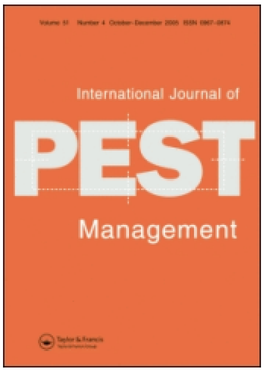

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Evaluation of integrated crop management strategies employed to cope with Striga infestation in permanent land use systems in southern Benin

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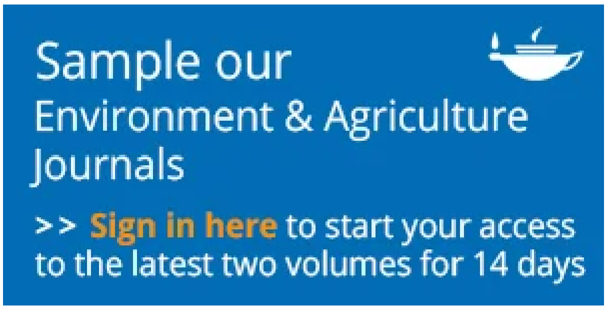
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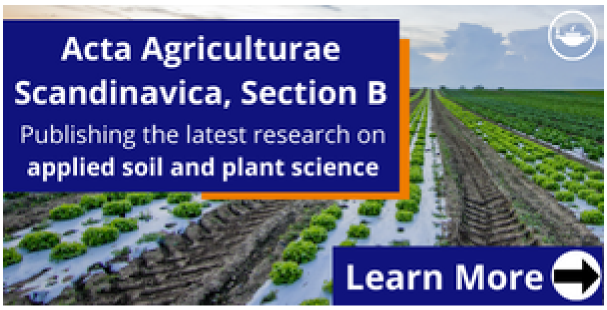
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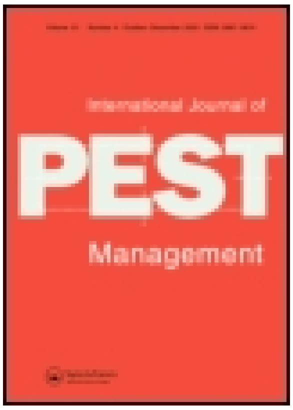

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Evaluation of integrated crop management strategies employed to cope with *Striga* infestation in permanent land use systems in southern Benin

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Striga hermonthica and *S. gesnerioides* pose serious threats to cereal and cowpea production, endangering peoples' livelihoods on the Abomey plateau, Benin. A 2-year joint experiment was undertaken with farmers in two hamlets to investigate the potential of managing sowing dates of cowpea, sorghum transplanting, and trap cropping as ways of increasing agricultural production and reducing *Striga* damage. Early sowing of cowpea failed due to dry spells. Late sowing reduced cowpea yield due to water deficiency at the end of the growing season. Transplanting sorghum seedlings raised in fertilised or *Striga*-free nurseries doubled or tripled cereal yield and substantially reduced *S. hermonthica* infestation compared to direct early-sown sorghum. Transplanting sorghum from plant hills to fill gaps was unsuccessful. Trap crops such as cowpea and groundnut increased subsequent maize yield. Trap cropping had only a small effect on *S. hermonthica* infestation. The very poor soils in Somè central were a major constraint upon yield improvement to acceptable levels even after the introduction of the new crop (and *Striga*) management methods.

Keywords: soil fertility decline; *Striga*; crop losses; participatory learning; integrated crop management; permanent land use; transplanting; legumes

1. Introduction

In many parts of the Guinea savannah of West Africa, intensification of traditional cropping systems led to continuous cropping of cereals and unsustainable cropping practices, resulting in depletion of organic matter and plant nutrients. Consequently, crops grew less vigorously and problems with parasitic weeds (especially species of the genus *Striga* (Orobanchaceae)) became more serious (Berner et al. 1995; SP-IPM 2003; Oswald 2005). The most common and devastating *Striga* species in the savannah zone is *S. hermonthica* (Del.) Benth., a parasite of millet (*Pennisetum americanum* (L.) K. Schum.), sorghum (*Sorghum bicolor* (L.) Moench), maize (*Zea mays* L.), rice (*Oryza sativa* L.) and sugarcane (*Saccharum officinarum* L.) (Oswald 2005). Moreover, *S. gesnerioides* (Willd.) Vatke parasitises cowpea (*Vigna unguiculata* (L.) Walp.) (Lane et al. 1994; Dubé and Olivier 2001). Cowpea is usually grown in rotation or intercropped with cereals (maize, sorghum and millet), and in such cropping systems both *S. hermonthica* and *S. gesnerioides* infest the same plot, thus compounding the *Striga* problem (Dugje et al. 2006).

Striga species are among the most important constraints upon agricultural development in Africa (Ejeta 2007). *Striga* negatively affects the lives of over 100 million African people. The value of total annual crop loss in Africa has been estimated at 7 billion US dollars. Depending on ecological conditions and agronomic practices, *Striga* species cause estimated yield losses ranging from 10% up to almost complete crop failure. The areas badly affected by *Striga* are also the areas where many of the poorest people live with the highest percentage of cereals in their diet (Kanampiu et al. 2002; Ejeta 2007). Furthermore, these *Striga*-affected areas are also severely affected by other abiotic (low and erratic rainfall, low soil fertility) and biotic (other pests and diseases) constraints. *Striga* is therefore best regarded a symptom of a complex of factors that cause poor soil quality, and *Striga* control without integrated natural resource management will have only a limited effect (Ransom 2000).

