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Development and testing of a control package for *Striga hermonthica* on small-scale holdings in the Gambia

(*Keywords*: *Striga hermonthica*; millet; sorghum; Gambia; IPM)

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Abstract. Studies were carried out on farms to evaluate potential control practices which could be constituted into a package of recommendations for the control of *Striga hermonthica* in the Gambia. ICSV 1002, a variety of sorghum, was identified as being relatively more tolerant to *Striga* and to the common insect pests of sorghum. Spot treatment of emerged *Striga* shoots with 2% solution of product paraquat using a pistol-grip hand sprayer was found to control *Striga* without stimulating regrowth, improved yields and was more acceptable and cost-effective than handpulling of the shoots in early millet and sorghum. Where there might be objections to the use of paraquat because of its toxicity hazards, a mixture of 2,4-D (1% soln.) plus glyphosate (1% soln.) or 2,4-D (2% soln.) was a useful substitute. A tentative control package consisting of ICSV 1002, spot spraying of *Striga* shoots with paraquat, and side dressing of urea fertilizer at 30 kg N/ha at 4 w.a.p. was tested at two sites against farmers' practice on pilot scale. Infestation of *Striga* was reduced and yields were increased by 119% and 37% by the package at the two sites.

Introduction

Detailed survey of *Striga hermonthica* has shown that it was widespread with 75% of cereal fields infested at a rate of 1–2 shoots per m^2 (Carson, 1987). Although farmers are aware of the high crop losses associated with this parasitic weed they are not enthusiastic to control it by weeding, which is the only means available to them. Consquently, the soils reservoir of *Striga* seed is being built up while expansion in the production of cereals and declining soil fertility due to shorter fallow periods, and also encouraging its spread.

One of the priority areas or research in the weed programme of the IPM (Integrated Pest Management) project executed by CILSS (Permanent Interstate Committee for Drought Control in the Sahel) was to develop a control package of recommendations which will be technically feasible and economically viable on small holdings. Such an approach was necessary because it was long realized that there was no single method available for the effective control of *Striga* on small-scale farms in West Africa. (Pieterse, 1985).

The long list of suggested control practices includes the use of resistant varieties, handpulling, chemical control, use of high rates of organic and inorganic fertilizers, germination stimulants and biological control. Some of these practices were selected, on the basis that they had the potential of being technically feasible and viable on small holdings, and tested on farmers fields.

Both on-farm and on-station trials were carried out in line with objectives of the present studies which were:

(1) To evaluate varieties of sorghum in terms of tolerance to *Striga hermonthica*:
(2) To evaluate handpulling and spot spraying of shoots with herbicides as control practices in early millet and sorghum;
(3) To evaluate candidate herbicides for use in spot spraying of *Striga* in early millet and sorghum;
(4) To assess a tentative control package for *Striga* in sorghum.

Materials and methods

Evaluation of tolerant varieties

Three 'low-stimulant' tolerant varieties of sorghum were obtained from ICRISAT and these were ICSV 1001 (Framida), ICSV 1002 (Framida × E 35-1)-4-2), and ICSV 1006 (146 × CS 3541)-6 × Framida)-3-1), (Ramaiah, 1985).

The trial in 1984 was a split plot design in which the three exotic varieties were compared with a local variety, Samba Jabo, in terms of tolerance to *Striga* and general weeds. The varieties constituted the main treatments. Each main treatment was split to contain three weeding subtreatments: no weeding, removal of all weeds except *Striga*, and removal of all weeds. There were two replications. Subplot size was four rows 75 cm apart and 10 m long. Spacing within the rows was 40 cm apart with two plants per hill. Grain yield was determined at harvest and crop losses caused by *Striga* and general weed competition were estimated by comparing grain yields obtained both in the *Striga* infested and unweeded plots with yields obtained in the completely weed free treatment.

In the 1985 season a different experimental design was used to assess crop losses caused by *Striga* in the same four varieties of sorghum.

Two of the same type of trial were established at Sapu, in a mildly *Striga* infested area, and at Samba Kunda, in a heavily infested area in the Upper River Division. The design was a randomized complete blocks with two replications. The four varieties were the treatments and plot size was 20 by 20 m. Spacing was 75 cm between rows and 40 cm between hills in a row.

