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ALTERNATIVES TO MUCUNA FOR SOIL FERTILITY MANAGEMENT IN SOUTHERN BÉNIN: FARMER PERCEPTION AND USE OF TRADITIONAL AND EXOTIC GRAIN LEGUMES

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SUMMARY

In southern Bénin, the legume cover crop *Mucuna pruriens* var. utilis has been widely promoted for soil fertility improvement. Recent findings have shown, however, that the majority of farmers have not adopted it, and that alternative technologies are needed that are both attractive to farmers and beneficial in terms of soil fertility. A survey was carried out in southern Bénin to determine farmer perception and use of traditional grain legumes and to assess the adoption potential of new low-harvest-index grain legumes. Grain legumes were shown to be integral components of traditional cropping systems and constituted farmers' most important technology for soil fertility maintenance. More than 80% of respondents expressed interest in testing new, low-harvest-index varieties. Preferred grain characteristics and farmers' culinary preferences for grain legumes varied between locations and need to be taken into account if new germplasm is to be introduced. It is argued that farmers' interest and experience in legume cultivation provide an opportunity for the introduction of alternative legume-based technologies such as low-harvest-index grain legumes and techniques for the detoxification of mucuna seed. In addition, efforts should be made to increase the productivity of current legume production systems and to develop mucuna cultivars with reduced L-dopa content.

INTRODUCTION

The reduction of traditional fallow periods has led to widespread depletion of soil nutrients and organic matter in sub-Saharan Africa. Crop yields are low and, in many areas, are decreasing. The long-term sustainability of major farming systems is therefore at risk (Smaling *et al*., 1997). In southern Bénin, for example, this vicious cycle of reduced fallow periods and declining soil fertility has caused maize yields to decline over the past 100 years from around 2 to 0.53 t ha^{-1} in the Abomey-Calavi province and, to 0.28 t ha^{-1} on the Abomey plateau (Floquet and Mongbo, 1998; Igue *et al*., 2000).

The beneficial effect of legumes on soil fertility is widely recognized (Bationo *et al*., 1997; Giller, 2001) and substantial efforts have been made to advocate their more widespread use. In Bénin, the leguminous cover crop *Mucuna pruriens* var. utilis was

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promoted in the late 1980s and early 1990s as a low-input technology for soil fertility improvement and for the control of the noxious weed *Imperata cylindrica* (Vissoh *et al*., 1998). Early adoption estimates were relatively high in four villages where mucuna fallow was first tested (Manyong *et al*., 1996). However, a study by Honlonkou *et al*. (1999) indicated that the majority of farmers (93%) in southern Bénin had chosen not to adopt mucuna. In fact, their findings showed that an increasing number of mucuna users had abandoned the technology and that the area planted to the crop in Bénin had dropped by around 30% between 1996 and 1997. Although the causes of this behaviour have not been fully established, it can be speculated that mucuna had reduced *Imperata* to acceptable levels and, hence, farmers did not see the need to grow mucuna any longer. A second possible explanation may be that several research and development teams initially purchased mucuna seed from farmers for further distribution but discontinued purchases after 1995. For example, Sasakawa Global 2000, an international NGO had purchased large quantities of mucuna seed between 1992 and 1995 but discontinued this practice in 1996. This led to a collapse in the seed price. As a result, many farmers decided to stop growing the crop as it no longer provided a direct economic benefit (Honlonkou *et al*., 1999; Douthwaite *et al*., 2002).

It appears, therefore, that the adoption potential of mucuna cover-crop technology is rather limited in this environment (Carsky *et al*., 2001). Alternative legume technologies are needed that are both attractive to the majority of farmers and beneficial in terms of soil fertility improvement. Grain legumes have a long history in West Africa. They are grown presently on more than 220 000 ha in Bénin (FAOSTAT, 2002) and could be considered as an alternative technology. However, the potential contribution of most grain legumes for maintaining soil fertility is low compared with cover crops. Grain legumes such as groundnut (*Arachis hypogaea*) and cowpea (*Vigna unguiculata*), which are currently widely used in Bénin, were bred for high grain yields and harvest indices. Consequently a substantial proportion of the produced biomass and nitrogen is exported from the system with the grain (Schulz *et al*., 2001). Hence, more emphasis should be given to alternative grain legumes that produce large amounts of nitrogen-rich biomass plus some grain. At present, little is known about traditional grain legume production systems and farmers' interest in testing alternative crops. It was the objective of this study to determine current farmer perception and use of grain legumes and to assess the adoption potential of low-harvest-index grain legumes in southern Bénin.

