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Characteristics of speargrass (*Imperata cylindrica*) dominated fields in West Africa: crops, soil properties, farmer perceptions and management strategies

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Abstract

Speargrass is a dominant, competitive and difficult weed to control in tropical Asia, Latin America, and some parts of West Africa. In West Africa, no information is available on the cropping systems and soils most affected by speargrass infestation; Farmers' perceptions of speargrass and common management strategies employed by farmers are unknown. Surveys were conducted in 1996 and 1997 in the coastal/derived savanna (Benin and Nigeria) and southern Guinea savanna (Côte d'Ivoire) to characterize farming systems, soils, and farmers' management strategies in fields dominated by speargrass. Twenty-one crops were found in speargrass dominated fields. Speargrass was ranked as the most serious weed in both agroecological zones. Besides speargrass, *Commelina benghalensis* L., *Digitaria nuda* Shumach, *Cyperus rotundus* L., *Tridax procumbens* L., *Rottboellia cochinchinensis* (Lour.) Clayton, *Digitaria horizontalis* Willd, *Striga* spp., and *Euphorbia heterophylla* were also considered as important weeds in major cropping systems. Speargrass was undesirable because it reduces crop yield and quality, limits farm size, causes injury to the skin, increases labour requirement and increases the presence of pathogens and insects of economic crops. Nevertheless, some farmers indicated that speargrass was an important source of cheap roofing material, animal fodder and medicines. Most farmers used labour intensive control strategies to combat speargrass due to, among other reasons, lack of capital. Speargrass occurred in soils with a wide range of chemical properties and particle size distribution.

Keywords: Weed survey; Small-scale-farms; Weed control

1. Introduction

Speargrass [*Imperata cylindrica* (L.) Raueschel] is one of the most dominant, competitive, and difficult weeds to control in the humid and sub-humid tropics of Asia, West Africa, and Latin America (Garrity et al., 1997). In West Africa, it is a serious weed of intensive agriculture particularly in areas prone to recurrent burning in the coastal/derived savanna [also called forest/savanna transition zone] (Chikoye et al., 1999). The negative impact of speargrass on agriculture includes severe crop yield losses and high investment in labor for weeding. Crop yield reduction attributable to competition from speargrass has been estimated at 76–80% in cassava, 78% in yam, and 50% in maize (Koch et al., 1990; Chikoye et al., 2000). Small-scale farmers, who undertake most of the agricultural activities in West Africa, are more affected by speargrass because they rely on manual weeding which consumes lots of labour and which is not effective on underground rhizomes. For example, weeding maize and cowpea fields infested with speargrass twice has been reported to consume about 54% of the total labour budget (IITA, 1977). Akobundu et al. (2000) have however reported that at least four weedings are required to prevent reduction in maize yields due to speargrass interference in the derived savanna of Nigeria.

Speargrass occupies a broad area that stretches from Senegal to Cameroon, and from the coast in the south to the arid Sudan zone in the north (Ivens, 1975, 1980; Garrity et al., 1997). This area is heterogeneous with respect to climate, vegetation, soils, infrastructure, and farmer resource endowment (Manyong et al., 1996). To our knowledge, information on the characteristics of farming systems and soils dominated by speargrass and farmers' ways of combating speargrass in West Africa is

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not properly documented. To design, develop, and implement speargrass management strategies that have a high probability of adoption by the end-users, research programs should be participatory and address priority constraints of the farmers. This study was undertaken (1) to document cropping systems at risk from speargrass invasion, (2) to evaluate the importance of speargrass relative to other major weeds in major crops, (3) to identify constraints imposed by speargrass in major crops of West Africa, and (4) to characterize existing weed management strategies in various cropping systems with a view to identify opportunities for improving speargrass control.

