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Improving local technologies to manage speargrass (*Imperata cylindrica*) in southern Benin

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Improving local technologies to manage speargrass (*Imperata cylindrica*) in southern Benin

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Abstract

Speargrass (*Imperata cylindrica*) is difficult to control in the tropics. Farmers allocate most of their time and labour to weeding speargrass. We investigated in a joint experiment concluded with farmers, how effectively grain legumes suppress speargrass, and the relationships between speargrass suppression, legume grain yield, and subsequent maize yield. Without management, speargrass shoots and rhizomes increased with 31 and 17% per month, respectively. The integration of deep ridging, deep hoe weeding and shading suppressed speargrass more effectively than farmers' practices. Creeping varieties of cowpea that produced most biomass were most successful in suppressing speargrass and in enhancing subsequent maize yields, but erect cowpea cultivars produced more grain. Farmers traded off cowpea yield against speargrass suppression to bridge the hungry gap. They preferred the erect cowpea cultivar *wan*. The need to forego a harvest and the fact that pigeonpea is not consumed in the area makes pigeonpea presently unsuitable for integration into the cropping system.

Keywords: Speargrass, grain legumes, permanent cropping, labour, participatory approaches, integrated crop management, co-research

1. Introduction

In shifting cultivation, the need for fallowing is often more a function of weed–crop competition and the amount of labour required to maintain crop yields, than of declining soil fertility. Nye and Greenland (1960) hypothesised that a plot will be fallowed when the labour required to control weeds exceeds the labour needed to clear a new site. Thus, it is the decreasing land/labour ratio that drives the shift towards continuous cropping, and even while continuous cropping without nutrient addition depletes the soil, the short-term effect is still beneficial.

In southern Benin, where more than 60% of the nation's population lives, a drastic shortening of fallow periods resulted in a strong pressure on land. Consequently soils are degrading, and novel weed species, including the pioneer species speargrass (*Imperata cylindrica* (L.) Raeuschel), invade (Vissoh et al. 2007). Speargrass is a perennial rhizomatous grass weed found on all continents in the tropics and parts of the sub-tropics. It is a particular problem in high rainfall areas of South-East Asia and West Africa (Holm et al. 1977; Akobundu 1987; Akobundu and Agyakwa 1987). In West Africa, speargrass is a major

production constraint in plantations of oil palm, coconut, and rubber; and in food crops such as cereals and root and tuber crops (Vissoh et al. 1998). Speargrass has a low nutrient demand, thriving on both infertile and fertile soils (Garrity et al. 1997). It is also an effective competitor for light, nutrients, and water due to its extensive root system. Moreover, it has allelopathic effects on crops such as maize (*Zea mays* L.), and interferes through physical penetration of roots and below-ground tissues of crops resulting in damage and subsequent rotting (Akobundu and Ekeleme 2000; Van Rijn 2000; MacDonald 2004; Lum et al. 2005). Once established, speargrass can survive almost indefinitely with frequent burning, with the species increasing the risk of fire.

Speargrass control is primarily a problem of labour. Hoeing takes 90–100 workdays ha⁻¹, while digging out speargrass rhizomes requires 175 workdays ha⁻¹ (Chikoye et al. 2000; Vissoh et al. 2004). Because of its rhizome-forming habit, speargrass cannot easily be eliminated by hand cultivation. Farmers are therefore forced to weed frequently. However, increasing labour expenditure for speargrass control is not particularly effective, given speargrass' propensity for rapid re-growth.

Uncontrolled or poorly controlled speargrass can result in severe crop yield losses. Complete crop failure usually occurs when crops are grown in slashed plots without additional weeding (Chikoye 2003). In developing countries, legume cover crops and tree-based farming systems, and to a lesser extent herbicides, have been tested to reduce speargrass density (Van Noordwijk et al. 1997; Akobundu et al. 2000; Chikoye et al. 2001; MacDonald 2004). Despite the effectiveness of green manure cover crops, small-scale farmers experience a number of disadvantages (Deffo et al. 2004; Vissoh et al. 2004). The adoption of herbicides is generally low (Chikoye et al. 1999, 2000; Vissoh et al. 2004). However, legumes that produce edible grains, while providing a dense canopy that suppresses speargrass, can be attractive to the majority of farmers and beneficial in terms of soil fertility improvement. Grain legumes that provide food and cash to farmers have a long history in West Africa (Schulz et al. 2003). In southern Benin, cowpea (*Vigna unguiculata* (L.) Walp.) is traditionally the main leguminous food crop for home consumption and cash.