MATERIALS AND METHODS

Study area

The survey was carried out in 1999 in six counties (*sous-préfectures*) in three provinces (*départements*) in southern Bénin (Figure 1). The area is characterized by bimodal rainfall that peaks in June and October and averages around 1100 mm a^{-1}. This rainfall distribution allows for a long growing season from March to July and a shorter one from August to November, resulting in a 211–270 d growing period (Jagtap, 1995). Farmers practice continuous cultivation or short-duration fallows; major crops

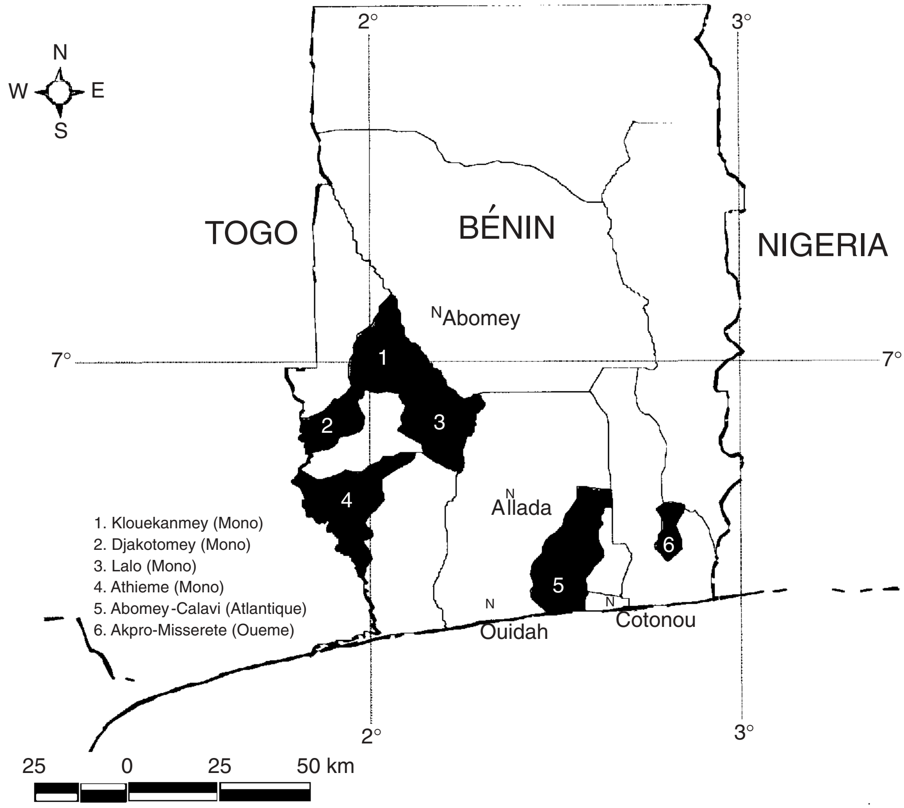

Figure 1. The six counties in three provinces (in parenthesis) in which the survey was carried out in southern Bénin.

in the area are oil palm, maize, and cassava. Population density is high with around 220 inhabitants km^{-2} (Ministère du Développement Rural, 1993). The dominant soil texture is sand to sandy loam of low inherent soil fertility, often referred to as *Terre de Barre* and classified as Ferralic Nitisols (FAO/ISRIC/ISSS, 1998).

Farmer selection and data analysis

The survey reported here followed up an earlier, more extensive survey, which had the objective of studying the adoption process of mucuna in southern Bénin (Honlonkou *et al.* 1999). In the course of the Honlonkou survey, villages in three southern provinces (Atlantique, Mono and Oueme) of Bénin were selected, based on two criteria (i) their inhabitants had been exposed to mucuna, and (ii) the area was accessible during the growing season, i.e., the time of the year when the survey was conducted. From those villages, 12 were randomly selected and, following a population census, 534 randomly selected farmers were interviewed in 1998. For the survey reported here, 226 interviewees of the three provinces sampled in the Honlonkou survey were randomly selected and interviewed again in 1999. The same farmers were revisited to avoid duplication and to reduce costs. For example, the socioeconomic data required for this survey could be extracted from the Honlonkou survey. For the study reported here, a semi-structured survey was pre-tested in May 1999 in the presence of the first author and was administered over the period from July to December by experienced enumerators who could speak the local language (Fon). Respondents were interviewed individually and care was taken to ensure that fellow villagers could not overhear the interview. Information regarding crop yields and areas were as farmers recollected for the 1998 cropping season; farmers' interest in new, low-harvest-index grain legumes was elucidated by asking: 'Would you be interested in growing legumes other than those you currently grow; a legume that would produce a small quantity of edible grain and large quantities of residues?'