Intensive research into *Striga* control has been carried out in Africa; nevertheless, the *Striga* problem not only has persisted but has increased. Ejeta (2007) suggested that the capability of currently available technologies for effective *Striga* management is debatable. Resource-poor farmers, who constitute 80% of the farming population, have often insufficient financial resources to purchase agricultural

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inputs. Various low-cost and practical *Striga* control alternatives at farm level have been reported to reduce the *Striga* seed bank, improve soil fertility and increase yields of subsequent crops (Carsky et al. 2000; Gacheru and Rao 2001, 2005; Schulz et al. 2003; Ellis-Jones et al. 2004; Gbèhounou et al. 2004; Franke et al. 2006; Douthwaite et al. 2007). However, Kanampiu et al. (2002) argued that farmers did not consider research recommendations appropriate to their needs to provide sufficient food for their families on small, intensively cultivated holdings. Consequently, *Striga* management technologies remain rather ineffective, especially in regions where they are most needed (Vissoh et al. 2007). Their adoption by farmers is often constrained by acute land and labour shortage and the prevailing land tenure systems. Adoption of strategies that work is also limited by the fact that farmer's knowledge of the biology of *Striga* species (host plant specificity, lifecycle) is incomplete (Stringer et al. 2007). It is therefore important to develop *Striga* control measures with the active participation of farmers in order to provide methods that are effective, work and are acceptable under their socio-economic conditions.

The aim of this study was to contribute to the development and improvement of effective *Striga* control practices in southern Benin. Specifically it aimed to: (1) identify the most promising *Striga* control measures that are available to small-scale farmers in the study area, (2) evaluate, with the help of farmers, the effectiveness of these measures, and (3) assess farmers' perception of the feasibility and acceptability of improved *Striga* control measures within the framework of their cropping practices.

2. Materials and methods

2.1. Study area

Surveys and experiments were conducted at Somè, located in the district of Za-Kpota, Republic of Benin (7°13′N, 2°12′E). Two hamlets, differing in pressure on the land and in their cropping history, were chosen. At the central hamlet of Somè, plots used for experimentation have been permanently cropped for the last 30 years without external inputs. In Assiankpa there was a history of permanent cropping for 15 years. Additionally, prior to the present study, plots in Assiankpa were used for 4 years by INRAB (Institut National de Recherches Agricoles du Bénin) researchers for participatory management of *S. hermonthica*. These trials included maize response to different rates of inorganic fertilisers (Flatin 2003).

Previously, the district of Za-Kpota was endowed with abundant land. The bulk of the food consumed in the kingdom of Danxomè was produced in this area. In recent decades, however, rapid population growth has resulted in acute land shortage, more permanent and intensive land cultivation, and severe invasion of *Striga*.

The area has a bimodal pattern with average rainfall of 970–1100 mm from 2000 to 2005. However, there are indications that in the 20–30 years the amount of rainfall is reduced, the onset of the rainy season is less predictable (the consequence of which is to shift the effective start of the cropping season from mid-March to April) and the number of rainy days are declining (and the number of dry days between rains increasing). Early planting with the first rains often suffers early drought spells resulting in the need for second or third planting when rains are established. Soils are ferralitic and classified as Nitisols (Raunet 1977; FAO/UNESCO 1990). Next to rainfall, farmers mentioned soil fertility and *Striga* species as main constraints upon agricultural production (Vissoh et al. 2004). Cultivated plots are usually infested by both *S. hermonthica* (on cereals) and *S. gesnerioides* (on cowpea).

2.2. *Investigation of* Striga *spp. management strategies*

A survey was conducted in 2002 in Somè central and Assiankpa, using questionnaires, focus group discussions and informal interviews to inventory the various *Striga* control strategies. The latter strategies included farmers' own practices and adapted research recommendations. The questionnaire was administered in both hamlets to each of 25 farmers, randomly selected. Both male (old, middle-aged and young) and female respondents were interviewed. Triangulation was used to ascertain the reliability of data collected. Fields were visited using participant observation to cross-check quantitative and qualitative data collected during survey, group and informal discussions.

Farmers' practices identified during the diagnostic study (Vissoh et al. 2004) included planting dates of early maturing varieties (allowing crops to escape *Striga* in time because *Striga* seeds need conditioning before they can germinate and attach), crop rotation and/or intercropping with grain legumes (that act as trap crops), and sorghum transplanting. Sorghum transplanting was not practised in order to control *S. hermonthica*, but farmers acknowledged that transplanted sorghum could not only out-yield directly sown sorghum but also reduce *Striga* emergence. These strategies were selected with farmers for joint experimentation. An assessment of integration of *Striga* control methods was adopted in a 2-year experiment within a context of permanent land use systems. Table 1 presents crop succession per growing season from 2003 to 2005.

Table 1. Sequence of experiments with farmers.

Year/Season	2003* Major rainy season	2003* Minor rainy season	2004 Major rainy season	2004 Minor rainy season	2005 Major rainy season	2005 Minor rainy season
Planting dates	Testing of sowing dates of local cowpea varieties	–	Planting dates of cowpea varieties	Intercropping maize–cowpea (trap crop)	Planting dates of cowpea varieties	Intercropping maize–cowpea (trap crop)
Trap crops			Trap crops grown as sole crops	Intercropping maize–grain legumes (trap crops)	Trap crops grown as sole crops	Intercropping maize–grain legumes (trap crops)
Sorghum transplanting	Sorghum transplanting (getting insight into farmers' practices) Rotation with cassava		Sorghum transplanting		Sorghum transplanting	

*Learning from farmers' practices (experiments neither replicated nor randomised and therefore not reported).

2.3. *Assessment of sowing dates of cowpea varieties as* S. gesnerioides *control method*

Planting early cowpea varieties at the very onset of the rainy season could be a strategy to reduce *S. gesnerioides* infestation. Early planting tries to exploit the narrow window of opportunity between too-early sowing (and incurring a drought risk at the start of the rainy season) and sowing more or less in the optimal rainfall period but then having the larger *Striga* risk. Two different cowpea varieties were planted in each hamlet during the major rainy season in 2004 and 2005. The varieties included a local variety chosen by farmers and an improved tolerant variety (TVX – 1850-01F) suggested by the researcher. Both are early maturing (less than 3 months duration). Three planting dates were tested, spaced out 10 days apart.

A four-factorial experiment including hamlet (Somè central vs. Assiankpa), year (2004 vs. 2005), cowpea variety, and planting dates was set up in a randomised block design with four replications. The experimental plots measured each 48 m^2 (6 × 8 m). Plants were spaced 0.75 m between rows and 0.4 m along rows with two plants per hole. Plants were sprayed three times 20, 35 and 50 days after sowing using the organophosphate insecticide Acephate 75S (*Orthène*; *O,S*-dimethyl acetylphosphoramidothioate), at a dose of 1 kg ha^{-1} of powder soaked in 15 L of water.