The objective of this study was to help identify land use systems that increase crop yields through the development of speargrass management strategies that are acceptable, feasible and work under farmers' conditions. More specifically, the study attempted to: (1) identify farmers' strategies to control speargrass, (2) assess the agronomic effectiveness of some grain legumes to suppress speargrass, produce acceptable grain yields and yields of subsequent crops, and improve soil fertility for permanent land use, (3) assess economic benefits of the improved technology compared to the traditional practice, and (4) determine farmers' perceptions about the feasibility and acceptability of these management strategies.

2. Materials and methods

2.1. Study area

A survey and experiments were conducted at Dame-Wogon (District of Bonou; 6°34' N, 2°27'E), a village in southern Benin about 70 km northwest of Porto-Novo. The rainfall pattern is bimodal and has an annual range from 1000 to 1400 mm. The soil is sandy loam on the plateau and clayey in the bottom of the valley. Soils on the plateau are ferralitic and have the following chemical properties: pH (H₂O) (5.4), total C (7 g kg⁻¹), total N (0.3 g kg⁻¹), P-Olsen (2.3 mg kg⁻¹), P-total (178 mg kg⁻¹), CEC (26 mmol kg⁻¹), base saturation (14%) (Glitho 2001). In a diagnostic study in the area (Vissoh et al. 2004), farmers ranked soil fertility and weeds as major constraints upon agricultural production. Before the study, the site was abandoned for more than 5 years due to severe speargrass infestation.

2.2. Survey

A survey was conducted to identify the various speargrass management strategies. A questionnaire was administered to 50 farmers randomly selected in Damè-Wogon. Both male and female respondents were selected. Fields were visited for observation and to cross-check quantitative and qualitative data collected during the survey.

2.3. Experimental design

An experiment was designed in 2004 during the major rainy season with a group of farmers in a randomised block design with four replications. Nine treatments were tested, including a control without speargrass management, farmers' traditional management, and seven legume cultivars under improved speargrass management. Farmers' traditional management consisted of superficial ridging (about 10–15 cm), sowing of cowpea (cultivar *wan*) and superficial hoe-weeding. The improved practice consisted of deep ridging and deep hoe-weeding (about 20–40 cm) after determining the depth of the rhizomes, and sowing of grain legumes at sufficiently high density to shade speargrass. Crops comprised five cowpea cultivars including three erect, early-maturing, and two creeping, late-maturing cultivars, and two pigeonpea (*Cajanus cajan* L.) cultivars (early- and late-maturing).

Each elementary plot measured 5 × 5.5 m. Erect cowpea cultivars were sown at a spacing of 0.8 × 0.4 m, creeping cultivars at 0.8 × 0.5 m. Spacing of early-maturing pigeonpea was 0.8 × 0.4 m, of late-maturing pigeonpea 0.8 × 0.8 m. After thinning, two plants per hill were left for all grain legumes. Cowpea grains were harvested and the leaf biomass was incorporated into the soil. Maize (DMR-ESRW) was sown at a spacing of 0.8 × 0.4 m during the minor rainy season in a split plot design with four replications. Half of each plot received a fertiliser application at the rate of 100 kg ha⁻¹ NPK (14, 23 and 14 kg of N, P and K, respectively) 15 days after sowing, and 50 kg ha⁻¹ urea dosing 46% (23 kg N) at tasselling.

Maize was also sown in 2005 during the major rainy season. All plots except the control were ridged and sown with maize with two seeds per hill in a split plot design. Plots with late-maturing pigeonpea could not be cropped with maize during the second rainy season. In order to compare pigeonpea varieties, plots with the early-maturing cultivar were not cropped with maize as well. Fertilisers were applied to one half of each plot similarly to 2004. During the minor rainy season, the same legumes were planted on the same plots for two major reasons: (1) continuation of speargrass suppression to prevent rapid re-infestation by remaining viable rhizome fragments, (2) improving soil organic matter and nitrogen content to allow a permanent land use system.