Three batches of hills, 50 sorghum hills per batch, with newly emerged *Striga* shoots were labelled at 0, 2 and 4 weeks commencing at the time *Striga* was seen to emerge in

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each plot. At harvest, three other batches of non-attacked sorghum hills were selected in close proximity to their labelled and attacked counterparts. Panicle yield was determined per hill basis for all the hills concerned. The idea was that each time a *Striga*-attacked hill was harvested, a neighbouring or nearest non-attacked hill in similar edaphic conditions was also harvested. Percentage crop losses or otherwise were estimated on the basis of the difference between the means of panicle weight of non-attacked and those of the neighbouring attacked hills at each of the three periods of emergence of *Striga*.

One replicate of the trial at Samba Kunda was discarded because of uneven crop performance due to previous field history.

Evaluation of handpulling and spot treatment of Striga *with herbicide in early millet and sorghum*

Three long term pre-extension demonstration trials were established on farmers fields of early millet at Kuntaur and Sapu, all in the MacCarthy Island Division, and at Karantaba in Lower River Division. The design was a randomized complete blocks with two replications. Plot size was 20 by 20 m. The treatments were as follows:

1. Farmer practice—in which no particular effort was made to control *Striga*, other than what obtained in general weedings.
2. Handpulling of *Striga* shoots at flowering, maturity and two weeks after harvest of the crop.
3. Spot spraying of emerged Striga shoots with 2% solution of paraquat at same stages as above.

Striga shoots were counted before commencing treatments and after harvest, but before the last application of treatment, in a total of 10 quadrats of size 1 m^2 per plot. All farm operations were carried out by the participating farmers who were also responsible for effecting the treatments under supervision. Grain yields were determined in the plots at harvest. Economic analysis of the inputs and returns were carried for the treatments.

Two long term pre-extension demonstration trials were established for sorghum at Kayoum Bintang in Western Division and at Sapu in MacCarthy Island Division. Both design and plot size were the same as in the early millet trials.

There were, however, four treatments which were as follows:

1. Farm practice.
2. Handpulling of *Striga* shoots at 70 days after planting, flowering, and two weeks after harvest of crop.
3. Spot spraying of emerged *Striga* shoots with 2% solution of product paraquat at stages described above.
4. Spot spraying with 2, 4-D solution (2%) as above.

Spot spraying was carried out using a 500 ml capacity pistolgrip hand sprayer which delivered 1 ml of solution per squirt. Grain yield and cost-effectiveness of the treatment were determined. The trials were permanently demarcated and were to run for at least five years in order to monitor the long term benefits of preventing *Striga* plants from setting seed.

Evaluation of herbicides for use in spot treatment of Striga *in early millet and sorghum*

Two trials were established on farmer fields in 1986. The design was a randomized complete blocks with three replications. Plot size was a single 50 m row of the crop in question. In the early millet trial, the herbicides and handpulling treatment were applied at flowering stage of the crop. The corresponding stage for applying treatments in the sorghum trial was 90 days after planting. Herbicides were applied using a 500 ml hand sprayer. *Striga* shoots were counted before and three weeks after effecting treatments. Grain yields were also determined and statistically analysed.

To assess a tentative control package for Striga *in Sorghum*

This tentative package was identified in the course of the programme. The test was carried out at two sites, Sololor in the MacCarthy Island Division and Daba Kunda in Upper River Division. A 50 by 50 m portion of a farmer's field was demarcated and planted according to the package specification of: resistant variety-ICSV 1002; fertilizer—Spot apply urea at 30 kg N/ha at 4 weeks after seeding; spot spraying—spot spray *Striga* shoots within 2% solution of paraquat at 90 days after planting and at 50% flowering of the crop.

Planting of the trial was done at the same time that the farmer was planting the rest of the field. An adjacent plot of size 50 by 50 m planted to the farmer's variety and receiving his fertilizer and other cultural practices was pegged out for comparison with the package.

Assessments were made of *Striga* populations and grain yields in both the farmers plot and plot receiving the package.

Results and discussion

Evaluation of resistant varieties

The results of the 1984 trial at Sapu showed that even though all the exotic varieties exhibited relatively more stable yields in the face of *Striga* attack (i.e. more tolerant to Striga attack) these differences were not significant (Table 1) High variability in the general weed fauna and *Striga* populations contributed to a high standard error which made the weeding effect non-significant. However, the main treatment effect was significant with ICSV 1001 significantly out-yielding the local Samba Jabo.