2.4. *Transplanting of sorghum*

A local late-maturing variety of sorghum (more than 6 months) was used. A three-factorial experiment including hamlet, year, and various nursery or transplantation treatments was set up in a randomised block design with four replications. The following types of nursery beds were set up:

(1) farmers' traditional methods of setting up nursery bed on ridges (sow more seeds per hole and then thin for transplanting;
(2) farmers' traditional methods of setting up nursery bed in furrows;
(3) nursery bed enriched with organic matter (on household refuse heaps);
(4) nursery bed enriched with mineral fertiliser (application of 70 g of NPK per hill containing about 10 seedlings);
(5) nursery bed installed on (moderately) fertile, *Striga*-free plots in remote outfields;
(6) direct sowing of sorghum the same day nursery beds were set up (control plot); and
(7) direct late sowing of sorghum the same day sorghum seedlings were transplanted.

After approximately 4 weeks sorghum seedlings were supposed to be transplanted, but due to a drought spell the transplanting dates were delayed 2–3 weeks. In central Somè, due to land shortage, each plot measured 30 m^2 (6 × 5 m) and sorghum seedlings were widely spaced out, 0.75 m between rows and 2 m along rows and two plants per hole. For uniformity, the direct sown sorghum was thinned to two plants per hill, even though farmers use more than 10 plants per hill. In Assiankpa the same spacing was adopted but the plot was a bit larger (6 × 8 m).

2.5. *Trap cropping as a* S. hermonthica *control measure*

Five different grain legumes comprising two cowpea varieties (the same as used in the planting dates experiment), a local groundnut variety (*Arachis hypogea* L.), soybean (*Glycine max* (L.) Merrill cv. Jupiter), and a local variety of Bambaranut (*Vigna subterranea* (L.) Verdc.) were planted in a randomised block design with four replications. At the start of the experiment the fields were ploughed manually. An improved maize variety (DMR-ESRW) was used as a control. Each of the grain legumes was intercropped with maize. A three-factorial (hamlet, year, legume taxon) experiment was set up in a randomised block design with four replications during the second rainy season. This trial was carried out on the same plots where the previous cowpea experiment was conducted because the permanent land use did not allow to use alternative fields for the experiment. All crops were sown at 0.75 m row spacing. Cowpea was spaced 0.4 m along rows and two plants per hill. Soybean was sown at 0.3 m along rows and two plants per hill, and groundnut and Bambaranut were sown at 0.2 m along rows and two plants per hill. Maize was planted 0.4 m along rows and two plants per hill in the control and at 1.5 m along rows with two plants per hill while intercropped.

2.6. *Data collection and analysis*

Cowpea pods were harvested for yield determination from two quadrats per plot each measuring 9 m^2 (3 × 3 m). Cowpea grains were dried and weighed; yields were converted to 14% moisture content. *Striga gesnerioides* shoots were counted weekly in 9 m^2 (3 × 3 m) plots. In central Somè, *Striga* counts took place 65, 75 and 90 days after planting of cowpea. In Assiankpa, *Striga* shoots were counted at 51, 58, 65, 70, and 89 days after planting.

Sorghum grain yield was estimated from two quadrats of each plot measuring 6.25 m^2 (2.5 × 2.5 m) at central Somè and 9 m^2 (3 × 3 m) at Assiankpa. The numbers of sorghum plants, where panicles did not set grains were counted. *Striga hermonthica* was counted 8 and 9 weeks after direct sowing of sorghum in central Somè and Assiankpa, respectively.

Maize yield per plant was determined in the trap crop experiment. Because of different planting densities between maize monocropping and maize, intercropping data were not converted to an area basis. Both *S. hermonthica* and *S. gesnerioides* plants were counted from two quadrats of each plot measuring 9 m^2 (3 × 3 m).

Three- and four-way ANOVAs were carried out on the agronomic data using Statistical Analysis Systems (SAS 1999). Means were compared using Student–Newman–Keuls (SNK) test. A log transformation [$\log(x + 1)$], where x is the number of *Striga* shoots, was undertaken to meet the ANOVA assumptions.

3. Results

3.1. **Striga** *spp. management practices used by farmers in Somè*

Ninety percent of the farmers used one or more strategies that affect *Striga*. Most farmers applied more than one strategy simultaneously. Early sowing was often part of multiple strategies, and it was applied by 66% of the farmers interviewed. Hand-pulling of *Striga* was practised by only 4% of the interviewed respondents. Fertilisers were primarily used to increase crop production, but farmers were aware that increased soil fertility also reduces *Striga*. Twenty percent of the farmers used inorganic or organic fertilisers including poultry manure, household refuse, or a mix of both sources. Ten percent of the farmers did not apply any management against *Striga*.

Sorghum transplanting was widespread with 94% of the interviewed farmers practising at least one of the types identified. The remaining farmers (6%) did not transplant sorghum. The majority of the farmers (86%) transplanted sorghum using thinned seedlings. Transplanting sorghum from established nursery beds, which is much more time-consuming, was practised by 8% of the farmers.

3.2. *Cowpea –* **Striga gesnerioides** *management*

The results of the four-way ANOVA are presented in Table 2. Cowpea yield was significantly affected by hamlet and sowing date. Cowpea yield was significantly lower in Somè central than in Assiankpa. Later sowing reduced cowpea yield.

Abundance of *S. gesnerioides* was significantly affected by hamlet and cowpea cultivar. Much more *S. gesnerioides* emerged in Somè central than in Assiankpa. More *Striga* plants emerged on the local cultivar than on the improved resistant cultivar, but this did not result in cowpea yield differences. The two-way interaction sowing date × cowpea cultivar, and the three-way interaction hamlet × year × cowpea cultivar were also significant.

3.3. *Sorghum transplanting as means to control* **S. hermonthica**

Results of the three-way ANOVA are presented in Table 3. Sorghum yield was significantly affected by hamlet, year, and nursery or transplantation treatment. The hamlet × year interaction was also significant. Sorghum yield was significantly higher in Assiankpa than in Somè central. Application of mineral fertiliser or organic amendment in nursery beds resulted in the highest sorghum yields, whereas direct late sowing and sowing in nursery beds in furrows resulted in very low yields. There was no significant difference in yield between direct early sown sorghum and transplanted sorghum from nursery beds on ridges.