The data were analyzed using the FREQUENCY and GENMOD procedures of SAS Institute (1989), and the general association Chi-square test for equal proportions. Socioeconomic determinants for farmers' interest in testing low-harvest-index legumes were analyzed using a LOGIT model. It was hypothesized that adoption would be favoured by:

- young, educated farmers as they might be more aware of the need to introduce and test innovations;
- fulltime farmers operating in areas with good market access because their livelihood depends on the income generated by farming and because they would benefit from selling legume grain;
- farmers with large families and farms because they would have access to sufficient land and labour to grow the crop; and
- male farmers who usually have control over household resources in the study area.

RESULTS

Production constraints

Continuous cropping was practiced by more than 60% of farmers. Of those who still practiced fallow, more than 90% reported a decrease in fallow periods (Table 1). The majority of all respondents (95%) complained about declining soil fertility in their fields. On average, the quantities of organic and inorganic soil amendments applied did not seem to have changed greatly over the past 10 years. More than 60% of respondents identified *Imperata cylindrica* as an important production constraint.

Table 1. Farmer perceived soil fertility and soil fertility management dynamics over the previous 10 years (before 1999).

		Number of farmers reporting			
Criteria	n	Increase	Decrease	No change	$p >$ ChiSq
Soil fertility	226	2	215	9	<0.01
Fallow period	86 (only those who still practice fallow)	4	78	4	<0.01
Use of organic manure	226	93	85	48	<0.01
Use of inorganic fertilizer	86 (only those who still practice fallow)	63	29	134	<0.01

Table 2. Adoption and use of grain legume species grown in southern Bénin.

Legume species	Adoption n	Adoption %	Motive for growing legume (%) Grain	Forage	Soil fertility
Cowpea (*Vigna unguiculata*)	200	88	96	1	77
Groundnut (*Arachis hypogaea*)	179	79	93	1	71
Lima bean (*Phaseolus* spp.)	82	36	92	2	61
Pigeonpea (*Cajanus cajan*)	50	22	92	8	76
Soyabean (*Glycine max*)	22	10	82	5	68
Bambara groundnut (*Voandzeia subterranea*), Kersting's groundnut (*Kerstingiella geocarpa*)	19	8	79	0	68

Table 3. Average area (cumulative area of first and second season crops) per farm and yield of cowpea, groundnut and soyabean.

Legume species	n	Area ha ± s.e.	Yield kg ha^{-1} ± s.e.
Cowpea	199	0.23 ± 0.014	522 ± 28.0
Groundnut	174	0.22 ± 0.015	726 ± 36.7
Soyabean	20	0.10 ± 0.018	314 ± 91.5

For legume crops, farmers identified insect pests in cowpea (*Vigna unguiculata*) (82% of cowpea farmers) and rodents in groundnuts (*Arachis hypogaea*) (23% of groundnut farmers) as major yield-limiting factors. Conversely, lima bean (*Phaseolus lunatus*) appeared to be a relatively trouble-free crop as only 16% of lima bean growers complained about insect damage.

Grain legume adoption and use

Grain legumes were used widely in the study area (Table 2); 99% of respondents grew at least one out of the seven identified grain legume species. Cowpea and groundnut were the most popular. Both were grown annually on 0.22 ha (cumulative crop area for long and short growing seasons) out of an average total farm area of 0.85 ha. In contrast, only 10% of respondents grew soyabean (*Glycine max*). Average legume grain yields were generally low and varied greatly between farmers (Table 3). For example, average groundnut yields were 730 kg ha^{-1} whereas the ten best groundnut farmers reported average yields of 1840 kg ha^{-1}. Cowpea, groundnut, and soyabean are usually grown on a field scale, whereas other species, such as lima bean, are mostly grown in kitchen gardens or on boundaries around fields. Therefore, reliable crop area and yield estimates were not available for these species.