The results of the trial at Sapu in 1985 also produced differences in crop losses for the four varieties but these were also not significant. ICSV 1001 was again more tolerant and the best yielder. However, this variety performed poorly in the trial at the heavily infested site of Samba Kunda. In contrast, ICSV 1002 was more consistent in its level of tolerance at both sites. It could either mean that ICSV 1001 may not have a broad spectrum of resistance to withstand, presumably, the different ecotypes at the two sites; or that there is a density threshold above which the resistance of ICSV 1001 breaks

down. ICSV 1002 was therefore put forward as a recommendation not only because of its stable tolerance but also because it possessed good grain and cooking qualities. It was also found to be more tolerant to insects like *Dysdercus superstitiosus* and *Heliothis armigera* which have potential of becoming pests on sorghum (Sanyang, 1985). ICSV 1002 is in fact gaining wide acceptance in Burkina Faso and Cameroon (Ramaiah, 1985). Being a 'low-stimulant' tolerant variety the idea was to use it areas of heavy infestation to reduce populations of *Striga* to low levels which can then be controlled by other agronomic means.

Table 1. Summary of percentage crop losses caused by Striga *in four varieties of sorghum in trials conducted at Sapu and Samba kunda, 1984–85*

	Percentage crop loss			Mean
Varieties	Sapu 1984	Sapu 1985	Samba kunda 1985	grain yield (kg/ha)
ICSV 1001	2	13	37	1368
ICSV 1002	8	19	25	1390
ICSV 1006	0	31	30	1287
Samba Jabo (local)	20	36	—	1034
Means	8	24	30	—

Evaluation of handpulling and spot treatment of Striga *with herbicides*

Early millet. Results of the trial established at Kuntaur are shown in Table 2. *Striga* infestation was very severe at Kuntaur. Both handpulling and spot treatment with paraquat reduced Striga populations effectively and increased grain yield significantly in 1985 and 1986. The chemical treatment increased income by over D60·00 while handpulling was not cost-effective because of the high labour demand and cost. Figures of *Striga* populations at the beginning of the treatment in 1986 showed that there were relatively fewer shoots in the handpulling and spot treatment plots than there were in the control.

Infestation at Sapu was less severe and spot spraying of the shoots increased grain yield by over 22% in both years (Table 2). Handpulling increased yield by 4 and 10% in 1985 and 1986, respectively. Difference in yield between the three treatments was not significant although the chemical treatment increased income by more than D90·00 in both years. Again, the high cost outlay on labour for handpulling made it uneconomic in both years.

Results of the trial of Karantaba (Table 2) showed that the chemical treatment increased grain yield by 33 and 28% over farmers practice and also increased income by D125·00 and D21·29 in 1985 and 1986, respectively. Handpulling was less effective. There was marked effect of handpulling and spot treatment administered in 1985 on the *Striga* populations in the following year.

Emergence of *Striga* was noted to be around the flowering time of early millet (7–8 w.a.p.). Hence it was important to destroy the *Striga* shoots within the shortest possible time in order to arrest the heavy drain on photosynthates meant for grain filling. In fact, much of the yield gains derived from spot spraying with paraquat could be attributed to the greater number of grains per spike.

Paraquat, being a desiccant, destroyed the *Striga* shoots within a matter of hours, and the spray could also reach those

Table 2. Evaluation of handpulling and chemical control of Striga *in early millet at Kuntaur, Sapu and Karantaba, 1985–86*

		1985				1986			
Site	Treatment	Grain yield kg/ha	No. *Striga* shoots per m² at harvest	Percentage yield increase	Incremental income Dal/ha	Grain yield kg/ha	No. Striga shoots per m² before treatment	Percentage yield increase	Incremental income Dal/ha
Kuntaur	Farmer practice	91	41·7	—	—	112	55·0	—	—
	Handpulling	230	4·0	153	−184·83	245	48·5	118	−188·01
	Spot spraying (paraquat)	291	0·7	219	69·50	405	40·3	261	100·07
	L.S.D. (5%)	86	—	—	—	89	—	—	—
Sapu	Farmer practice	1068	3·8	—	—	1345	3·3	—	—
	Handpulling	1109	1·5	4	−126·27	1488	2·7	10	−182·70
	Spot spraying (paraquat)	1315	0·3	23	95·43	1642	1·0	22	102·91
	L.S.D. 5%	—	—	—	—	—	—	—	—
Karnataba	Farmer practice	916	4·5	—	—	515	5·8	—	—
	Handpulling	1021	2·8	12	−92·32	562	3·2	9	−233·06
	Spot spraying (paraquat)	1221	0·1	33	125·00	657	2·2	28	21·29
	L.S.D. 5%	—	—	—	—	—	—	—	—