2. Materials and methods

2.1. Study area

The study was conducted from July to September in 1996 and 1997 in the savanna benchmark zones of the Ecoregional Program for the Humid and sub-Humid Tropics of sub-Saharan Africa (IITA, 1996). Benchmark zones are focal points for strategic and adaptive research conducted by the International Institute of Tropical Agriculture (IITA) and its partners (Fig. 1). The main criterion for choosing the study area was the presence of speargrass. The coastal/derived savanna (CDS) benchmark area is located in southern Benin. It is characterized by a growing period of 211–270 days and annual rainfall of > 1300 mm that has a bimodal distribution trend. The first rain season starts late March or beginning of April and ends in August. The second season starts late August or early September and ends mid November. This allows for two cropping seasons in a year. However, there is high risky of crop failure during the second season because of erratic rainfall (Mutsaers, 1991). The Southern Guinea Savanna (SGS) benchmark area is located in northern Côte d' Ivoire. It has a growing period of 181–210 days and annual rainfall between 900 and 1500 mm. The rainfall trend is unimodal and lasts for 5 months (June – October). The study area was expanded to include the CDS and SGS zones of Nigeria because speargrass is not important in the Northern Guinea Savanna (NGS) where the benchmark area is located. In each country, the study was a collaborative activity between IITA and national programs (Agricultural Development Projects in Nigeria, Centre National de Recherche Agronomique (CNRA) in Côte d' Ivoire, and Institut National de Recherche Agronomique du Benin (INRAB) in Benin).

2.2. Data collection

Data was collected through village and household interviews and intensive field sampling. Area sampling procedures were used. Grid cells measuring 10 min × 10 min each were superimposed on maps of the study area and villages located near the center of each cell were selected. A global positioning system (Magellan Pro-Mark X, Magellan Systems Corporation, 960 Overland Court, San Dimas, CA 91773) was used to locate villages closest to the center of each grid cell. Data were collected from 40 villages in each country. In each village two types of interviews were conducted, i.e. village level and farmer interviews. The village interview consisted of adult male and female members of the village and was aimed at getting the general overview of major crops grown and problem weeds. Farmers who indicated that speargrass was a major weed in their fields were assigned numbers from 1 to *n*. Those assigned with odd numbers were selected for more detailed interviews. When the selected farmers were more than three (maximum number of farmers interviewed per village), a final choice of farmers considered differences in crops grown, distance to the field and willingness to be interviewed. A total of 190

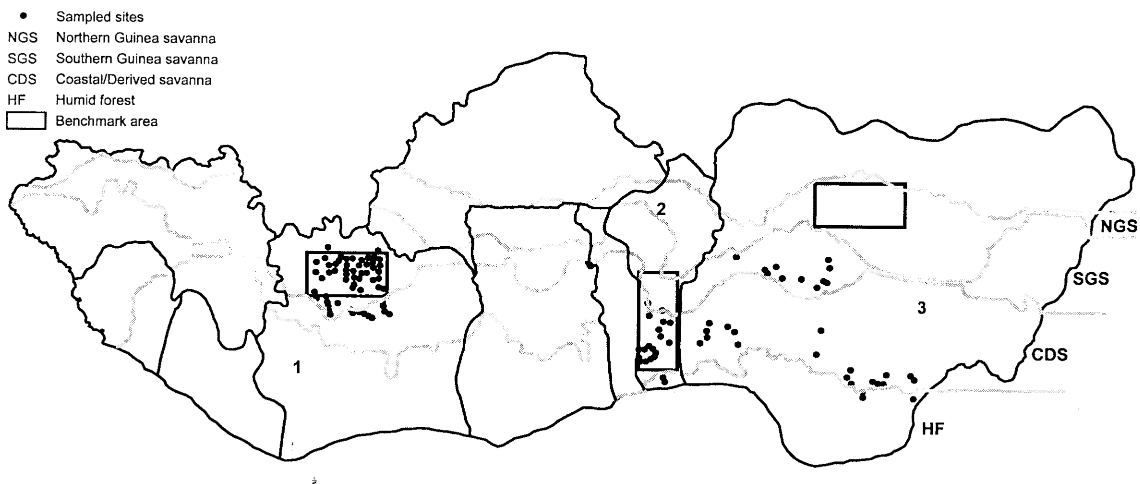

Fig. 1. Map showing areas surveyed in 1. Côte d'Ivoire, 2. Benin, and 3. Nigeria.

Table 1
Soil properties and management factors collected during the survey through farmer interviews and field sampling

Soil properties	Field management factors	Weed management factors
% Organic carbon	Major crops	Major weeds
% Nitrogen	Principal crop mixtures	Methods of weed control
Available phosphorus	Length of fallow	Economic importance of speargrass
Soil pH	Length of cropping phase	Major constraints to better weed control
% Sand	Land preparation methods	Types of herbicides applied
% Silt		Spraying interval and number of times fields sprayed per season
% Clay		Weeding interval and number of times of weeding per season

farmers were interviewed in the SGS while 139 farmers were interviewed in the CDS. Information collected from the farmer interviews is summarised in Table 1. Where possible, farmers were interviewed in the field designated for sampling and respondents were encouraged to give independent answers without the influence of other village members. Farmers were asked to list and rank the most important crops and weeds found in their fields. The most important crops or weeds were assigned a value of five while those considered less important were assigned the rank of one. Weeds were identified by botanical names. When weeds could not be readily identified, they were pressed between newspapers and transported to the IITA herbarium for further identification.