The main motive for growing grain legume crops was the production of grain. Their beneficial effect on soil fertility, however, was widely appreciated. In fact, Figure 2 indicates that the cultivation of grain legumes was the most widely used practice for soil fertility maintenance, whereas inorganic fertilizer and farmyard manure were of considerably less importance. Owing to the high degree of intensification in that area,

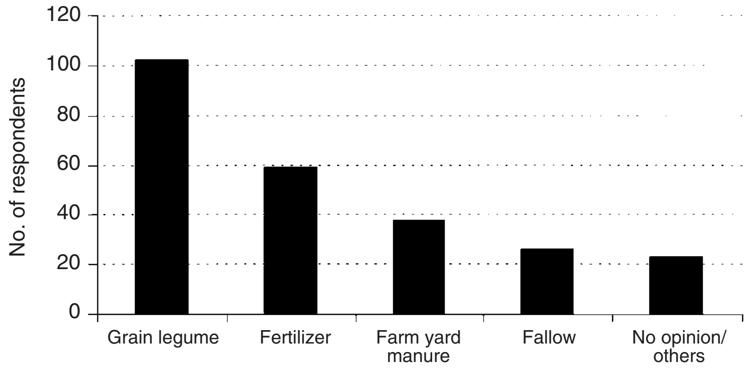

Figure 2. Most widely used technology for soil fertility maintenance (multiple answers permitted; $p >$ ChiSq: <0.01).

fallow was no longer a viable option for most farmers. Legume residues were generally left in the field despite the fact that almost 50% of farmers keep small ruminants such as goats and, as is commonly done in the northern Guinea savanna agro-ecozone of Nigeria, the residues could have been used as forage or sold to livestock owners.

Legume cropping systems

Grain legumes were grown primarily during the long growing season from March to July (484 replies for all legumes) and to a lesser extent during the second season from August to November (225 replies for all legumes). Averaged over species and growing seasons, legumes were grown in almost equal proportions as intercrops (337 replies for all legumes) and as sole crops (424 replies for all legumes). Intercropping was more widely practiced for groundnut (59% of groundnut fields) than for cowpea (28% of cowpea fields). Predominant companion crops for the legume intercrops were maize and cassava.

Preferred grain characteristics and culinary qualities in grain legumes

Farmers' preferences are shown in Tables 4 and 5. Averaged over provinces, taste was identified as the most important criterion, followed by texture. Other grain characteristics, such as grain size and shape, were not important. Preferred grain characteristics appeared to vary over locations. For example, grain colour was considered important by 12% of respondents in Atlantique province but was not important in Oueme. Averaged over provinces, farmers preferred white grain with a juicy or succulent taste and a 'crushed' texture after cooking, i.e. a texture intermediate between mashed and intact grains (Table 5). Pulses with strong 'beany' taste were liked only in Atlantique (29%) and Mono (19%).

Adoption potential of alternative grain legumes

Almost all farmers (99%) would have liked to test the cooking and culinary qualities of potential new grain legumes and 84% expressed interest in growing alternative low-harvest-index legumes. Moreover, 90% of respondents would grow mucuna if the grain could be sold or consumed. Results from the LOGIT analysis (Table 6) indicated

Table 4. Most important grain and culinary characteristics of grain legume seed in three provinces (% of respondents in each province).

	Province			
Characteristics	Atlantique (n = 68)	Mono (n = 119)	Oueme (n = 39)	Weighted average†
Taste	65	62	90	68
Texture after cooking	18	19	5	16
Colour	12	2	0	4
Cooking time	4	3	5	4
Size	0	3	0	1
Shape	0	2	0	1
Others	1	9	0	5
$p >$ ChiSq				<0.01

† Chi-square test based on count data.

Table 5. Preferred taste, texture, and colour of grain legumes in three provinces (% of respondents in each province).

	Province			
Characteristics	Atlantique (n = 68)	Mono (n = 119)	Oueme (n = 39)	Weighted average†
Taste				
Juicy, succulent	64	68	97	71
Beany	29	16	3	18
Sweet	6	13	0	9
No opinion	1	3	0	2
$p >$ ChiSq				<0.01
Texture after cooking				
Crushed	46	74	100	69
Mashed	52	18	0	25
Intact	1	5	0	3
No opinion	1	3	0	2
$p >$ ChiSq				<0.01
Colour				
White	37	48	38	42
Brown	37	18	3	21
Red	1	15	0	8
Spotted	10	1	0	4
No opinion	15	18	59	24
$p >$ ChiSq				<0.01

† Chi-square test based on count data.

