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The effectiveness of *Celosia argentia* (*Striga* "chaser") to control *Striga* on Sorghum in Uganda

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Abstract

Field, screen house and laboratory studies were carried out to assess the capacity of *Celosia argentia* to control *Striga* on sorghum in Uganda. The field experiment was aimed at determining the effectiveness of inter-planting *Celosia argentia* into sorghum in the suppression of *Striga* and increasing sorghum yield. The screen house experiment looked at the optimum proportion of *C. argentia* to be inter-planted into sorghum to effectively suppress *Striga* and maintain a good sorghum yield. The laboratory study was to quantify the capacity for *C. argentia* to effect *Striga* seed germination.

Inter-planting *C. argentia* into sorghum reduced *Striga* emergence by an average of 55% in a season and increased the yield of a susceptible sorghum variety in the field by 35% compared to the sole sorghum treatment. Results of the screen house experiment showed that inter-planting *C. argentia* into sorghum at a ratio of 2:1 suppressed *Striga* best by as much as 48% and resulted in the highest yield increase (100%) compared to the sole sorghum treatment. The laboratory study showed that *C. argentia* could induce suicidal germination in *Striga* seed by as much as 68% compared to cotton which was taken to be the standard.

Keywords: *Celosia argentia*; *Striga*; *Sorghum bicolor*

1. Introduction

Witchweeds (*Striga* spp.) are root hemi-parasites which cause significant loses to food crops in Asia and Africa. In Africa, up to 45 million ha of arable land is threatened by these weeds (Sauerborn, 1991). In Uganda, there are two species of economic importance; *Striga hermonthica* and *Striga asiatica*. The former, which is the most widely distributed *Striga* species in Uganda, severely affects sorghum yield, the third most important cereal crop in the country. Yield loses at individual farms are estimated at 60–100% (Anonymous, 1997). Small-scale farmers are the most severely affected by *Striga* because they have limited ways and means of controlling it. Current farming practices including; intensive cultivation of small pieces of land with shortened or no fallow (Webb et al., 1993) and continuous cereal cropping have led to a rapid decline in soil fertility and a build up of *Striga* seed in the soil seed bank.

Effective and economically affordable means of *Striga* management for small-scale farmers are not presently available in Uganda. During a survey conducted by the National Agricultural Research Organisation (NARO) in 1997, to quantify the *Striga* problem in eastern Uganda, farmers pointed out an age old practice of inter-planting a *Striga* "Chaser" into sorghum for the control of *Striga* (Anonymous, 1997). This plant was correctly identified at the Department of Botany herbarium in Makerere University as *Celosia argentia* (Amaranthaceae).

No comprehensive study has been conducted to determine the effectiveness of *C. argentia* in suppressing *Striga*. In experiments done in Nigeria however, *Celosia argentia* was found to suppress weeds more than weeding twice when inter-planted into chewing cane (Busari et al., 1997). In sorghum, the mechanism by which *C. argentia* affects *Striga* infestation is not known but is hypothesised to be through stimulation of *Striga*

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seed germination. The objectives of this study were therefore: (a) to evaluate the effect of inter-planting *C. argentia* into sorghum in the suppression of *Striga* infestation, (b) determine the optimum proportion of *C. argentia* to be inter-planted into sorghum to effectively reduce *Striga* infestation while maintaining increased sorghum yield and (c) to find out the effect of *C. argentia* on *Striga* seed germination.

2. Materials and methods

2.1. Field experiment: the effect of inter-planting C. argentia into sorghum on Striga emergence and sorghum growth and yield

The objective of this experiment was to evaluate the effect of *C. argentia* in suppressing *Striga* and increasing sorghum yield in the field. An established trap crop, cowpea was used as a basis of comparison. The land was ploughed twice using an ox-plough. Plots measuring 5.6 m $\times$ 5 m were marked out. Three treatments were applied as follows:

(i) Cowpea inter-planted into sorghum.
(ii) *Celosia argentia* inter-planted into sorghum.
(iii) Sorghum planted alone (control).