2.4. Data collection

The number of speargrass shoots was determined four times (before the set up of the experiment, before deep weeding, at cowpea harvest, and at maize harvest) from two subplots measuring 0.25 m² each per elementary plot. These subplots were dug out three times (before ridging, at cowpea harvest, and at maize harvest) and rhizomes collected. Rhizome dry weight was determined after oven drying at 70°C for 48 h. Because initial speargrass density differed somewhat between plots (the control plots had a significantly lower number of shoots compared to other treatments at the start of the experiment), changes in shoot number and rhizome biomass are reported.

In 2004, at legumes harvest leaf dry weight was assessed from two subplots of 0.25 m² after oven drying at 70°C for 48 h. Legume pods were harvested for yield determination from two subplots of each plot measuring 6 m² leaving out plants on the borders. Legume grains were dried and adjusted to moisture content of 14%. Maize cobs were harvested in December from the two central rows measuring 7.4 m² of each subplot for yield determination. Maize grain yield was adjusted to moisture content of 12%.

Individual farmers who participated in the experiment were asked to rank the different grain legumes based on their general performance.

2.5. Partial economic budgets

Costs and benefits for all treatments were determined using partial budgets (Alimi and Man-yong 2000). Only the variable costs, i.e. costs that varied among technologies, were considered. These variable costs were subtracted from the gross benefits to obtain net benefits. The marginal costs and the marginal net benefits were calculated to finally determine the marginal rate of return of the improved speargrass management practices compared to farmers' traditional practices. The marginal rate of return was determined for *wan* and late-maturing pigeonpea. The partial budget was determined over three growing seasons (including one season with legumes and two seasons with maize).

2.6. Data analysis

Analysis of variance (ANOVA) was carried out on the agronomic data using Statistical Analysis Systems (SAS 1999). Means were compared using the Student–Newman–Keuls (SNK) test. Change of speargrass shoots and rhizomes were calculated as fractional decrease/increase per month. Correlations were calculated between cowpea biomass, cowpea grain, speargrass suppression (shoots and rhizomes), and the yield of a subsequent maize crop.

A logarithmic transformation [$\log(x+1)$], where x is the number of shoots or rhizome dry weight, was undertaken to ensure normal distribution and homogeneity of variances.

3. Results and discussion

3.1. Speargrass management strategies used by farmers and improved practices

Almost all farmers (94%) applied some strategies for speargrass management. These strategies are integrated control options rather than a single practice. Their strategy comprises slashing, burning, ridging, and rotating cowpea with maize. A guide for improved management of speargrass at farm level was jointly developed with participating farmers (Figure 1). This new set of practices includes deep ridging taking into account depth where rhizomes are found; sowing of cowpea or pigeonpea cultivars at higher density to shade speargrass shoots; deep hoe-weeding; hand pulling whenever necessary; treatment of cowpea to prevent damage by defoliating insects; and deep ridging by incorporating cowpea residues into the soil. Farmers' evaluation of improved management showed that the effectiveness of this scheme depends on the time during which speargrass is shaded. Therefore, the set of practices should be repeated the following year, if speargrass is not sufficiently suppressed. The bottleneck, which may constrain adoption of these integrated practices, is labour shortage. The integrated practice is three times as labour demanding as farmers' practices. Farmers stated that despite labourers receiving a great deal of money, as well as food and drink, deep ridging was not properly done unless the farmer involved himself to set a good example. Women reported they were cheated by labourers who did not ridge and hoe weed as deeply as expected.

3.2. Speargrass dynamics

Monthly rates of change in shoot number and rhizome dry weight are presented in Table I. Changes in shoot numbers and rhizome biomass were very significantly correlated ($r=0.96$, $n=9$; $P < 0.001$). Without management, speargrass shoots and rhizome biomass increased with 31 and 17% per month, respectively. All management practices led to a decline in speargrass shoots and roots. Farmers' traditional practice was least effective. The improved practices were significantly better than farmers' practices for all cowpea cultivars (except rhizome biomass with *azobahundé*) and for late-maturing pigeonpea.