In each field, where management and other information was collected from the farmer, five soil cores (442 cm^3) were collected from two diagonal transects. Soil from each field was bulked and analysed for particle distribution and chemical properties (organic C, N, and available P) at the IITA Analytical Services Laboratory (Table 1).

2.3. Data analysis

The most important crops were ranked using the frequency of occurrence. Frequences were computed according to

$$Fk = \frac{\sum Y_i}{n} \times 100, \qquad (1)$$

where Fk is the frequence of crop k, Y_i is the incidence of crop k, n is the total number of farmers who grew crop k in each zone. A semi-quantitative matrix ranking method (Ashby, 1990) was used to rank weeds, constraints to better weed management, economic importance of speargrass, and speargrass management practises. The number of respondents citing a given factor (e.g. major weed) was multiplied by the corresponding rank. All products for a given factor were summed to give the overall weight for that factor. Overall weights for each factor were then arranged in order of magnitude. The higher the overall weight the more important the given factor was. Mean values for soil chemical properties and particle size distribution were computed in each zone and their differences examined using the standard errors of the mean.

3. Results and discussion

3.1. Major crops and crop mixtures in speargrass infested fields

Twenty-one crops were grown in the study area either in mono or mixed culture, indicating the diversity of crops at risk from speargrass infestation (Table 2). The most important crops in decreasing order of importance were maize, cassava, yam, cowpea, groundnut, cotton, and sorghum. There were ecological differences in the distribution of the crops. Maize, yam, groundnut and cowpea were found at similar frequencies in both zones. The percentages of farmers who responded that they grew cassava in their fields was two times higher in the CDS than in the SGS. Cotton and sorghum were almost exclusively found in the SGS. These results agreed with Manyong et al. (1996) who characterized major crops of the savanna.

Except cotton (83.9% in monoculture) and a few monocultures of maize, cassava, yam, sorghum, groundnut and cowpea (< 30% of fields), the bulk of crops were grown in 67 different combinations involving 2–6 crops. The most frequently occurring crop mixture involved 2–4 crops. Maize, cassava, yam, sorghum, cowpea and groundnuts appeared in 37, 36, 31, 11, 13, and 13 different crop mixtures, respectively. The most common crop combination in the CDS were maize + cassava (69% of the respondents). In the SGS, maize + yam (75%), and sorghum + minor crops (75%) were the most important crop combinations. Cowpea and groundnuts were mainly grown as components of maize, cassava, or yam because they are low growing and not very competitive with the primary crop. Intercropping is popular in resource-poor communities because it, among other reasons, diversifies and stabilizes crop production and

Table 2
Frequency of crops (% of responses) found in speargrass-infested fields in the derived savanna (CDS) and southern Guinea Savanna (SGS) of Côte d'Ivoire, Benin, and Nigeria[a]

Common name of crop	Botanical name of crop	All zones $n = 487$	CDS $n = 227$	SGS $n = 260$
Maize	*Zea mays* L	30.6	30.8	30.4
Cassava	*Manihot esculenta* Krant	20.9	29.1	13.8
Yam	*Dioscorea* spp.	10.3	10.6	10.0
Cowpea	*Vigna ungiculata* (L.) Walp.	8.0	8.8	7.3
Groundnuts	*Arachis hypogea* L.	6.4	5.7	6.9
Cotton	*Gossypium hirsutum* L.	6.4	2.2	10.0
Sorghum	*Sorghum bicolor* L. Moench	5.1	1.3	8.5
Millet	*Eleusine corocana* L	2.3	0.0	4.2
Melon	*Citrullus edulis* L.	2.1	3.1	1.2
Okra	*Hibiscus esculentum* L.	1.8	1.8	1.9
Sweet potato	*Ipomea batatas* (L.) Lam.	1.6	1.3	1.9
Pigeon pea	*Cajanus cajan*	1.4	2.6	0.4
Bambara groundnuts	*Voandzeia subterranea* (L.) Thouars	0.8	0.0	1.5
Pepper	*Capsicum annuum* (L.) Millsp.	0.6	0.0	1.2
Vegetable	*Celosia* and *Amaranthus* spp.	0.4	0.9	0.0
Tomato	*Lycopersicon esculentum* Mill.	0.4	0.4	0.4
Cocoyam	*Colocasia* and *Xanthosoma* spp.	0.2	0.4	0.0
Local beans	*Phaseolus vulgaris* L.	0.2	0.4	0.0
Pineapple	*Ananas comusus* L.	0.2	0.4	0.0
Soybean	*Glycine max* (L.) Merr.	0.2	0.0	0.4
	Total	100.0	100.0	100.0