The percentage of sorghum plants bearing no seeds followed more or less the same patterns: significant effects by hamlet, year and nursery or transplantation treatment, and significant hamlet ×

Table 2. Effect of the main factors (hamlet, year, cowpea cultivar, and sowing data) on cowpea grain yield (kg ha^{-1}) and number of *S. gesnerioides* emerged (per 9 m^2).

Main factors	Cowpea yield (kg ha^{-1})	Emerged *Striga gesnerioides* (9 m^2)
Central Somè	291 ± 14 a	1.44 ± 0.09 a (93.2)
Assiankpa	362 ± 18 b	0.30 ± 0.06 b (9.0)
2004	337 ± 18 a	0.81 ± 0.09 a (45.1)
2005	316 ± 15 a	0.92 ± 0.10 a (57.1)
Local cultivar	311 ± 17 a	1.03 ± 0.10 a (64.4)
Improved cultivar	341 ± 16 a	0.71 ± 0.09 b (37.8)
Early sowing	389 ± 18 a	0.94 ± 0.12 a (54.7)
Intermediate sowing	321 ± 23 b	0.83 ± 0.11 a (34.4)
Late sowing	269 ± 16 b	0.83 ± 0.12 a (64.3)

Source of variation	df	*F* value	
Hamlet	1	10.99***	125.79***
Year	1	0.93 n.s.	1.07 n.s.
Cultivar	1	1.93 n.s.	9.68**
Sowing date	2	10.26***	0.57 n.s.
Hamlet × year	1	0.18 n.s.	2.27 n.s.
Hamlet × cultivar	1	0.05 n.s.	0.46 n.s.
Hamlet × sowing date	2	0.62 n.s.	0.41 n.s.
Year × cultivar	1	0.73 n.s.	0.06 n.s.
Year × sowing date	2	1.11 n.s.	0.11 n.s.
Cultivar × sowing date	2	0.86 n.s.	6.01**
Year × hamlet × cultivar	1	4.13*	6.36*
Year × hamlet × date	2	0.11 n.s.	2.07 n.s.
Hamlet × cultivar × date	2	0.09 n.s.	0.23 n.s.
Year × cultivar × date	2	0.04 n.s.	0.61 n.s.
Hamlet × year × cultivar × date	2	0.43 n.s.	0.47 n.s.

The results of the four-way ANOVA are given in the lower part of the table. Numbers in brackets have been subjected to logarithmic transformation. 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. ± indicates standard error. Significance of ANOVA: n.s. not significant; *$0.01 < P < 0.05$; **$0.001 < P < 0.01$; ***$P < 0.001$.

year and hamlet × treatment interactions. In plots with direct late-sowing and in plots where in nursery beds in furrows was sown almost all sorghum plants did not bear fruit.

Emergence of *S. hermonthica* was also significantly affected by hamlet, year, and treatment, and the hamlet × year, and hamlet × treatment interaction. The highest numbers of *S. hermonthica* emerged in plots with direct early-sowing. Sorghum seedlings transplanted on ridges (farmers' practice) were already parasitised before being transplanted and therefore numbers of *Striga* were not significantly different from those in plots with direct sowing. The lowest *Striga* numbers were observed both in nurseries where mineral fertiliser or organic amendments were applied (and where sorghum yields were highest) and in plots with direct late sowing and in sowing in nursery beds in furrows (but where sorghum yields were very low). The numbers of *S. hermonthica* did therefore not bear a straightforward relationship with cereal performance.

3.4. Farmers' perceptions of and constraints to nursery establishment

Farmers compared the different types of nurseries regarding their effectiveness in increasing sorghum yield and reducing *Striga* incidence. They also compared nursery practices in terms of input availability, their costs, and labour demand. Farmers preferred the nursery established on fertile, *Striga*-free plot for the following reasons: (1) chemical fertilisers are neither available nor affordable and (2) transporting organic material (dumped refuse) is labour-intensive and not everyone owns a household refuse heap near their houses, (3) heaps are also valued by women, and (4) using these heaps compels farmers to fence nurseries, otherwise small ruminants and poultry destroy the seeds and seedlings.

Strengths and weaknesses of sorghum transplanting were analysed with farmers (Table 4). Farmers mentioned constraints on sorghum transplanting at nursery establishment, transplanting, and post-transplanting. In the nursery, sorghum seeds and seedlings can be destroyed by rodents, granivorous birds and ants, necessitating replanting and/or the use of rodent traps, which require additional labour or costs. Unpredictable rainfall negatively affects seedling growth or delays transplanting when there are prolonged dry spells. Seedling transplantation is time-consuming and labour-demanding. Just after transplanting, a high mortality rate can occur when there is a prolonged dry spell.

3.5. Effectiveness of some legumes as trap crops to control **S. hermonthica**

Results of the three-way ANOVA are presented in Table 5. Maize yield was significantly affected by hamlet and treatment, and by the hamlet × year, hamlet × treatment, and hamlet × year × treatment interaction. Production in Assiankpa was much higher than in Somè central. When maize was monocropped, yield was around 2 t ha^{-1} in Assiankpa, and 0.6 t ha^{-1} in Somè central. Maize yield was lowest in the control, the treatment with Bambaranut, and in the treatment with the improved cowpea cultivar, and highest in the treatments with the local cowpea variety and groundnut. *Striga hermonthica* emergence was significantly affected by hamlet and by treatment. *Striga* emergence was significantly higher in Somè central than in Assiankpa. Emergence was lowest after the use of groundnut as trap crop. The other legumes performed inefficiently as trap crop, because emergence of *S. hermonthica* was not

Table 3. Sorghum yield (kg ha^{-1}), percentage of plants not bearing grains (per 9 m^2) and emerged *Striga hermonthica* (per 9 m^2), and *F* values in a three-way analysis of variance in sorghum transplanting.