1985
Cost of herbicide = D18·00 per litre (1985)
Application cost = D16·50
Cost of handpulling = D258·50
Cost of harvesting extra grain = D0·17 kg.
Cost of grain = D0·70 per kg.

1986
Cost of herbicide = D36·00/litre
Labour and grain cost the same as in 1985

shoots that had emerged between the tillers of the crop. Besides there was no regrowth from sprayed plants. This performance was in direct contrast to claims by Ogborn (1984) that paraquat was not very active against *S. hermonthica*. There was also no danger of harming the host crop while administering paraquat with the hair sprayer because the plane of the spray was always below the level of the growing point of the host cereal.

The high labour input demanded of handpulling would always lead to control being protracted and therefore ineffective in reducing crop losses. Moveover, it was difficult to reach and handpull *Striga* shoots emerging within the stool of the millet crop.

Sorghum. Results of the trial on the evaluation of handpulling and chemical control of *Striga* in sorghum at Sapu are presented in Table 3. Field infestation of *Striga* was not severe, being 3·6 shoots per m^2. Spot treatment with paraquat and 2,4-D reduced *Striga* populations in 1985. Both handpulling and paraquat produced yields which were significantly better than the farmers practice in 1985. However, in 1986 it was paraquat and 2,4-D treatments which improved grain yields significantly over farmers practice. The same treatments brought in incremental returns in both years. In contrast, handpulling was only cost-effective in 1985.

Yields in the trial at Kayoum Bintang in 1985 and 1986 were generally low owing to poor husbandry practices (Table 3). Paraquat was the most effective treatment and increased yields by 40% in 1985 and by 135% in 1986 followed by 2,4-D and handpulling, in that order. Handpulling reduced income by over D140·00 in 1985 and by over D79·00 in 1986 because of its heavy outlay on labour and correspondingly low increase in grain yield.

Paraquat was very effective, quick-acting and killed the *Striga* shoots without stimulating regrowth. Thus, apart from its toxicity hazards which can be prevented by proper education, it was the most effective and economical treatment. Although 2,4-D is far safer and half the price of paraquat it was slower in action taking days to kill the *Striga* shoots. This meant that further damage was possible even after its application. Regrowth of shoots was also observed in some of the shoots treated with 2,4-D.

The technique of spot spraying was easily mastered by the participating farmers in a matter of minutes. Applicators were inexpensive and a wide array of equipment ranging form 350 ml capacity hair-sprayers, to 750 ml capacity 'Hardi' sprayer, all trigger operated, could be use for the spot treatment. Labour requirement was also low, requiring one man-day to complete spot treating 1 ha of field with infestation of 3–5 shoots/m^2. The products paraquat and 2,4-D are not expensive and the low dosages required for effective control implies low costs. For instance a field with infestation of 1 shoot per m^2 (10 000 shoot/ha.) will require a spray volume of 10 litre and 200 ml of product.

The results of the trials so far suggest that spot treatment of *Striga* shoots with low dosages of either paraquat and to some extent 2,4-D was a promising method of controlling *Striga* in cereals.

Evaluation of herbicides for post-emergent control of Striga *in early millet and sorghum*

The phytotoxic effect of the herbicides on *Striga* followed the same pattern in both crop (Table 4). Paraquat killed all the sprayed shoots and there were no regrowths. Glyphosate and 2,4-D achieved the same level of control in sorghum but 2,4-D was more effective in millet. The mixture of 2,4-D and

Table 3. Evaluation of handpulling and chemical control of Striga *in sorghum at Sapu and Kayoum Bintang, 1985–86.*

