aux besoins des exploitants agricoles et que l'on devrait en recommander davantage l'emploi. Cela ne s'est pas fait parce que l'utilisation traditionnelle très répandue des plantes de couverture est passée largement inaperçue et parce que bien des scientifiques pensaient que ces plantes ne convenaient pas pour les petites exploitations. Cependant, la situation a évolué rapidement au cours des 10 dernières années. Il ressort de l'expérience menée par de nombreux petits exploitants agricoles qui utilisent actuellement des plantes de couverture que les premières évaluations ne sont plus valables. Les petits exploitants agricoles accepteront les plantes de couverture (1) si elles sont plantées sur des terres qui présentent peu de coûts d'opportunité (par exemple, intercalées avec des cultures vivrières ou des cultures commerciales, sur des terres en jachère, sous des cultures arbustives ou pendant des périodes où l'on s'attend à une sécheresse, à des inondations ou à un gel) ; (2) si leur utilisation demande très peu de main-d'œuvre supplémentaire (ou, comme dans certains cas, si, en éliminant des mauvaises herbes, elle entraîne une économie de main-d'œuvre) ; (3) si les semences sont faciles à obtenir sans frais pour l'agriculteur ; et (4) si leur biomasse (graines, feuilles, lianes) rapporte quelque chose en plus de l'amélioration de la fertilité des sols. Beaucoup de systèmes de plantes de couverture reposent sur des légumineuses qui sont appréciées non seulement parce qu'elles maintiennent la fertilité des sols, mais aussi parce que leurs graines ou leurs gousses sont comestibles. Les agriculteurs apprécient également les plantes de couverture qu'ils peuvent utiliser comme fourrage et qui les aident à lutter contre les mauvaises herbes. De façon plus générale, ils recherchent des utilisations multiples, quelle que soit pratiquement la technique envisagée. Des pratiques qui répondent simultanément à plusieurs contraintes importantes de leur exploitation ont donc beaucoup plus de chances d'y être adoptées. À l'inverse, il est peu probable que des mesures de conservation des sols réussissent, sauf si les pratiques proposées présentent d'autres avantages que l'amélioration de la fertilité des sols. Le développement de l'utilisation des

plantes de couverture comme fourrage et comme aliments est un défi, mais le recours à des pratiques qui visent à améliorer les sols contribuera à l'agriculture durable, ce qui est également très important.

Farmer and researcher experience with cover crops is a significant and compelling reason to call for action by governments and development agencies. In just the last few years, more than 10 000 farmers in Benin have taken up the opportunity to use *Mucuna pruriens* to control *Imperata cylindrica* and improve soil fertility (Vissoh et al., this volume). Farmers in Burkina Faso, Ghana, southern Mali, and Togo have also responded favourably (Galiba, personal communication, 1998[1]). More than 125 000 farmers are using cover crops in the state of Santa Catarina, in southern Brazil, and many more farmers in the neighbouring states of Paraná and Rio Grande do Sul are using them too (Calegari et al. 1993; Calegari et al. 1997). In Central America and Mexico, more than 200 000 farmers appear to be using cover crops in a wide variety of cropping systems (Arteaga et al. 1997; Flores 1997; Buckles et al. 1998; CIDICCO 1998). Clearly, cover crops are responding to the needs of farmers and should be more widely promoted.

The present use and rapid spread of cover crops around the world caught a good number of scientists by surprise. To some extent, this happened because the previously widespread traditional use of cover crops went largely unnoticed. For instance, Wilken (1987), in his otherwise excellent book, *Good Farmers: Traditional Agricultural Resource Management in Mexico and Central America*, concluded that cover cropping is not widespread in Mesoamerica. By contrast, some 20 traditional cropping systems involving the use of at least 14 plant species as green manures and cover crops have more recently been documented in the countries of the region (Arteaga et al. 1997; Flores 1997; CIDICCO 1998).

Another reason for the surprise is that until recently scientists thought cover crops were inappropriate for small farms (Young 1989). This belief may have seemed reasonable when commercial farms and small-scale farmers supported by development projects enjoyed access to subsidized chemical fertilizers and herbicides and when traditional cropping systems, such as shifting cultivation, were still relatively productive alternatives. But conditions have changed rapidly over the last decade; external inputs are both expensive and contaminating, and the productivity of traditional systems has plummeted. The experience of the many small-scale farmers now using cover crops, documented here and elsewhere, shows that earlier assessments are no longer valid.