Main factors		Sorghum yield (kg ha^{-1})	Percentage of plants not bearing grains (9 m^2)	Emerged *Striga hermonthica* (9 m^2)
Central Somè		152 ± 13 b	1.9 ± 0.0 (81)	0.2 ± 0.0 b (0.9)
Assiankpa		687 ± 54 a	1.2 ± 0.1 (33)	0.6 ± 0.1 a (7.6)
2004		400 ± 49 a	1.5 ± 0.1 a (58)	0.5 ± 0.1 a (6.2)
2005		398 ± 41 b	1.6 ± 0.1 a (59)	0.2 ± 0.0 b (1.8)
Direct early sowing		281 ± 49 b	65.3 ± 5.3 a	0.8 ± 0.1 a (11.7)
Direct late sowing		63 ± 16 c	92.1 ± 2.0 a	0.2 ± 0.1 c (1.6)
In furrows on infested plot		69 ± 27 c	89.8 ± 4.3 a	0.1 ± 0.1 c (0.4)
On ridge on infested plot		237 ± 44 b	60.6 ± 5.5 a	0.5 ± 0.1 ab (7.2)
Non-infested soil		537 ± 85 ab	47.6 ± 6.4 b	0.4 ± 0.1 bc (3.0)
Organic matter		632 ± 77 a	36.3 ± 5.2 b	0.1 ± 0.0 c (0.6)
Mineral fertiliser		809 ± 106 a	35.9 ± 5.9 b	0.2 ± 0.1 c (1.5)
Source of variation	**df**	***F* value**		
Hamlet	1	65.92***	258.95***	84.56***
Year	1	7.60**	5.70*	50.36***
Treatment	6	27.16***	27.70***	18.15***
Hamlet × year	1	14.08***	7.84**	17.57***
Hamlet × treatment	6	0.78 n.s.	19.72***	7.96***
Year × treatment	6	1.76 n.s.	0.73 n.s.	1.90 n.s.
Hamlet × year × treatment	6	2.17 n.s.	0.75 n.s.	0.21 n.s.

Values in brackets have been subjected to logarithmic transformation. 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. ± indicates standard error. Significance of ANOVA: n.s. not significant; *$0.01 < P < 0.05$; **$0.001 < P < 0.01$; ***$P < 0.001$.

Table 4. Farmers' perceptions of sorghum transplanting.

Strengths	Weaknesses
Nurseries	***Nurseries***
1- Nurseries are manageable due to their size.	1- Nurseries established late are damaged by rodents, grain eating birds, and ants.
2- Germination improved compared to direct sowing.	2- Intermittent drought spells result in retarded growth of seedlings on infertile and infested plots.
3- Seedlings grow quickly and vigorously.	3- Seedlings overgrow if the rains are late at transplanting time.
4- Sorghum seedlings grow vigorously before *Striga* emergence.	
Post-transplanting	***At transplanting***
1- Seedlings survival after transplanting is good when there is abundant rainfall just before and after seedlings transplanting.	1- Farmers injure their fingers during sorghum transplanting.
2- There is no need to filling gap.	2- Farmers suffer from backache.
3- Early establishment does not require labour to scare birds from the fields as compared to direct sowing.	3- Time and energy consuming compared to direct sowing.
4- Plants are strong and healthy.	4- Limited area can be transplanted due to shortage of labour.
5- *Striga* infestation is reduced compared to direct sowing.	5- Transplanting requires a managerial skill.
6- Higher yield compared to direct sowing.	***Post transplanting***
7- New knowledge is acquired.	High mortality rate of transplanting seedlings when a long drought spell occurs just after transplanting.

significantly reduced compared to sole maize. *Striga gesnerioides* occurred in plots with cowpea but not in plots with the other legumes. The number of *S. gesnerioides* was higher in Somè central than in Assiankpa. There were no significant differences between both cowpea cultivars. The presence of *S. gesnerioides* could have negatively affected the performance of cowpea as a trap crop for *S. hermonthica*.

4. Discussion

4.1. Striga *spp. management practices used by farmers in Somè*

Strictly speaking, farmers do not apply *Striga* management strategies. They resort to various strategies to manage their cropping system and these strategies also affect *Striga*. Early sowing (and the use of early-maturing varieties) of cowpea and sorghum is

Table 5. Maize yield (g) per plant, emerged *Striga hermonthica* (per 9 m^2) and *F* values in a three-way analysis of variance in maize–grain legumes intercrop.

Main factors	Maize yield (g)	Emerged *Striga hermonthica* (9 m^2)
Central Somè	12.8 ± 1.4 b	1.5 ± 0.1 a (44.7)
Assiankpa	46.6 ± 3.6 a	0.5 ± 0.1 b (6.4)
2004	28.2 ± 3.3 a	0.9 ± 0.1 a (27.0)
2005	31.2 ± 3.2 a	1.0 ± 0.1 a (24.1)
Bambara nut	22.1 ± 4.7 b	1.0 ± 0.1 ab (26.9)
Sole maize	19.9 ± 3.8 b	1.2 ± 0.1 a (28.1)
Local cowpea cultivar	42.6 ± 8.4 a	1.0 ± 0.1 ab (23.1)
Tolerant cowpea cultivar (TVX 1850–01F)	22.6 ± 3.2 b	1.1 ± 0.1 a (35.0)
Groundnut	37.4 ± 6.5 a	0.8 ± 0.1 b (26.0)
Soybean	33.5 ± 4.2 ab	0.9 ± 0.1 ab (14.2)

Source of variation	df	*F* value	
Hamlet	1	105.29***	202.22***
Year	1	0.87 n.s.	2.99 n.s.
Treatment	5	5.48***	3.00*
Hamlet × year	1	0.00 n.s.	2.21 n.s.
Hamlet × treatment	5	3.63**	1.50 n.s.
Year × treatment	5	2.90*	0.91 n.s.
Hamlet × year × treatment	5	3.58**	0.99 n.s.