Late-maturing pigeonpea was the best speargrass suppressor of all legumes. With cowpea cultivars, late-maturing, creeping varieties suppressed speargrass better than early-maturing, erect varieties,

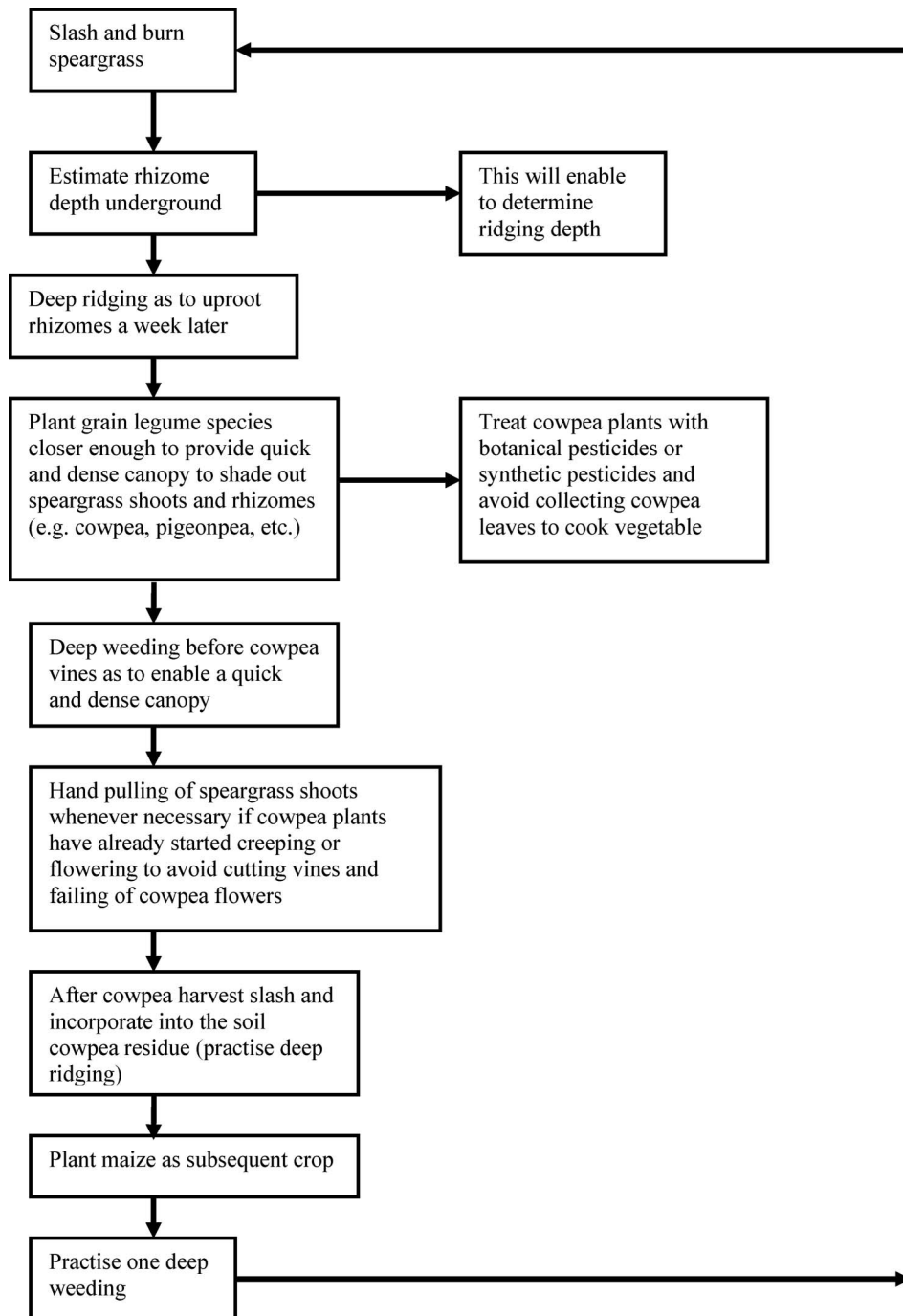


Figure 1. Guide of speargrass management for permanent land use.

especially with regard to rhizome biomass. The main difference between erect and creeping growth forms is the rate at which the soil is covered and shaded. The effectiveness of shading to suppress speargrass is well documented (Chikoye et al. 2002, 2005; Chikoye and Ekeleme 2003; Ekeleme et al. 2003; MacDonald 2004). The local variety *wan* was equally effective as the other erect varieties in reducing speargrass shoots, but significantly outperformed the other erect varieties in reducing rhizome biomass. Speargrass suppression with early-maturing pigeonpea was not significantly different from farmers' practice.