[a]n = number of responses.

economic returns, distributes farm labour more uniformly and often gives better control of weeds than sole cropping (Midmore, 1993). Intercrops of contrasting phenology maintain complete canopy cover over the ground for a relatively longer time thereby preventing weed seed germination through reduced soil temperature and changes in spectral light quality to non-optimal levels. Full canopy cover also reduces the photosynthetically active radiation reaching weeds under the crop thereby reducing their competitive ability (Benvenuti et al., 1994).

3.2. Farmers' perceptions of important weeds

In both ecological zones, 88 different species were reported to be important weeds of commonly grown crops. Fifty-five per cent of the respondents indicated that speargrass was the most serious weed across ecological zones. Among the frequently cited weeds ranked in order of seriousness besides speargrass, were *Commelina benghalensis* L., *Digitaria nuda* Schumach, *Tridax procumbens* L., and *Cyperus rotundus* L. in the CDS (Table 3). In the SGS, *C. benghalensis*, *Rottboellia cochinchinensis* (Lour.) Clayton, *Digitaria horizontalis* Willd., *Striga* spp., *T. procumbens*, *Euphorbia heterophylla* L., and *C. rotundus* were perceived as the most devastating weeds. Farmers' ranking of dominant weeds corresponded with results from field sampling (Chikoye and Ekeleme, 2000). Most weeds encountered during the survey have been reported as troublesome weeds elsewhere (Weber et al., 1995; Marnotte, 1997). *C. benghalensis* is a major weed in cotton and cereals in the drier savannah of West Africa (Ahanchede, 1994; Ahanchede and Gasquez, 1997). It is difficult to kill because of its succulent stems and its ability to produce above and underground seeds, and propagation through vegetative means favours the persistence of this weed (Ahanchede, 1994). *R. cochinchinensis* is a very competitive weed with crops particularly maize and it has irritating hairs on its stem which makes it difficult to

Table 3
Farmers' perceptions of important weeds (% responses) in coastal/derived savanna (CDS) and southern Guinea savanna (SGS)[a]

Common name	Botanical name	All zones $n = 605$	CDS $n = 212$	SGS $n = 393$
Speargrass	*Imperata cylindrica* (L.) Rauesch.	55.3 (1)	62.1 (1)	51.4 (1)
Tropical spiderwort	*Commelina benghalensis* L.	11.4 (2)	11.8 (2)	11.2 (2)
Coat buttons	*Tridax procumbens* L.	6.0 (4)	6.4 (4)	5.8 (5)
Digitaria	*Digitaria nuda* L.	6.2 (3)	11.4 (3)	3.2 (7)
Itchgrass	*Rottboellia cochinchinensis* (Lour) Clayton	5.1 (5)	—	8.0 (3)
Purple nutsedge	*Cyperus rotundus* L.	4.4 (7)	8.4 (5)	2.0 (8)
Crabgrass	*Digitaria horizontalis* L.	4.6 (6)		7.3 (4)
Witchweed	*Striga* spp.	3.9 (8)	—	6.1 (5)
Wild poinsettia	*Euphorbia heterophylla* L.	3.2 (9)	—	5.0 (6)
	Total	100.0	100.0	100.0

[a]n = number of responses; numbers in the parentheses indicate overall ranking by farmers where 1 represents the most important weed and 8 the least important. (—) not important according to farmers.

control manually in small-scale farms. It is also tolerant to most herbicides that are applied in cotton and maize fields in the SGS (Martin and Gaudard, 1997). *C. rotundus* is ranked the world's worst weed (Holm et al., 1977). It is difficult to kill by manual weeding because of its underground rhizomes and tubers (Marnotte, 1997). *Striga* spp. are very serious parasites of cereals and legumes in Africa. For example, *S. hermonthica* (Del.) Benth infests millions ha of arable land in Africa and may cause yield losses of 70–100% in cereals and legumes (Kim and Lagoke, 1999). *E. heterophylla* is a very competitive weed in soybean and cowpea in West Africa (Akobundu and Agyakwa, 1998) and difficult to control because it breaks off at ground level when pulled and produces new shoots which may require additional weeding (IITA, 1995).