Sorghum was spaced at 60 cm between rows and 20 cm between plants. Cowpea and *C. argentia* were planted in between the sorghum rows in equal proportion to the sorghum crop giving a 1:1 inter-crop: sorghum ratio. Thinning was done 2 weeks after crop emergence leaving two plants per hole. The experiment was weeded twice, at 2 weeks and 4 weeks after crop emergence. The experimental design was a randomised complete block. This experiment was conducted for three seasons (first rains 1999, second rains 1999 and first rains 2000). In the first rains of 1999, the experiment was replicated five times in one farmer's field while in the second rains, 1999 and first rains, 2000, the experiment was replicated twice in each of the five farmers' fields totalling to ten replications in order to acquire more reliable *Striga* emergence data. Data were collected on *Striga* emergence, sorghum growth parameters (days to 50% flowering and plant height), number of harvestable heads per plot and grain yield.

2.2. Screen house experiment: to determine an appropriate C. argentia/sorghum interplanting ratio, which can effectively suppress Striga and maintain increased sorghum yield

A pot experiment was established in the screen house to determine an appropriate *C. argentia*/sorghum inter-planting ratio, which can effectively suppress *Striga* and maintain increased sorghum yield. The pots measured 23 cm diameter at the top and 30 cm heigh.

Filter papers were placed at the bottoms of 36 perforated plastic pots in order to avoid loss of *Striga* seeds through drainage. Each pot was filled with sandy loam soil collected from Serere Agricultural and Animal production Research Institute (33° 27′E 1° 31′N; 100 m above sea level) (Department of Lands and Survey, 1967).

Eighteen (18) of the pots were infested with 0.2 g of 8 months old *Striga hermonthica* seeds collected from Kumi district in eastern Uganda. The *Striga* seeds were collected on sorghum hosts in farmers' fields. The *Striga* seeds were placed 8 cm below the surface of the soil. The other 18 pots were left un-infested. The pots were watered on the first day of infestation and then later after 4 days in order to condition the *Striga* seeds. After 7 days, *C. argentia* and sorghum were planted in all the thirty six pots. Each pot was provided with 0.25 g of NPK fertilizer and watered. Two weeks after emergence, the plants were thinned leaving the following *C. argentia* : sorghum inter-planting ratios, which were to be tested: 1:1, 1:2, 1:3, 2:1, 3:1, 0:1 (sole sorghum).

The experiment was arranged in a completely randomised design and replicated three times. Watering was done after every 2 days until the end of the experiment. Weeds were controlled by hand removal. Data were collected on *Striga* emergence per pot, sorghum flowering, sorghum plant height at flowering, sorghum shoot dry matter per plant and sorghum grain yield.

2.3. Laboratory experiment: to determine the influence of C. argentia on Striga seed germination

In this experiment, *C. argentia* was compared with known *Striga* germination stimulants i.e. cotton, cowpea, Seredo an improved sorghum variety tolerant to *Striga* and Inoke a *Striga* susceptible local sorghum variety. The effect of *C. argentia* was determined using a method adapted from Abayo et al. (1997). The test plants were grown in pots filled with sand for 14 days in the screen house. Eight months old *Striga hermonthica* seeds were surface sterilised in the laboratory for 5 min using 1% sodium hypochlorite solution and washed with distilled water. The seeds were then conditioned by soaking in 30 ml distilled water and incubated in the dark at 28°C for 14 days. After 14 days, the test plants were gently up rooted, their roots washed with distilled water and cut into 1 cm lengths.

Two moistened regular filter papers were placed in each of six petridishes of 9 cm diameter. An aluminium foil ring of 1 cm diameter and 1.5 cm height was placed in the centre of each petridish. One gram of root pieces of test plants were placed in the centres of the aluminium foil rings. Each petridish contained one test plant with the sixth petridish treated with only distilled water. Discs of regular filter paper, 6 mm in diameter, containing 30–40 conditioned seeds of *S. hermonthica* each, were placed around each ring in four rows running perpendicular to the ring to form a cross. Each row contained three discs placed edge to edge with the first disc touching the edge of the ring. This was to account for distance away from the stimulant source. The disc closest to the central ring was considered as "distance 1", the second as "distance 2" and the third as "distance 3" (Abayo et al., 1997). Since each disk was 6 mm in diameter, distances 1–3 were taken to be from the edge of the centre ring to the middle of each disc, i.e., 3, 9 and 15 mm respectively.