3.3. Cowpea biomass production and grain yield

Farmers judge grain legumes not only because of their suppressive effect on speargrass. Direct effects (legume grain yield) and carry-over effects on a subsequent cereal crop (due to soil fertility improvement) need to be assessed together with speargrass suppression. Those direct yield effects make grain legumes different from green manure cover crops like *Mucuna*, which have been rejected by small-scale farmers because they do not provide a direct return on their investment (Vissoh et al. 1998).

A comparison of the five cowpea cultivars under improved management showed that cowpea cultivars producing most leafy biomass were most effective in suppressing speargrass rhizomes (Figure 2). The relationship was highly significant ($r = -0.78$, $n = 20$, $P < 0.001$). The relationship between cowpea leafy biomass and suppression of speargrass shoots was marginally significant ($0.05 < P < 0.1$), suggesting that shading affect rhizomes more than shoots.

Biomass of the various cowpea cultivars was significantly negatively correlated with cowpea grain yield ($r = -0.66$, $n = 20$, $P < 0.01$; Figure 3). This negative correlation fits with the general pattern, illustrated by Vanlauwe and Giller (2006), that legumes with a high harvest index (high grain yield) make more limited contributions to soil fertility. Because cowpea leaf biomass correlated positively with speargrass suppression, cowpea grain yield correlated negatively with speargrass suppression and soil fertility enhancement. Farmers in

Table I. Monthly rate of change of speargrass shoots and rhizome dry matter in 2004.

Treatments	Change in shoot number per month (%)	Change in rhizome dry weight per month (%)
Control	31 ± 2 a	17 ± 3 a
Farmers' practice	-11 ± 1 b	-12 ± 1 b
Wan	-27 ± 3 c	-27 ± 2 d
Assissihunkpo	-26 ± 3 c	-23 ± 1 c
Azobahunde	-27 ± 1 c	-17 ± 1 b
Atakpra	-34 ± 3 d	-32 ± 2 d
Délékinwa	-30 ± 2 c	-32 ± 3 d
LM <i>C. cajan</i>	-36 ± 3 d	-40 ± 4 e
EM <i>C. cajan</i>	-12 ± 1 b	-14 ± 1 b
Probability	0.0001	0.0001

Means followed by a common letter in the same column are not significantly different ($P > 0.05$) using the Student-Newman-Keuls test.

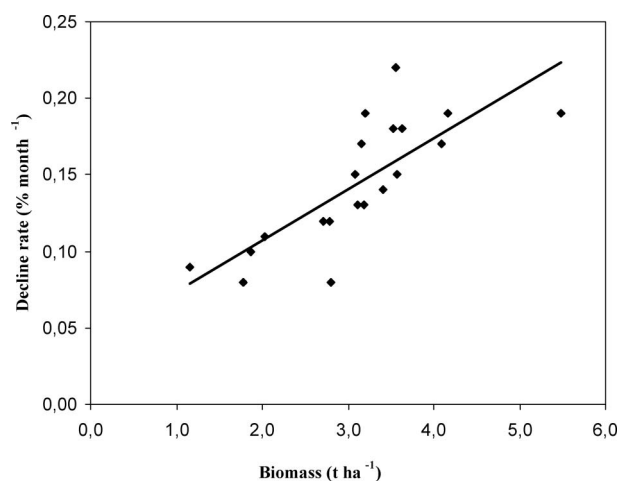


Figure 2. Relation between cowpea biomass and monthly decline rate of rhizome dry weight.

Damè-Wogon therefore have to trade off cowpea grain yield with speargrass suppression. The need to overcome the hungry period, when food reserves run low, compels farmers to choose early-maturing cowpea varieties, which are less effective in suppressing speargrass. The use of late-maturing cowpea cultivars is too risky; if sown early, the cultivars may perish because of drought spells, but if sown late, farmers may be prevented from cultivating maize, a staple food crop during the second rainy season.

3.4. Maize yield

Maize yield in 2004 and 2005 was significantly affected by cowpea cultivar. Higher maize yields occurred in plots where creeping cultivars were sown and their residues incorporated. In these plots there was also less emergence of speargrass (Table II). *Wan* outperformed the other erect cowpea cultivars, both in enhancing maize yield and in suppressing speargrass.