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[1]M. Galiba, Director, SG 2000, personal communication, 1998.

What, then, are the conditions under which small-scale farmers will use cover crops? Our assessment of farmer experience, based on a decade of observation, suggests that small-scale farmers will only accept cover crops when

- They are grown on land that has few opportunity costs (for example, intercropped with food or commercial crops, on land left fallow, under tree crops, or during periods of expected drought, flooding, or freezing);
- Their use requires very little additional labour (or, as in some cases, saves labour by controlling weeds);
- Seed is readily available at no out-of-pocket cost to the farmer; and
- Their biomass (seeds, leaves, vines) provides benefits over and above improvements to soil fertility.

The first three conditions are generally acknowledged. The fourth, however, merits closer examination. The following experiences are informative.

Many traditional cover-crop systems involve legumes that are appreciated not only because they maintain soil fertility but also because the seeds or pods can be eaten by people. This is true of most of the intercropped *Vicia* spp. in southern Honduras, El Salvador, and southern Mexico, as well as the high-altitude *Phaseolus coccineus*, which was traditionally used all the way from upstate New York (Seneca bean) to Mexico (*ayocote*), Guatemala (*piloy*), and Honduras (*chinapopo*) and south through the Andean countries into northern Chile.

The velvetbean (*Mucuna* spp.), probably the most popular of all cover crops used today, was grown in its centres of origin in Asia as a food crop before being displaced by other legumes (Watt 1883 and Burkill 1966, both cited in Buckles 1995). Its spread through various countries in southern Africa and West Africa by farmers was probably due to its food uses (Osei-Bonsu et al. 1996; Ezueh 1977). In central Honduras, where NGOs have taught farmers to intercrop velvetbean with maize, abandonment of the technology has been disappointingly high, except in those villages where velvetbean is being processed (to rid it of L-Dopa) and consumed by the people in tortillas or as a drink (coffee and hot-chocolate substitutes) (Bunch 1990, 1994; RB's field observations). That it has potential for use as a food rich in protein, as noted by Lorenzetti et al. (this volume), is an especially important observation, as this can motivate small-scale farmers to use this agronomically very beneficial crop.

Farmers also need feed and forage for their animals. Although most of the species currently used as cover crops (with the exception of *Melilotus albus*) cannot be grazed continuously, many can be used for cutting and carrying or can be harvested as seed and used as feed. Even after months of drought, *Lathyrus nigrivalvis* and lablab bean (*Dolichos lablab*) make useful forages in cut-and-carry systems in Guatemala, Honduras, and Mexico (Flores 1997; RB's field observations). During the early part of this century, *Mucuna* seeds were used extensively as a major component of livestock feed in the southern United States (Buckles 1995), and they are currently used for pig feed in Campeche, Mexico (Flores 1997; RB's field observations). The costs of using velvetbean are estimated to be two-thirds lower than the costs of using commercial feeds, with equivalent liveweight gains (Poot, personal communication, 1996[2]). Forage uses of cover crops need to be tested in various settings and much more widely promoted if small-scale farmers are to use them consistently.

The appeal to small farmers of multipurpose cover crops is also borne out by practices that contribute to weed control as well as to soil fertility. Jack bean (*Canavalia ensiformis*), tropical kudzu (*Pueraria phaseoloides*), and perennial peanuts (*Arachis pintoi*) are used under a variety of plantation crops, including coffee, bananas, and oil palms. The ability of velvetbean to control *Imperata* spp. in Benin and Ghana, as reported here (various authors, this volume), is of major significance, given the problems caused by this invasive grass. Farmer use of velvetbean to control *Imperata* spp. and *Saccharum* spp. has also been reported for Colombia and Panama (RB's field observations). Traditional systems include the use of perennial velvetbeans in Southeast Asia and annual velvetbeans in southern Mexico (Buckles and Perales 1998) for improved fallows and weed control. In southern Brazil, hundreds of thousands of farmers regularly use some 30 species of cover crops, not only because these improve the fertility of the soil, but also because the increased OM in the soil allows the farmers to switch to no-till systems of land preparation, thus greatly reducing their costs (Calegari et al. 1997).