Since these distances were equidistant, the degree of germination was to be an indication of the amount of germination stimulant produced by the test plant. The distances were therefore also independent variates just as the different crops and replications. The rows were treated as replicates. Three millilitres of distilled water was added to the roots in each ring. Distilled water was considered to be the negative control while the susceptible sorghum variety was considered to be the positive control. The petridishes were covered and kept in the dark at room temperature for 48 h. After 48 h the discs were taken out so as to count germinated *Striga* seeds under a microscope at low power (×16 magnification). The germinated seeds out of the total number of seeds in each disk were counted. Percent germination induced by each crop at each distance was computed.

Table 1
The effect of inter-planting *Celosia argentia* and cowpea into sorghum on *Striga* emergence

Treatment	*Striga* emergence[a] (plants/m^2)			
	1999a	1999b	2000a	Mean
Cowpea/sorghum	8.6[b]	4.4[b]	33.0[b]	15.3
C. argentia/sorghum	13.5[b]	7.1[b]	34.4[b]	18.3
Sorghum(sole)	24.6	21.1	76.7	40.8
C.V. (%)	26.3	12	6.1	

[a] Analysis based on transformed data. Means presented as original data.
[b] Significantly low, L.S.D. (5%).

2.4. Data analysis

Data for all the three experiments described above were analysed using Genstat 5 release 3.2 statistical package.

3. Results and discussion

3.1. Field experiment: the effect of inter-planting C. argentia and cowpea into sorghum on Striga emergence and growth and yield of sorghum

Inter-planting *C. argentia* and cowpea into sorghum consistently reduced *Striga* emergence compared to where sorghum was planted alone for all the three seasons of this study (Table 1). The difference in *Striga* suppression between cowpea and *C. argentia* was not significant in all the seasons but cowpea suppressed *Striga* slightly more than *C. argentia*. *C. argentia* reduced *Striga* emergence by an average of 55% in a season compared to the sole sorghum treatment. The effect of cowpea in suppressing *Striga* had earlier been reported (Ariga et al., 1997a; Obilana and Ramaiah, 1992). These inter-crops reduce *Striga* emergence by inducing suicidal germination of *Striga* seeds. Cowpea, being a leguminous crop, additionally fixes nitrogen into the soil, which further suppresses *Striga* development.

The early growth stages of sorghum i.e. time of flowering and plant height at flowering were not significantly affected by the different treatments in all the three seasons of this study (data not shown). This shows that inter-planting sorghum with *C. argentia* or cowpea has no effect on the early growth stages of sorghum. However, the later growth stages of sorghum (heading and grain yield) were clearly affected by the treatments (Table 2). The number of harvestable heads per plot was significantly affected by inter-planting particularly during the first rains of 2000. Inter-planting *C. argentia* into sorghum gave a significantly higher number of sorghum heads per plot compared to the other treatments. Sorghum grain yields were generally lower than expected particularly in the second rains of 1999 and first rains of 2000. This was due to low rainfall and pests and diseases. In the second rains of 1999, the

Table 2
The effect of inter-planting *Celosia argentia* and cowpea into sorghum on sorghum yield

Treatment	No. heads per plot				Grain yield (kg/ha)			
	1999a	1999b	2000a	Mean	1999a	1999b	2000a	Mean
Cowpea/sorghum	268.8	223	151	214.3	413	163	134	236.7
C. argentia/sorghum	294	224	229	249	697	186	168	350.3
Sorghum(sole)	294	174	119	195.7	674	153	93	306.7
s.e.d	19.3	30.3	26.4		102.5	46.2	30.1	
C.V. (%)	10.7	44.6	33.7		31.6	82.3	48.4	

average rainfall during the growing period was 87 mm and in the first rains of 2000 it was 96.5 mm. No measure was taken to control pests and diseases.

However, inter-planting *C. argentia* into sorghum maintained higher sorghum grain yield than other treatments in all the three seasons of the study. In the first rains of 1999, inter-planting cowpea into sorghum resulted in the lowest sorghum grain yield. This is because cowpea grew much vigorously and exerted greater competition on sorghum. During the second rains, 1999 and first rains, 2000, the sole sorghum treatment gave the lowest yield. Cowpea did not exert much competition because the amount of rainfall was so low to enable it grow vigorously.