In subsistence agriculture, small-scale farmers hardly use chemical fertilisers because they lack resources or they do not have easy access to fertiliser, unless they are cotton growers. We assessed whether fertiliser use would be profitable under conditions of more effective speargrass suppression. There was no significant interaction between cowpea cultivar and fertiliser treatment. Without fertiliser maize yields ranged from 0.9 to 1.7 t ha⁻¹ in 2004, and from 1.0 to 1.8 t ha⁻¹ in 2005, and with fertiliser from 1.4 to 2.3 t ha⁻¹ in 2004, and from 1.5 to 2.4 t ha⁻¹ in 2005. Fertiliser use on average increased maize yields by 0.5 t ha⁻¹ in 2004 and 0.6 t ha⁻¹ in 2005. The fertiliser effect (Table II) indicates that it could be advantageous to apply fertiliser in combination with improved speargrass management practices.

There was a significantly positive correlation ($r = 0.79$, $n = 20$, $P < 0.001$) between grain legume

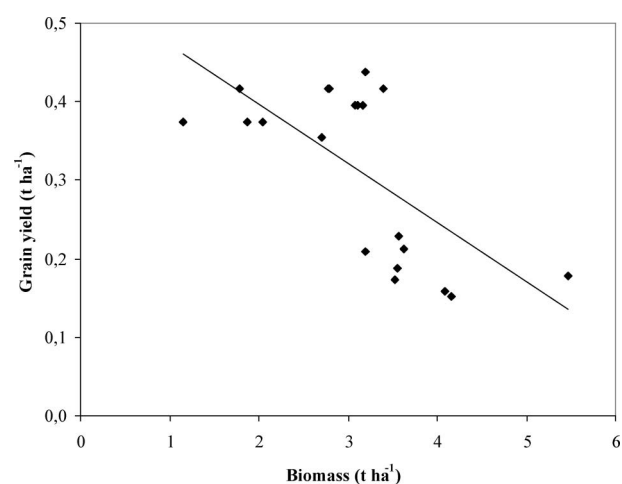


Figure 3. Relation between cowpea biomass and cowpea yield.

Table II. Response of maize (t ha^{-1} ; average of unfertilised and fertilised treatment) to grain legume residue and fertiliser application, and shoot abundance (numbers) and rhizome dry weight (g m^{-2}) of speargrass.

Treatment	N	Degree of freedom	Maize grain yield years		Number of shoots	Rhizome dry weight
			2004	2005		
Wan	8		1.56 ± 0.13 c	1.76 ± 0.15 b	3.79 ± 0.32 c	6.44 ± 1.12 c
Assissihunkpo	8		1.31 ± 0.12 d	1.46 ± 0.10 c	4.56 ± 0.24 b	12.15 ± 2.16 b
Azobahundé	8		1.13 ± 0.10 e	1.25 ± 0.11 d	5.59 ± 0.20 a	21.54 ± 2.61 a
Atakpra	8		1.98 ± 0.12 a	2.12 ± 0.12 a	2.63 ± 0.23 d	4.24 ± 0.68 c
Délékinwa	8		1.77 ± 0.10 b	1.87 ± 0.16 b	2.63 ± 0.23 d	3.77 ± 0.59 c
Probability			0.0001***	0.0001***	0.0001***	0.0001***
F value						
Variety		4	36.88***	27.04***	28.43***	28.83***
Fertiliser		1	113.94***	109.22***	8.61**	0.50 n.s
Variety \times fertiliser		4	0.62 n.s	0.81 n.s	0.29 n.s	0.01

Values that are followed by a different letter in a column indicate significant differences between treatment at $P < 0.05$ with Student–Newman–Keuls test. Significance of ANOVA: n.s., not significant; ** $0.001 < P < 0.01$; *** $P < 0.001$.

biomass and maize yield. Because legume biomass was negatively correlated with legume grain yield, maize yield was also negatively correlated with cowpea grain yield ($r = -0.78$, $n = 20$, $P < 0.001$) (Figure 4). Again, farmers have to trade off cowpea grain yield with speargrass suppression and soil fertility enhancement. The same trends were also observed when fertilisers were applied to maize.