that farmers' interest in testing these new low-harvest-index grain legumes was not substantially influenced by the included socioeconomic factors. Market access was the only significant factor affecting the likelihood of adoption of new grain legumes; farmers with better market access were more likely to adopt them. In addition, the analysis seemed to suggest that better educated farmers were less willing to test new grain legumes. However, this somewhat counterintuitive result should not be overrated

Table 6. Determinants for the adoption potential of low-harvest-index grain legumes†

Parameter	Level	Estimate ± s.e.	$p >$ ChiSq
Gender	Female	0.69 ± 0.52	0.18
	Male	0.00 ± 0.00	–
Non farm employment	Yes	0.00 ± 0.00	–
	No	0.72 ± 0.66	0.28
School years	–	0.14 ± 0.08	0.10
Family size	–	0.00 ± 0.07	1.00
Farm size	–	–0.15 ± 0.29	0.62
Age	–	–0.02 ± 0.02	0.22
Distance to market	–	0.24 ± 0.09	<0.01
Intercept	–	–2.84 ± 1.08	<0.01

† The Y-variable in the model is the answer to the question: 'Would you be interested in growing legumes other than those you currently grow; a legume that would produce a small quantity of edible grain and large quantities of residues?' Yi = 1 if the farmer was interested and Yi = 2 if the farmer was not interested. Goodness of fit of the model using the scaled deviance is 0.81 (Value 134.3 with 166 degrees of freedom).

because it was due to two outliers with 12 and more school years who were not interested in testing new legumes.

DISCUSSION

Declining soil fertility and infestation with *Imperata cylindrica* were still perceived as important constraints in southern Bénin. The majority of farmers (93%), however, chose not to adopt mucuna despite its intensive promotion as a means to alleviate these constraints (Honlonkou *et al*., 1999). It appears, therefore, that the two potential benefits of mucuna, i.e. soil fertility improvement and weed control, did not suffice to convince the majority of farmers to adopt the technology. In contrast, most farmers would be willing to grow mucuna if the grain could be consumed or sold. This is consistent with findings by Honlonkou *et al*. (1999) and Douthwaite *et al*. (2002), suggesting that farmers' main motive for adopting mucuna may have been the artificially created market for its seed. It also corroborates findings by Houndékon *et al*. (1998) that farmers were reluctant to adopt mucuna because it took land out of production that could otherwise be used for growing food or cash crops.

The results of this study have shown that grain legumes were cultivated by virtually every farmer and are indeed integral components of traditional farming systems. Farmers were aware of their beneficial effects on soil fertility and consciously used them to rehabilitate degraded fields. Farmers' expertise in growing grain legumes and their concomitant interest in testing alternative new legumes provide an excellent 'window of opportunity' for the introduction of grain legume-based resource management technologies. For this, several alternative avenues exist, as indicated in the following section.

Increasing the productivity of current legume systems

Average legume grain yields varied widely but were generally low. The fact that some farmers obtained excellent yields highlights the yield potential for grain legumes in this environment and indicates that there appears to be ample scope for increasing the productivity of current grain legume-based systems. This could be achieved through the introduction of improved germplasm and agronomic practices. For example, Carsky *et al*. (2003) reported cowpea yield gains of 156% in southern Bénin with a new cowpea line that was resistant to the parasitic weed *Striga gesnerioides*. Also, Carsky (2002) increased soyabean and cowpea yields by applying P and K fertilizer and/or organic matter on the same soils in southern Bénin. Increased grain yields are likely to lead simultaneously to higher residue- and, possibly, nitrogen yields, both of which would contribute to soil fertility improvement. In addition, insect pests and rodents were identified as serious yield-limiting factors and improved plant protection measures might, therefore, have a substantial impact on legume grain and residue productivity.

It was beyond the scope of this study to determine detailed root causes for these low and highly variable grain legume yields in southern Bénin. It can be speculated that factors such as poor soil fertility, high levels of pest and disease pressure, inadequate crop husbandry practices, and lack of resistant germplasm are contributing to this situation. However, given the lack of more quantifiable information and the scope for greatly increasing legume yields by overcoming these biophysical production constraints, more detailed follow-up studies are warranted.