3.2. The screen house experiment

3.2.1. The effect of different sorghum:C. argentia inter-planting ratios on Striga emergence

Striga emergence was influenced by the different sorghum:*C. argentia* inter-planting ratios (Table 3). The lowest emergence value of three *Striga* plants/pot was recorded where the proportion of *C. argentia* was high i.e. 1:3 and the highest value of 11 *Striga* plants/pot was recorded in the treatment where *C. argentia* was lowest i.e. 3:1. In general, the number of *Striga* plants that emerged increased with time with the lowest being recorded at 5 weeks after emergence of sorghum. The results show that increasing the population of *C. argentia* relative to sorghum suppresses *Striga*.

Table 3
The effect of different proportions of sorghum and *C. argentia* on *Striga* emergence[a]

Sorghum/*C. argentia* ratio	*Striga* emergence (plants/pot)			
	Weeks after crop emergence			
	5	7	9	Mean
1:1	4	12	12	9
2:1	6	13	12	10
3:1	7	13	12	11
1:2	1	6	7	5
1:3	1	4	4	3
1:0	3	12	12	9
C.V. (%)	7.5	14	16	

[a] Analysis based on transformed data. Means presented as original data. L.S.D (5%) not significant.

3.2.2. The effect of different sorghum: C. argentia inter-planting ratios on the growth and yield of sorghum

All growth and yield parameters of sorghum were influenced by both *Striga* infestation and inter-planting ratio (Table 4).

3.3. Sorghum flowering

In the pots infested with *Striga*, sorghum failed to flower for most of the inter-planting ratios except for the 1:1 and 1:2 sorghum:*C. argentia* inter-planting ratios. These flowered 12 and 16 days late compared to the same ratios that were not infested with *Striga* respectively. There were no significant differences in flowering among the non-infested treatments.

3.4. Plant height

Sorghum plant height was significantly affected by the different treatments. The treatments infested with *Striga* had significantly shorter sorghum plants compared to the non-infested treatments. Among the infested treatments, the 1:2 and 1:1 sorghum:*C. argentia* inter-planting ratios had significantly taller sorghum plants particularly when compared with the 2:1 and 3:1 inter-planting ratios. There were no significant differences in sorghum height between the different inter-planting ratios under non-*Striga* infestation.

Table 4
The effect of different proportions of sorghum and *C. argentia* on the growth and yield of sorghum under *Striga* infestation and non-*Striga* infestation

Sorghum/*C. argentia* ratio	Infested pots					Non-infested pots				
	Days to flower	Plant height (cm)	Dry matter per plant (g)	Grain yield per plant (g)	Grain yield (kg/ha)	Days to flower	Plant height (cm)	Dry matter per plant (g)	Grain yield per plant (g)	Grain yield (kg/ha)
1:1	96	73.7	7.4	1.12	269.6	84.0	157.7	25.3	9.9	2382.7
2:1	—	25.8	2.9	0.0	0.0	85.8	132.3	15.0	3.8	914.6
3:1	—	25.0	2.2	0.0	0.0	85.0	125.7	15.0	3.8	914.6
1:2	93	80.0	8.8	1.5	361.0	77.3	146.0	25.0	8.9	2141.9
1:3	—	38.4	4.4	0.0	0.0	80.7	158.0	26.4	6.7	1612.9
1:0	—	42.7	8.9	0.0	0.0	81.0	146.3	30.4	9.3	2238.3
Mean	94.5	47.6	5.8	0.44	105.1	82.3	144.3	22.9	7.1	1700.8
s.e.d	2.9	22.6	1.4	2.3	56.2					
C.V. (%)	4.3	34.3	30.1	40.3	58.6					

— Did not flower at all.

3.5. Dry matter

The differences in dry matter per plant of sorghum were significant between the different treatments. The treatments under *Striga* infestation had significantly low dry matter per plant of sorghum compared to those without *Striga* infestation. Among the treatments under *Striga* infestation, the 1:2, 1:1 and 1:0 sorghum:*C. argentia* inter-planting ratios had significantly high dry matter per plant of sorghum compared to the other ratios. For the treatments without *Striga* infestation, 2:1 and 3:1 sorghum:*C. argentia* inter-planting ratios gave significantly lower dry matter per plant of sorghum compared to the other ratios.