3.5. Farmers' perceptions and preferences for the different legume cultivars

Results of the ranking by farmers are given in Table III. Farmers' ranking is not only determined by the effects that the various cultivars have on speargrass suppression, legume grain yield, and yield of subsequent maize crops (properties that have already to be traded off), but also by socio-economic factors (market prices, food quality, labour). Farmers ranked the erect cultivar *wan* as the most preferred cultivar. This result supports the suggestion by Giller (2001) that soil fertility benefits of legumes are better regarded as additional benefits than as primary criterion for legume selection. Should *wan* be not available, farmers prefer creeping, late-maturing cultivars (which are more effective in increasing maize yields and suppressing speargrass) over the other erect, early-maturing cultivars.

Wan is widespread in the study area while *atakpra* and *délékinwa* are alien to the study area, even though they are cultivated in the surroundings. Furthermore, *wan* is a short duration crop (80 days), which fits in the prevailing cropping system while the other varieties are long-duration (100–115 days). Cowpea varieties with shorter maturation times (60–75 days) such as *assissihunkpo* and *azobahundé* are not only rather ineffective in suppressing speargrass, but also their market prices are not attractive to farmers compared to that of *wan*. They are not easy to sell because they are not tasty and more susceptible to insect pests.

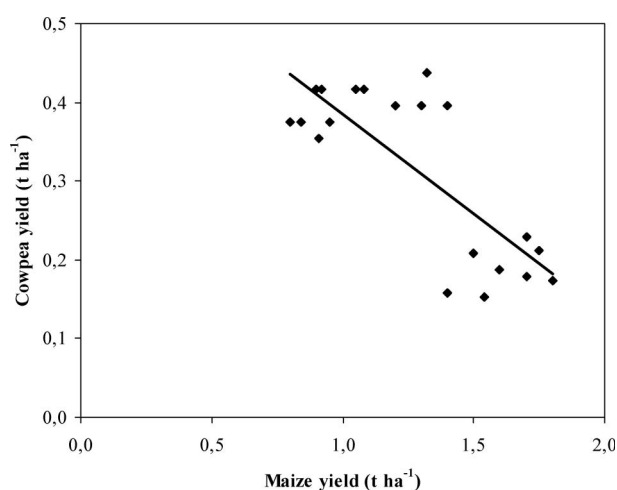


Figure 4. Relation between maize and cowpea yields.

All farmers, except one, preferred late-maturing pigeonpea (about 10 months) over the early-maturing variety (3 months). The single farmer who preferred early-maturing pigeonpea owned a plot in the bottom valley of the Ouème River. For him the need to harvest it before the flooding period, which occurs every year around August, is paramount. Farmers preferred cowpea to pigeonpea for several reasons. First of all, late-maturing pigeonpea does not fit into the cropping system where land is a limiting factor. Second, apart from sparse use of pigeonpea as a medicinal plant, this crop is not cultivated in the area. It is not even sold in the market. Having tasted pigeonpea meals (both cultivars), which participating women cooked, 90% of the farmers stated that it was not tasty; more than 50% complained about stomach ache, while the women who cooked the meal reported that it consumed too much time and firewood, scarce items in this environment. Finally, farmers reported that pigeonpea is not used for ritual ceremonies (see also Hinvi et al. 1991).

3.6. Economic analysis of speargrass management

The improved speargrass management strategy is a laborious activity, three times as costly as farmers' practice. Marginal benefits of improved practices with cowpea (*wan*) and late-maturing pigeonpea were compared to farmers' practices with *wan* (Table IV).

Provided that a farmer possesses the required financial resources, the budget assumes that labour and fertiliser can be acquired for these prices. While this assumption is true for labour (at least in a formal sense—labourers do not always perform according to what is expected from them), it is usually not the case for fertiliser (see above). Furthermore, labour and

Table III. Farmers' perception on the acceptability and farmer' use of different legume cultivars, 17 farmers were interviewed.