Promoting low-harvest-index grain legumes

Traditional grain legume breeding programmes focused on high grain yields and harvest indices. In recent years, more emphasis has been given to the development of late-maturing, dual-purpose (grain + forage or residue) types of cowpea, groundnut, and soyabean. These combine high total biomass yields with lower harvest indices than those of traditional grain legume varieties and, therefore, are more likely to contribute to soil fertility improvement. For example, Schulz *et al*. (2001) found that the harvest indices for groundnut may range from 0.31 (n = 227) for early maturing grain types which yielded on average 4.7 t ha^{-1} of biomass, to 0.18 (n = 126) for late-maturing, dual-purpose types yielding 7.2 t ha^{-1} of biomass. It has also been shown that late soyabean varieties have lower biomass harvest indices than early varieties (Singh *et al*. 2002) and are more effective in improving soil fertility (Carsky *et al*., 1997).

Also warranted, is more emphasis on screening currently underutilized crop species such as Bambara groundnut (*Voandzeia subterranea*), Kersting's groundnut (*Kerstingiella geocarpa*), lima bean (*Phaseolus lunatus*), and ricebean (*Vigna umbellata*) for their production potential in this environment. That farmers in southern Bénin are already familiar with most of these species should greatly facilitate the introduction and adoption of new, improved cultivars. For example, the use of lima bean is currently restricted to small-scale cultivation because only climbing, vine types are available. These require staking and, therefore, are unsuitable for field-scale cultivation. More-erect, bushy plant types that do not require staking are available, however, and future screening efforts should aim at identifying farmer-acceptable, high yielding cultivars that are adapted to the environment (Rachie and Roberts, 1974).

Current grain legume production systems are highly diverse in terms of species as well as spatial and temporal niches used to grow legume crops. Moreover, farmer preferences for particular grain characteristics and culinary properties vary substantially over locations. For the introduction of new cultivars and species, this variability needs to be taken into account by screening new germplasm not only in terms of biophysical parameters such as yields and N fixation but also with regard to their grain characteristics and culinary qualities for locally preferred traits. On the other hand, this diversity offers numerous opportunities for the introduction of new technologies. Finally, it is encouraging that, apart from market access, no other socioeconomic factors seemed to influence farmers' interest in testing alternative grain legumes. This indicates that the introduction of new crops might benefit farmers in an equitable way.

Reducing L-dopa content in mucuna seed

The principal obstacle for the use of mucuna seed for human and animal consumption rests with the fact that the seed contains L-dopa, a phytochemical that may lead to gastrointestinal disturbances and psychotic reactions. Findings of this survey indicated a substantial adoption potential for mucuna, provided its seed could be consumed or sold. Hence, more emphasis should be given to the development of cultivars with substantially reduced L-dopa content and, the promotion of methods for the detoxification of mucuna seed so as to create a market for its seed and thereby provide an incentive for farmers to extend cultivation of this crop.

Lorenzetti *et al*. (1998) found that L-dopa content varies significantly over different mucuna accessions and that mucuna seeds of plants cultivated within 10° of the equator appear to contain more than does seed of crops grown at higher latitudes. However, preliminary data from a genotype × environment trial (four accessions and four environments) on L-dopa production suggested greater control by genotypic rather than environmental factors (M. Eilittä, personal communication). These observations are encouraging as they imply that there is scope for reducing the L-dopa content in mucuna through breeding. In this context, however, a word of caution is relevant as the removal or reduction of this toxic substance may impair the capacity of mucuna to protect itself against predators and is, therefore, not entirely without risk (Lorenzetti *et al*., 1998). Methods for the detoxification of mucuna seeds and their food preparations have been extensively investigated (Osei-Bonsu *et al*., 1996). Versteeg *et al*. (1998) described a relatively simple procedure developed by researchers in Bénin that decreased the L-dopa content to between 0.32 and 0.42%, well below the 1% threshold level. However, at present there is limited information about the adoption potential for these detoxification methods and further participatory testing would be required before such methods are widely promoted.

CONCLUSION

For the successful introduction and widespread adoption of improved technologies, in particular in the area of natural resource management, more emphasis should be given to farmers' needs for short-term economic returns. The adoption potential of cover crops for soil fertility improvement is limited primarily because they fail to satisfy these needs. Farmers seem to prefer legume crops that produce at least a small quantity of edible and/or marketable grain in addition to improving soil fertility. To a certain extent at least, these two requirements are mutually exclusive and, therefore, 'compromise technologies' need to be identified that satisfy farmers' needs and contribute to soil fertility improvement. Potential 'compromise technologies' are available, for example, in the form of low-harvest-index grain legumes. These need to be further developed and tested, preferably employing farmer participatory methodologies to ensure that farmers' interests are adequately represented.

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