3.6. Grain yield

As in flowering, sorghum failed to produce grain in infested treatments for most of the sorghum:*C. argentia* inter-planting ratios except for the 1:2 and 1:1 ratios. Under *Striga* infestation, 1:2 sorghum:*C. argentia* inter-planting ratio gave a higher grain yield both per plant and in kg/ha than the 1:1 ratio. In treatments without *Striga* infestation, 1:1, 1:2 and 1:0 sorghum:*C. argentia* inter-planting ratios resulted in higher grain yields per plant than 2:1, 3:1 and 1:3 ratios. Considering grain yield in kg/ha, 1:1 and 1:2 sorghum:*C. argentia* inter-planting ratios had higher sorghum grain yields despite having low sorghum populations compared to other treatments like 2:1 and 3:1 inter-planting ratios.

Basing on *Striga* emergence, sorghum plant height, sorghum dry matter per plant and sorghum grain yield, the appropriate sorghum:*C. argentia* inter-planting ratio, which can effectively suppress *Striga* and maintain increased sorghum yield is 1:2.

3.7. The laboratory experiment: the influence of C. argentia on Striga seed germination

C. argentia and all other crops tested stimulated *Striga* seed germination (Table 5). The crops differed significantly in their abilities to stimulate *Striga* seed germination. The susceptible sorghum variety stimulated *Striga* germination much more than all other crops and was closely followed by cotton though the difference between the two was not significant. The capacity of cotton and other trap crops to stimulate *Striga* seed germination has been reported (Abayo et al., 1997; Ariga et al., 1997b). However, no information has been reported for *C. argentia*.

In this study, it has been demonstrated that *C. argentia* can also induce *Striga* seeds to germinate. It is suggested that the differences in percent germination of *Striga* seeds induced by different crops is due to different amounts of germination stimulant produced.

Table 5
Percent *Striga* seed germination as induced by *C. argentia* and selected trap crops

Crop/plant	% germination of *Striga* seeds			
	Distance 1 (3 mm)	Distance 2 (9 mm)	Distance 3 (15 nm)	Mean
C. argentia	1.48	2.58	5.67	3.24
Cotton (BPA 97)	14.48	11.4	4.6	10.16
Cowpea (Ebelat)	0.35	0.85	0.93	0.71
Seredo (improved sorghum)	5.33	6.78	5.65	5.92
Inoke (susceptible sorghum) (positive control)	15.25	9.33	7.55	10.71
Distilled water (negative control)	0.0	0.0	0.0	0.0
Mean	6.15	5.16	4.07	
s.e.d[a]	1.5			
s.e.d[b]	1.7			
C.V. (%)	60			

[a] Differences between treatments/crops.
[b] Differences between distances.

Crops which stimulated more *Striga* seeds to germinate possibly, produced more germination stimulant. The differences in percent germination of *Striga* seeds between the three distances away from stimulant source was not significant. However, for most crops, the percentage seemed to decrease with distance while for *C. argentia* and cowpea, it seemed to increase with distance. This possibly suggests the presence of germination inhibitors in *C. argentia* and cowpea root exudes such that dilution away from the stimulant source seemed to change the balance in favour of germination stimulants. The germination stimulants in cotton, cowpea and sorghum have been isolated and reported (Hauck et al., 1992; Muller et al., 1992). This has not been done for *C. argentia*. It is necessary that the germination stimulant produced by *C. argentia* also be isolated and characterised.

4. Conclusions

Celosia argentia reduces *Striga* emergence on sorghum by 55% and increases the yield of a susceptible sorghum variety by 35% in the field. The use of *Celosia argentia* in *Striga* control would result in increased sorghum productivity without a matching increase in cost of production. The appropriate inter-planting ratio between sorghum and *Celosia argentia* is 1:2, respectively. *Celosia argentia* can induce suicidal germination of *Striga* seeds; therefore, it can be used in short-term fallows to reduce *Striga* seed numbers in the soil.

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