Legume	Ranking	Farmers' perceptions
<i>Cowpea variety</i>		
Wan	1	Impressive biomass, complete canopy, good yield, early maturing, improves soil fertility, increases maize yield, attractive market price, fast to cook and sell, tasty
Atakpra	2	Late maturing, complete canopy, impressive biomass, good yield, improves soil fertility, increases maize, no outlet, lack of seeds
Délékinwa	3	Late maturing, complete canopy, impressive biomass, good yield, improves soil fertility, increases maize, no outlet, lack of seeds
Assissihunkpo	4	Poor biomass, good yield, incomplete canopy, low market price not fast to sell
Azobahundé	5	Early maturing, no good yield, incomplete canopy, susceptible to insect pest (storage), low market price, not fast to sell
<i>Pigeonpea variety</i>		
Late-maturing pigeonpea	1	Controls speargrass in one year, improves soil fertility and increases maize yield, not susceptible to insect pests, long duration crop, not appropriate to small-scale farmers, lack of seeds, lack of market, not tasty, takes time to be cooked, not used for ritual ceremonies
Early-maturing pigeonpea	2	Short duration, poor biomass, not effective in controlling speargrass, not tasty, takes time to be cooked, not used for ritual ceremonies, lack of seeds, lack of market

Table IV. Partial budget for cowpea and maize production of different speargrass control methods (farmers' and improved methods).

	Speargrass control method		
	Farmers' practice Cowpea variety <i>wan</i>	Improved control method	
		Cowpea variety <i>wan</i>	LM Pigeonpea
<i>Gross product</i>			
1. Mean cowpea yield in 2004 (kg ha ⁻¹)	248	401	–
2. Mean maize yield in 2004 (kg ha ⁻¹)	940	1880	–
3. Mean maize yield in 2005 (kg ha ⁻¹)	1035	2127	2860
4. Cowpea selling price (FCFA kg ⁻¹)	350	350	–
5. Maize selling price (FCFA kg ⁻¹)	500	500	500
6. Mean pigeonpea yield (kg ha ⁻¹)			330
7. Pigeonpea selling price (FCFA kg ⁻¹)			350
8. Gross product (FCFA ha ⁻¹) for 2 years	=1 × 4 + (2 + 3) × 5 1,074,300	1 × 4 + (2 + 3) × 5 2,143,850	2 × 5 + 6 × 7 1,545,500
<i>Variable costs FCFA ha⁻¹</i>			
9. Ridging (cowpea and maize/pigeonpea) (three growing seasons)	60,000 ¹	187500 ²	62,500 + 20000 = 82,500
10. Weeding/manual handpulling (cowpea and maize) (two major and one minor rainy seasons)	60,000 ³	187500 ⁴	46875 + 15000 = 61,875
11. Cowpea treatment (<i>Hyptis suaveolens</i> aqueous extract + pesticides)	30,000	30,000	–
12. Mowing of cowpea residue and pigeonpea plants	12,500	12,500	25,000
13. Fertiliser application	75,000	75,000	37,500
14. Total of variable costs	237,500	492,500	206,875
15. Net benefits (8–14)	836,800	1,651,350	1,338,625
Marginal costs		255,000	285,625
Marginal net benefits		814,550	312,725
Marginal rate of return (%)		319	109

¹20.000 × 3 seasons; ²62.500 × 3; ³15.000 × 2 × 2; ⁴46.875 × 4.

fertiliser have to be paid in advance, while the benefits can be reaped only after the harvest. So even if an investment is advantageous, farmers could still be constrained in making it. Finally, the partial budget takes into account variable costs over three rainy seasons. Short-term budgets inevitably lead to the consequence that continuous cropping, even when this leads to nutrient depletion and diminishing harvests, has a more positive budget than a cropping system where fallowing is included (as in late-maturing pigeonpea). Average market prices for the products were taken into account for the calculation of the gross products. Even though pigeonpea is not consumed in Dame-Wogon, there is still a market for it in the neighbourhood, but that market may be rapidly saturated.

Both partial budgets were positive, indicating that improved speargrass management does pay off. The marginal rate of return for the cowpea system was three times higher than for pigeonpea (Table IV). This difference was due to the fact that a total of 4 t of maize was produced by the cowpea system in two harvests while the pigeonpea system resulted in almost 3 t in one harvest. Furthermore, cowpea yield was higher than that of pigeonpea. Although pigeonpea is more effective in suppressing speargrass than cowpea, economically cowpea performs better.

4. Conclusion

Speargrass problems have worsened during land intensification necessitating novel weed management such as suppression through legumes. Including legumes in the cropping system leads to a further evolution towards permanent cropping systems in order to prevent re-infestation. Effective speargrass management also imposes a number of trade-offs that farmers need to make between speargrass suppression, cowpea grain yield, and subsequent maize yield through soil fertility improvement.

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