3.3. Economic importance of speargrass

Averaged over ecological zones, the presence of speargrass was undesirable because farmers felt, in decreasing order of importance, that it reduces crop yield, limits field size to that family labour can handle, increases labour requirements for weeding, causes physical injury to the skin, reduces quality of tuber crops, increases the occurrence of bush fires in perennial crops, and increases the incidence of insects and pathogens of economic crops (Table 4). The negative effects of speargrass were given different rating depending on the zone. For example, in the CDS reduced crop yield, physical injury to skin, reduced farm size and increased labour demand were considered more important (in decreasing order of importance). In the SGS, the ranking was in the following order of decreasing of importance: reduced farm size, reduced crop yield, increased labour requirement, physical injury and reduced crop quality. Nevertheless, some farmers indicated that speargrass is an important source of cheap roofing material (51% of respondents), animal feed (22%), source of medicines (13%) and protected the soil from erosion (8%).

3.4. Existing weed management practices

Farmers use a wide variety of labor-intensive practices to combat speargrass (Table 5). Labor-intensive practices (such as hoe-weeding, remounding and slashing) and abandoning land to fallow were the most common control practices cited by farmers in both ecological zones. Sixty per cent of the respondents indicated that hoe-weeding had to be repeated 2–4 times per season at an interval of 1–3 weeks. Remounding is a form of weeding that is combined with rebuilding mounds or ridges initially made during seedbed preparation. The soil that accumulates in the furrow after initial land preparation is scraped and placed back on the mounds or ridges thereby burying all weeds growing on the mound or ridge.

Table 4
Farmers' perception of the economic importance of speargrass in coastal/derived savanna (CDS) and southern guinea savanna (SGS) (% of responses)[a]

Constraints	All zones $n = 1278$	CDS $n = 456$	SGS $n = 822$
Reduces crop yield	23.0 (1)	26.3 (1)	21.1 (2)
Limits farm size	20.9 (2)	16.2 (4)	23.6 (1)
Causes physical injury (skin)	16.6 (3)	17.6 (2)	16.1 (4)
Requires more labour	17.0 (4)	13.6 (5)	18.9 (3)
Reduces crop quality	10.1 (5)	11.8 (3)	10.3 (5)
Increases fire harzard	7.7 (6)	9.7 (6)	6.5 (6)
Harbours pests/diseases	4.0 (7)	4.9 (7)	3.5 (7)
Total	100.0	100.0	100.0

[a] n = the number of responses; numbers in the parentheses indicate overall ranking by farmers where 1 represents the most important constraint and 7 the least important.

Table 5
Existing weed management practices in the derived/coastal savanna (CDS) and southern Guinea savanna (SGS) (% of responses)[a]

Method	All zones $n = 701$	CDS $n = 224$	SGS $n = 477$
Remounding	23.8 (2)	18.8 (3)	26.1 (2)
Hoe-weeding	34.4 (1)	33.1 (1)	35.0 (1)
Fallowing	8.5 (4)	10.8 (5)	7.8 (4)
Burning	8.3 (5)	11.8 (4)	6.8 (5)
Slashing	7.9 (6)	19.6 (2)	2.6 (6)
Herbicides	2.3 (7)	3.0 (7)	2.0 (7)
Grazing	14.8 (3)	3.7 (6)	19.8 (3)
Total	100.0	100.0	100.0

[a] n = number of respondents; numbers in the parentheses indicate overall ranking by farmers where 1 represents the most important weed management practice and 7 the least important.

Remounding is performed during the second or third weeding operation. In SGS, rebuilding of ridges and weeding is carried out using oxen-drawn equipment. Of the farmers who abandoned land infested with speargrass, majority of them (> 45%) said that they used natural bush fallow while 12.7% indicated that they used improved fallow (e.g. *Mucuna* spp.). Farmers said that average fallow length was less than 3 years in the CDS (44% of respondents) and 3–5 years in the SGS (45.4%). Across ecological zones, 8.3% of the responding farmers used fire to clear fields although they knew it did not control speargrass effectively. According to farmers, burning is cheaper than other methods of clearing fields. Very few farmers (2.3%) used herbicides for speargrass control because of the high cost of herbicides, lack of awareness, inability to operate sprayers, lack of capital and non-availability of effective herbicides. All farmers