In more general terms, the importance of the additional benefits of cover crops is consistent with the increasingly widespread observation that small-scale farmers look for multiple uses when considering virtually any technology. Practices that respond simultaneously to several important constraints on their farms have a much greater potential for adoption, even when effects on a specific constraint (low soil fertility, for example) may not be equal to the potential impact of a more targeted input (such as chemical fertilizer). Conversely, the promotion

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[2]N. Poot, Pronatura, Merida, Yucatan, personal communication, 1996.

of soil-conservation and soil-improvement measures is unlikely to succeed unless the practices provide benefits beyond improved soil fertility.

Experimentation with cover crops by numerous farmers, occasionally with strategic input from scientists and development workers, has resulted in the development of a number of multiple-use practices. This experience leads us to think that cover crops can be viable and highly beneficial components of many cropping systems. Nevertheless, the changing conditions of farmers and their environment call for the continuous development of new practices, drawing on as yet untried species and combinations of species. Although the development of food and forage uses of cover crops is probably the most important challenge, it also offers a very important opportunity for soil-improvement practices to contribute to sustainable agriculture.

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Appendix 2
Acronyms and abbreviations

ADB	African Development Bank
asl	above sea level
CEC	cation exchange capacity
CIEPCA	Centre d'information et d'échanges sur les plantes de couverture en Afrique (centre for information and exchange on cover crops in Africa)
CMDT	Compagnie malienne de développement des textiles (Malian textiles development company)
CP	crude protein
cv.	cultivar
DAP	days after planting
DAS	days after staking
DM	dry matter
DMT	N,N-dimethyltryptamine
DRRPS	Division of Research for Rural Production Systems [IRE, Mali]
DW	dry weight
FAO	Food and Agriculture Organization of the United Nations
FLI	fractional light interception
GMCC	green-manure cover crop
GTZ	Gesellschaft für Technische Zusammenarbeit (German organization for technical cooperation)
HPI	Heifer Project International
HPLC	high-performance liquid chromatography

IAR	Institute of Agronomic Research [Cameroon]
ICRAF	International Centre for Research in Agroforestry
IDRC	International Development Research Centre
IITA	International Institute of Tropical Agriculture
ILCA	International Livestock Centre for Africa
ILRI	International Livestock Research Institute
INERA	Institut d'étude et de recherches agricoles (agricultural study and research institute) [Burkina Faso]
IRE	Institute of Rural Economy [Mali]
IRZ	Institut des recherches zootechniques (institute of animal research) [Cameroon]
L-Dopa	3-(3,4-dihydroxyphenyl)-L-alanine
LW	liveweight
MRD	Ministry of Rural Development [Benin]
NARIB	National Agricultural Research Institute of Benin
NARS	national agricultural research system
NASRD	National Agency for the Support of Rural Development [Côte d'Ivoire]
NGO	nongovernmental organization
OHV	Operation High Valley [Mali]
OM	organic matter
PAR	photosynthetically active radiation
PLAE	battle against erosion project [Mali]
PLAW	People, Land and Water program initiative [IDRC]
PNT	Phosphate naturel de Tilemsi™
RACRD	Regional Action Centre for Rural Development [Benin]
RAMR	Recherche appliquée en milieu réel (applied research in practice) [Benin]
RH	relative humidity

SG 2000	Sasakawa Global 2000
SHZ	subhumid zone
SODEPRA	Société pour le développement des production des animaux (society for the development of animal production) [Côte d'Ivoire]
SSA	sub-Saharan Africa
SSP	Single Superphosphate™
TLU	tropical livestock unit
WARDA	West Africa Rice Development Association

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Annexe 2
Acronymes et sigles

CIEPCA	Centre d'information et d'échanges sur les plantes de couverture en Afrique
CMDT	Compagnie malienne de développement des textiles
CRDI	Centre de recherches pour le développement international
CREDESA	Centre régional pour le développement et la santé
GTE	initiative de programme Des gens, des terres et de l'eau [CRDI]
GTZ	Gesellschaft für Technische Zusammenarbeit (organisation pour la coopération technique)
IIAT	Institut international d'agriculture tropicale
L-dopa	3-(3,4-dihydroxyphenyl)-L-alanine
MO	matière organique
MS	matière sèche
PCEV	plantes de couverture et engrais verts
PDEBE	Projet de développement de l'élevage dans le Borgou-Est
PNT	Phosphate naturel de Tilemsi™
SG 2000	Sasakawa Global 2000

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