		1985				1986			
Site	Treatment	Grain yield kg/ha	No. *Striga* shoot/m^2 at harvest	Percentage yield increase	Incremental increase Dal/ha	Grain yield kg/ha	No. Striga shoots per m^2 before treatment	Percentage yield increase	Incremental income Dal/ha
Sapu	Farmer practice	1242	3·6	—	—	755	4·1	—	—
	Handpulling	1748	1·5	41	104·50	800	2·8	3	−136·00
	Spot spraying(2,4-D)	1638	1·2	32	170·00	1325	2·9	71	237·50
	Spot spraying (paraquat)	1890	0·5	52	287·50	1650	2·1	113	383·00
	L.S.D. (5%)	503	—	—	—	91	—	—	—
Kayoum	Farmer practice	188	3·9	—	—	175	4·1	—	—
Bintang	Handpulling	203	1·1	8	−140·00	313	3·8	78	− 79·50
	Spot spraying (2,4-D)	220	0·6	17	− 12·00	312	2·8	78	31·00
	Spot spraying (paraquat)	263	0·4	40	1·00	412	3·0	135	64·00
	L.S.D. 5%	61	—	—	—	150	—	—	—

1985
Cost of 2,4-D = D9·50/litre
Cost of paraquat = D18·00 per litre
Harvesting extra grain = D0·10 per kg
Grain cost D0·60 per kg.

1986
Cost of 2,4-D = D19·00/litre
Cost of paraquat = D36·00/litre
Labour for handpulling = D148·50.

Table 4. Evaluation of herbicides for post-emergent control of Striga *in early millet and sorghum at Kvntaur, 1986.*

Treatment	Early millet: count of *Striga* per 50-row				Sorghum: count of *Striga* per 50 m row			
	Before treatment	3 weeks after treatment	Percentage control	Grain yield kg/50 m	Before treatment	3 weeks after treatment	Percentage control	Grain yield kg/50 m
Handpulling	280	98	65	3·10	180	60	66	3·6
Paraquat (2%)	355	0	100	3·55	161	0	100	4·7
2,4-D (2%)	290	50	83	3·20	211	50	76	4·07
Control	324	347	0	2·64	256	267	0	2·15
Glyphosate (2%)	373	118	68	3·31	213	48	77	4·10
Paraquat (1%) + Glyphosate (1%)	263	6	98	3·52	182	10	84	4·38
2,4-D (1%) + Glyphosate (1%)	235	32	86	3·35	210	27	87	4·33
L.S.D. 0·05	—	—	—	0·41	—	—	—	0·55

Table 5. Comparison between farmers' practice and recommended package for Striga *control in sorghum.*

Treatment	Sololor			Daba Kunda		
	Grain yield kg/ha	Percentage increase	*Striga* shoots per m²	Grain yield kg/ha	Percentage increase	*Striga* shoots per m²
Farmers' practice	436	—	2·7	1616	—	3·4
Control package	959	119	0·1	2216	37	0·2

glyphosate gave better control in both crops than the individual herbicides used alone, albeit at double strength. The mixture of paraquat and glyphosate was relatively more effective than the glyphosate and 2,4-D mixture.

In all, the phytotoxic effect of paraquat was rapid, it being a desiccant, and superior to the rest. The phytotoxic effect of both glyphosate and 2,4-D was considerably slower being observed at 2 to 4 days after application. An explanation can be found in thier mode of translocation. Glyphosate and 2,4-D are 'phloem mobile' herbicides and may tend to accumulate in the upper parts of the parasite, i.e. in the meristematic parts, leaving the lower portion of the plant unscathed for a time. Glyphosate is also very expensive being twice the cost of paraquat and thrice the cost of 2,4-D. However, the mixture of glyphosate and 2,4-D will be much cheaper and can be a good substitute if the safety of paraquat is called into question.

Grain yields were much improved by the use of paraquat in both crops. Yield of paraquat treated plots were significantly better than either that of the control, 2,4-D handpulling or glyphosate in the sorghum trial.

To assess a tentative control package for Striga *in sorghum*

The results of the two trials at Sololor and Daba kunda are shown in Table 5. The package proved to be much superior to farmer's practice. There was 119% increase in yield of the package over the farmers practice at Sololor. Corresponding yield increase at Daba kunda was 37%. Populations of *Striga* were reduced to insignificant levels by the combined action of the resistance variety and the spot treatment of shoots with paraquat.

The control package was very promising and it will be extended to several villages in due course.

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