Numbers in brackets have been subjected to logarithmic transformation. 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. ± indicates standard error. Significance of ANOVA: n.s. not significant; *$0.01 < P < 0.05$; **$0.001 < P < 0.01$; ***$P < 0.001$.

used first and foremost to shorten the hungry period at the end of the dry season. Farmers realise that early sowing of cowpea and cereals also affects *Striga* abundance. Early planting and the use of early-maturing crops have been proposed as strategies to reduce the impact of *Striga* (Emechebe et al. 2004; Gbèhounou et al. 2004). Integrated *Striga* management control technologies require increased labour. In northern Nigeria labour requirements of integrated *Striga* control was more than 80% higher than farmers' practices, especially at the start of the cropping cycle (Franke et al. 2006). In an area that is severely land and labour-constrained, and where the younger generation, due to lack of access to land, leaves agriculture for off-farm activities, such additional requirements can hardly be met. Labour constraints, next to the very low soil fertility, were also causes of wide spacing in the planting of both cereals and legumes. Franke et al. (2006) observed that farmers used wider cereal spacing than as recommended in the integrated *Striga* control programme. According to Douthwaite et al. (2007), only 27% of the farmers in northern Nigeria adopted recommended close legume spacing, and these authors suggested that labour constraints and soil fertility would not allow this. Farmers in Za-Kpota specifically stated that hand-pulling is labour-intensive and time-consuming, and that it does not provide immediate return. Ejeta (2007) noted that hand-weeding can be effective at low *Striga* abundance, but that the rampant infestation levels often observed nowadays would make such a strategy ineffective, at least in the short term.

Compost is only seldom available. Farmers consider compost application time-consuming and labour-intensive, due to the large amount recommended per unit area. While animal manure is scarce, application of mineral fertiliser is beyond the financial means of most Somè farmers. The availability of mineral fertilisers has also tremendously declined after the collapse of the cotton sector (Sinzogan et al. 2007).

A small percentage of the farmers (6%) were so labour-constrained that they did not transplant sorghum. While the remaining farmers did transplant sorghum, only 8% of them could afford the much more-time consuming activity of transplanting sorghum from established nursery beds.

4.2. *Cowpea* – **Striga gesnerioides** *management*

Under conditions of more predictable rainfall at the start of the rainy season, early sowing of cowpea could reduce *S. gesnerioides* infestation and enable crops to grow vigorously before conditions are favourable to the parasite (Touré et al. 1996; Dubé and Olivier 2001). The farmers in Za-Kpota employed these strategies. However, our experiment was unsuccessful, insofar as early planting (mid-March) of cowpea cultivars did not take place, due to the delay in the start of the rainy season that forced farmers who had sown in mid-March to sow cowpea twice. Planting took place in May when rains were more or less established. Therefore, our experiment therefore showed only the risks of late sowing. The negative effect of late sowing on cowpea yield was likely due to the fact that later-sown plants suffered water shortage at the end of the growth cycle due to insufficient rainfall. Sowing dates did not significantly affect the number of *S. gesnerioides* plants that emerged. We assume that, once rainfall is sufficiently regular, the difference of 10 days that elapsed between two consecutive sowing dates was insufficient to induce differences in *S. gesnerioides* infestation.

Overall, these results indicate that farmers have to trade off the risk of insufficient rainfall and the risk of *Striga* infestation. Both early-sowing (before *Striga* seeds are conditioned) and late-sowing (when conditioned *Striga* seeds turn into secondary dormancy because of a lack of a suitable host) are risky under the prevailing agro-ecological conditions, because farmers may either have to sow twice (in the case of too-early sowing) or cowpea plants cannot complete their life cycle (in the case of too-late sowing). The vagaries of the climate therefore seem to allow no alternative but cowpea sowing at the time when the risk of *S. gesnerioides* infestation is highest. Farmers, especially those in Somè central, where the very poor soils result in a low rainfall use efficiency by the crops, seem to have no choice but to synchronise the cycle of cowpea and its parasite.

4.3. *Sorghum transplanting as means of controlling* S. hermonthica

Application of mineral fertiliser or organic amendment in nurseries resulted in the highest sorghum yields, whereas direct late sowing and sowing in nursery beds in furrows resulted in very low yields. Transplanting seedlings from unfertilised nursery beds (the regular farmer practice) did not increase yield compared to early sowing, most likely because transplanted seedlings were already infected by *S. hermonthica*. These results are in agreement with previous studies carried out on sorghum transplanting (Berner et al. 1995; Gbèhounou et al. 2004). Transplanted sorghum from nursery beds enriched with mineral fertilisers and organic matter were better able to resist *Striga*-induced stress. The use of transplanted seedlings also delayed emergence of *S. hermonthica* in a range of maize varieties (Oswald and Ransom 2002). Older sorghum roots, formed before transplanting, were found to resist parasite attack (Dawoud et al. 1996). Van Ast et al. (2005) demonstrated that cereal yield reduction is determined by the timing of first *Striga* infection rather than by the number of infections. The main difference between direct sowing and transplanting was the age at which sorghum roots were exposed to *Striga*.

Oswald et al. (2001) observed that *Striga* emergence was not reduced and that sorghum failed to produce grain yield in three out of four seasons when seedlings were only 17 days old at transplanting. Apparently, the age at which seedlings are transplanted is crucial. The Centre for Arid Zone Studies ([CAZS] 2002) recommends that early sorghum and early pearl millet varieties should be transplanted when seedlings are 10–40 days old. In our experiment, transplanted sorghum seedlings were 43 and 51 days old in 2004 and 2005, respectively, even though we initially planned transplanting seedlings of 30 days. Drought spells delayed transplanting in both years.

For farmers, the primary objective of sorghum transplanting is to manage their cropping calendar. Managing sowing dates is also important to control *S. hermonthica* in sorghum. As in the case with cowpea, early sowing of the cereal is risky because of drought spells at the start of the rainy season. The extremely low sorghum yield produced by delayed direct sowing was due to insufficient rainfall, in combination with the low rainfall use efficiency in such degraded plots. Despite a reduced *Striga* infestation, late direct sowing is not an appropriate *Striga* control measure to be recommended to farmers, as has also been noted by Gbèhounou et al. (2004). Seedlings raised in the furrows did not grow well for two major reasons: (1) nursery beds were unfertile because the top layer soil was removed during ridging and (2) intermittent dry spells retarded seedling growth.

4.4. *Farmers' perceptions of and constraints to nursery establishment*

Farmers concluded that the benefits of transplanting sorghum seedlings from fertilised or relatively fertile nursery beds outweigh the constraints because it substantially increases yield and reduces *Striga* emergence even though seedling transplantation is time-consuming and labour-demanding and is associated with back stress and finger injuries. They acknowledged that transplanted plants had a head start over the germinating *Striga* compared to direct sowing. Sorghum transplanting, for which only small amounts of fertiliser are needed because only 70 g of NPK per hill containing 10 seedlings is applied, can be a simple, effective, and easily adopted practice for small-scale farmers compared to other *Striga* control measures.