who used herbicides, only used glyphosate or paraquat for speargrass control in all areas visited. Both those herbicides are non-selective and result in total vegetation control. Glyphosate is more effective against speargrass because it translocates to the underground rhizomes. Paraquat is a contact herbicide that primarily injures the shoots and has no effect on the rhizomes of speargrass. Shoot growth may occur within 35 days after application (Anon., 1995). In SGS, particularly in the cotton growing areas in Côte d'Ivoire, farmers used other herbicides (e.g. mixture of dipropetryn + metolachlor [Cotodon®], a mixture of atrazine + metolachlor [Primagram®], pendimethelin, propanil, and atrazine) for general weed control in cotton, maize and rice fields. Acquisition of chemicals was organized through informal and formal farmer-run cooperatives. The main reasons farmers used herbicides were that they were labor saving and were much more efficient than hand weeding.

The study found that farmers did not depend on any single practice but combined various practices in an integrated manner to get more effective suppression of speargrass. For example, use of fallow was combined with burning or slashing and herbicides or hoe-weeding. In addition to direct weed management using methods listed in Table 5, farmers used a variety of seed preparation practices that contribute to reducing the problem of speargrass. The most important land preparation methods were variants of tillage using the hoe or oxen-drawn implements, e.g., moldboard plow and ridgers (15.5% of farmers). Thirty-two per cent of the interviewed farmers slashed or used fire to remove excess vegetation before hoe-tillage. Tillage affects speargrass in may ways: (1) fragmentation of the rhizomes into small pieces stimulates shoot sprouting which can later be controlled using herbicides or hoe-weeding, (2) tillage can be used to drag rhizomes to the soil surface where they can be desiccated by the sun (Ivens, 1975) or (3) tillage can bury rhizomes to depth (>30 cm) that prevent or delays sprouting of shoots.

Most farmers indicated that they could not develop sustainable management strategies for speargrass because they lacked capital (62.9% of the respondents). Other reasons were lack of better management options (13.8%), lack of adequate labour (8.3%), lack of equipment (6.6%), health problems (6.6%), and non-availability of herbicides (2.2%). This study highlights the need to develop low-cost technology for speargrass control since most farmers indicated that they do not have adequate resources.

3.5. Soil properties and particle size distribution

Speargrass was found on soils with different fertility status (Table 6). For example, soils collected from the SGS had higher % C and % total N than soils from the CDS ($P \leqslant 0.03$). Available P and pH were similar in both agroecological zone ($P > 0.10$). Percent sand was higher in soils from the CDS than those from the SGS while % silt and % clay followed the opposite trend. These results agree with previous research that has shown that speargrass occurs on soils with a wide range of soil properties (Garrity et al., 1997; Santoso et al., 1997; Chikoye et al., 1999). In soils with inherent low soil fertility such as those encountered in this study, poor crop growth facilitates the growth and dominance of speargrass (Santoso et al., 1997).

Table 6
Mean values for soil chemical properties and particle size distribution from speargrass infested fields in CDS and SGS[a]

Variables	CDS (n = 139)	SGS (n = 190)	$P < F$
Chemical properties			
% Organic C	0.77	1.06	0.0001
% N	0.07	0.08	0.0325
Bray-1 P (mg/kg)	8.07	9.44	0.3394
pH	6.41	6.29	0.1424
Particle size distribution			
% Sand	78.29	70.35	0.0001
% Silt	13.11	16.26	0.0066
% Clay	8.59	12.85	0.0001

[a] n = number of fields sampled.

4. Conclusion

Speargrass was found in broad range of crops and soils under different management practices. Adaptation to contrasting environments is one of the survival mechanism for speargrass (Townson, 1991). Farmers considered speargrass as their most serious weed. Given that farmers indicated that they lack resources to effectively manage speargrass, development of improved technology which do not demand high monetary investment should be a priority. The use of cover crops for weed control and other benefits may be one such technology that can be promoted for adoption by resource poor farmers as it demands little use of external inputs. This technology is already popular in certain areas of west Africa (Versteeg et al., 1998) and needs to be tested in other areas where speargrass is a serious problem. Other areas of improvement would be the timing of tillage operation to coincide with the onset of the dry season. This would expose speargrass rhizomes to sunlight. In the SGS, where draught power is available repeated tillage at 2 week intervals would be recommended. In cotton growing areas, where chemical control is popular, there is need to improve farmers awareness in the choice of herbicides that control speargrass.

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