4.5. *Effectiveness of some legumes as trap crops to control* S. hermonthica

Several authors have shown that grain legumes grown either in rotation or intercropped with maize reduce *S. hermonthica* incidence and improve maize yield (Carsky et al. 2000; Kureh et al. 2000; Oswald and Ransom 2001; Gbèhounou and Adango 2003; Kuchinda et al. 2003; Ellis-Jones et al. 2004). Abunyewa and Padi (2003) observed that Bambaranut and soybean reduced *S. hermonthica* density to less than one-third compared to 2 years continuous cropping.

However, the effect of legume trap crops in intercropping or rotations on subsequent cereal yield may not always be large. Our results indicated an effect of a local cowpea cultivar and groundnut on maize yield, but no effect of soybean, Bambara nut and an improved cowpea cultivar. Numbers of *S. hermonthica* were only reduced with groundnut as trap crop. Oswald et al. (2002) noted in intercropping systems of maize and legumes that *S. hermonthica* numbers in the next cereal crop were not significantly reduced. Similarly, Reda et al. (2005) found no significant *S. hermonthica* control through intercropping sorghum with legumes. Khan et al. (2007) also found no significant legume effect, except by the allelopathic *Desmodium*, whose root exudates inhibit *Striga* germination, in intercropping systems with maize.

Considering the importance of legumes in their cropping system, *S. hermonthica* control methods based on coating maize seeds with a herbicide, a practice developed and successfully adopted in Kenya (Kanampiu et al. 2007) may be problematic in the poor and labour-constrained area of Za-Kpota.

4.6. Differences between Somè central and Assiankpa

The greatest source of variation in the ANOVAs was consistently the factor hamlet. This great difference between both villages is due to their different histories, with Somè central having a history of permanent cropping for 30 years without external inputs, and Assiankpa having a history of 15 years permanent cropping, and a recent history of participatory research with INRAB where fertilisers had been made available. An important question, therefore, is to what extent improved crop and *Striga* management practices, when taken up by the local populations, would help escape them from malnutrition and poverty. The often significant hamlet × treatment interactions signify that thresholds need to be passed before treatments can be successful. It is unlikely that, without substantial external inputs (as have been provided in Assiankpa before), the people from Somè central would find a window of opportunity to escape from their biophysical and social constraints. The alternative, especially for young men, in this low soil fertility environment is to leave agriculture and look for alternative sources of income such as tapping oil palm wine, temporal migration, petty trade and/or informal employment in towns.

5. Conclusion

Joint experimentation with farmers showed the potential of various management practices to increase agricultural production and to reduce damage by *S. hermonthica* on cereals and by *S. gesnerioides* on cowpea. These practices were to some extent effective and acceptable to farmers under their economic conditions and could, thereby, contribute to improved farming. However, the success of these practices was very different between both hamlets due to their different histories. In the very poor soils of Somè central, improved management alone is likely insufficient for farmers to escape from food insecurity and poverty, and substantial external inputs would be necessary to create windows of opportunity for successful integrated crop and *Striga* management.

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References

Abunyewa AA, Padi FK. 2003. Changes in soil fertility and *Striga hermonthica* prevalence associated with legume and cereal cultivation in the Sudan savannah zone of Ghana. Land Degrad Dev. 14:335–343.

Berner DK, Kling JG, Singh BB. 1995. *Striga* research and control – A perspective from Africa. Plant Dis. 79:652–660.

Carsky JR, Berner KD, Oyewole DB, Dashiell K, Schulz S. 2000. Reduction of *Striga hermonthica* parasitism on maize using soybean rotation. Int J Pest Manage. 46:115–120.

CAZS (Centre for Arid Zone Studies). 2002. Transplanting sorghum and millet as a means of increasing food security in semi-arid, low income countries. p. 26. Available from: http//www.bangor.ac.uk/transplanting. Accessed 2007 Nov 14.

Dawoud DA, Sauerborn J, Kroschel J. 1996. Transplanting of sorghum: A method to reduce yield losses caused by the parasitic weed *Striga*, in advances in parasitic plant research. In: Monero MT, Cubero JI, Berner D, Joel DM, Musselman LJ, Parker C, editors. Proceedings of the 6th Parasitic Weed Symposium; Cordoba, Spain. p. 777–785.

Douthwaite B, Schulz S, Olanrewaju AS, Ellis-Jones J. 2007. Impact pathway evaluation of an integrated *Striga hermonthica* control project in northern Nigeria. Agr Syst. 92:201–222.

Dubé M-P, Olivier A. 2001. Le *Striga gesnerioides* et son hôte, le niébé: interaction et méthodes de lutte. Can J Botany. 79:1225–1240.

Dugje IY, Kamara AY, Omoigui LO. 2006. Infestation of crop fields by *Striga* species in the savannah zones of northeast Nigeria. Agr Ecosyst Environ. 116:251–254.

Ejeta G. 2007. The *Striga* scourge in Africa: A growing pandemic. In: Ejeta G, Gressel J, editors. Integrating new technologies for *Striga* control, towards ending the witch-hunt. Singapore: World Scientific Publishing. p. 3–16.

Ellis-Jones J, Schulz S, Douthwaite B, Huissaini MA, Oyewole BD, Olanrewaju AS, White R. 2004. An assessment of integrated *Striga hermonthica* control and early adoption by farmers in northern Nigeria. Exp Agr. 40:353–368.

Emechebe MA, Ellis-Jones J, Schulz S, Chikoye D, Douthwaite B, Kureh I, Tarawali G, Hussaini AM, Kormawa P, Sanni A. 2004. Farmers' perception of the *Striga* problem and its control in northern Nigeria. Exp Agr. 40:215–232.

FAO/UNESCO. 1990. Soil Map of the World, Revised Legend World Soil Resource 60. Italy, Rome.

Flatin, V.O.A. 2003. Evaluation de l'efficacité de quelques pratiques culturales dans la lutte contre *Striga hermonthica* sur le plateau d'Abomey: cas du village Somè (Commune de Za-Kpota), mémoire d'Ingénieur Agronome, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, Bénin.

Franke AC, Ellis-Jones J, Tarawali G, Schulz S, Hussaini MA, Kureh I, White R, Chikoye D, Douthwaite B, Oyewole BD, et al. 2006. Evaluating and scaling-up integrated *Striga hermonthica* control technologies among farmers in northern Nigeria. Crop Prot. 25:868–878.

Gacheru E, Rao MR. 2001. Managing *Striga* infestation on maize using organic and inorganic nutrient sources in western Kenya. Int J Pest Man. 47:233–239.

Gacheru E, Rao MR. 2005. The potential of planted shrub fallow to combat *Striga* infestation on maize. Int J Pest Man. 51:91–100.

Gbèhounou G, Adango E. 2003. Trap crops of *Striga hermonthica*: *In vitro* identification and effectiveness *in situ*. Crop Prot. 22:395–404.

Gbèhounou G, Adango E, Hinvi JC, Nonfon R. 2004. Sowing date or transplanting as components for integrated *Striga hermonthica* control in grain–cereal crops? Crop Prot. 23:379–386.

Kanampiu F, Ransom J, Gressel J, Jewell D, Friesen D, Grimanelli D, Hoisington D. 2002. Appropriateness of biotechnology to African agriculture: *Striga* and maize as paradigms. Plant Cell Tiss Org. 69:105–110.

Kanampiu F, Diallo A, Burnet M, Karaya H, Gressel J. 2007. Success with the low biotech of seed-coated imidazoline-resistant maize. In: Ejeta G, Gressel J, editors. Integrating new technologies for *Striga* control, towards ending the witch-hunt. Singapore: World Scientific Publishing. p. 145–157.

Khan ZR, Midega CAO, Hassanali A, Pickett JA, Wadhams LJ. 2007. Assessment of different legumes for the control of *Striga hermonthica* in maize and sorghum. Crop Sci. 47:730–736.

Kuchinda NC, Kureh I, Tarfa BD, Shinggu C, Omolehin R. 2003. On-farm evaluation of improved maize varieties intercropped with some legumes in control of *Striga* in the northern Guinea savannah of Nigeria. Crop Sci. 22:533–538.

Kureh I, Chiezey UF, Tarfa BD. 2000. On-station verification of the use of soybean trap-crop for the control of *Striga* in maize. Afr Crop Sci J. 8:295–300.

Lane JA, Moore THM, Cardwell DV, Singh BB, Bailey JA. 1994. Virulence characteristics of a new race of the parasite angiosperm, *Striga gesnerioides*, from southern Benin. Euphytica. 72:183–188.

Oswald A. 2005. *Striga* control – technologies and their dissemination. Crop Prot. 24:333–342.

Oswald A, Ransom JK. 2001. *Striga* control and improved farm productivity using crop rotation. Crop Prot. 20:113–120.

Oswald A, Ransom JK. 2002. Response of maize (*Zea mays*) varieties to transplanting in *Striga hermonthica* infested fields. Weed Sci. 50:392–396.

Oswald A, Ransom JK, Kroschel J, Sauerborn J. 2001. Transplanting maize and sorghum reduces *Striga hermonthica* damage. Weed Sci. 49:346–353.

Oswald A, Ransom JK, Kroschel J, Sauerborn J. 2002. Intercropping controls *Striga* in maize based farming systems. Crop Prot. 21:367–374.

Ransom JK. 2000. Long-term approaches for the control of *Striga* in cereals: Field management options. Crop Prot. 19:759–763.

Reda F, Verkleij JAC, Ernst WHO. 2005. Intercropping for the improvement of sorghum yield, soil fertility and *Striga* control in the subsistence agriculture region of Tigray (northern Ethiopia). J Agron Crop Sci. 191:10–19.

Raunet, M. 1977. Caractérisation du milieu physique des points d'expérimentation agronomique, Rapport Institut de Recherches Agronomiques Tropicales (IRAT)/United Nations Development programmes/Institut National de Recherche Agricoles du Bénin (INRAB) (ex. DRA) Cotonou, Bénin Republic.

SAS. 1999. Procedures Guide Version 8.1. Cary (NC): Statistical Analysis Institute, Inc. p. 554.

Schulz S, Hussaini MA, Kling JG, Berner DK, Ikie FO. 2003. Evaluation of integrated *Striga hermonthica* control technologies under farmer management. Exp Agr. 39:99–108.

Sinzogan AAC., Jiggins J, Vodouhè S, Kossou DK, Totin E, Van Huis A. 2007. Cotton industry institutional linkages in Benin: Stakeholder analysis and actor perspectives. Int J Agri Sustain. 5:213–231.

SP-IPM. 2003. Tackling the Scourge of Parasitic Weeds in Africa, IPM Research Brief No.1. International Institute of Tropical Agriculture (IITA) Cotonou, Benin.

Stringer LC, Twyman C, Thomas DSG. 2007. Learning to reduce degradation on Swaziland's arable land: Enhancing understanding of *Striga asiatica*. Land Degrad Dev. 18:163–177.

Touré M, Olivier A, Ntate RB, St-Pierre AC. 1996. The influence of sowing date and irrigation of cowpea on *Striga gesnerioides* emergence. In: Moreno MT, Cubero JI, Berner D, Joel D, Musselman LJ, Parker C, editors. Advances in parasitic plant research. Cordoba (Spain): Junta de Andalucia. p. 787–794.

Van Ast A, Bastiaans L, Katile S. 2005. Cultural control measures to diminish sorghum yield loss and parasite success under *Striga hermonthica* infestation. Crop Prot. 24:1023–1034.

Vissoh PV, Gbèhounou G, Ahanchédé A, Kuyper TW, Röling NG. 2004. Weeds as agricultural constraint to farmers in Benin: Results of a diagnostic study. NJAS-Wageningen J Life Sci. 52:305–329.

Vissoh PV, Mongbo R, Gbèhounou G, Hounkonnou D, Ahanchédé A, Röling NG, Kuyper TW. 2007. The social construction of weeds: Different reactions to an emergent problem by farmers, officials and researchers. Int J Agri Sustain. 5:161–175.