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Research Article

Striga asiatica L. Moench Management in *Sorghum bicolor* L. Moench using Organic and Inorganic Nutrient Sources in Zimbabwe

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Abstract

Background and Objective: Management of *Striga asiatica* is a challenge under Zimbabwe's small holder sector. The aim was to determine the effects of quantities of diammonium phosphate (DAP) fertilizer and cattle manure on *Striga* infestation of the two sorghum varieties: Tsweta and Macia common to Zimbabwe. **Methodology:** A $2\times2\times3$ factorial experiment laid down as a completely randomized design was set up in a controlled environment at Henderson Research Station in Zimbabwe. The first factor was variety at two levels: Macia and Tsweta, fertiliser at two levels: Diammonium phosphate and cattle manure. **Results:** The results indicated that the rates of 320 and 160 kg ha^{-1} of diammonium phosphate reduced *Striga asiatica* emergence by 13 and 11 weeks, respectively. The application of DAP reduced *Striga asiatica* attachments and the reduction was higher in Tsweta than Macia cultivar. In contrast, the different rates of manure had no effect ($p>0.05$) on *Striga* attachments. Contrary to the stunted growth in control pots DAP increased growth of sorghum under infestations. There were varietal differences in the response of sorghum to manure application. **Conclusion:** The DAP offered protection to the sorghum cultivars from *Striga asiatica* during the early stages of growth. The DAP can thus protect sorghum from the *Striga* scourge even when applied at half the conventional rate. Infested sorghum gave higher yields when fertilized by both DAP and cattle manure although the increase was greater on DAP compared to manure. Manure also protects sorghum from *Striga* but to a lesser extent when compared to DAP.

Key words: Sorghum, *Striga asiatica*, diammonium phosphate, yield, cattle manure

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sorghum is one of the five major cultivated species in the world because it has several important uses such as food, feed, fuel and fiber production[1]. Grain sorghum is one such cereal host crop that can seriously be damaged by the effects of *S. asiatica* common in Zimbabwe. *Striga* species are obligate hemi-parasites that attach to the root of their host to obtain water, nutrients and carbohydrates[2]. The parasite attaches to the root of sorghum by a haustorium which abstracts water, nutrients and organic solutes from the host xylem and phloem vessels[3]. According to Berner *et al.*[4] infestations result in severe grain losses estimated to be US$7 billion annually for sub-saharan Africa.

Nitrogen and phosphorus deficiency as well as water stress accentuate the severity of *Striga* damage to the hosts[5]. Degraded soils, nutrient depletion and low soil fertility conditions are recognized as the major drivers responsible for low sorghum production in sub-saharan Africa[6]. Generally, sorghum is grown by smallholder farmers whose capital investments in agriculture are low hence nutrient supplementation to the soil is reduced. Soil fertility improvement through addition of major nutrients such as N and P cannot be afforded by farmers in the sector. Yoneyama *et al.*[7] and Lopez-Raez *et al.*[8] have shown that increased secretion and exudation of strigolactones which are germinating stimulants by host roots occurs when the crop is grown in soils that are deficient in nitrogen and phosphorus.

In sub-saharan Africa, sorghum farmers lack the ability to finance sorghum cultivation. The application of diammonium phosphate and manure would augment soil fertility that results in improved plant fitness and crop yield. The farmers may not afford the full recommended rates of the diammonium phosphate hence the need to take up reduced rates. It is known that the application of fertilizer increases the host yield but is not known how reduced fertilizer and manure application affect the *Striga* populations[9]. Sorghum varieties may be genotype specific in terms of their response to fertilizer application so it is the objective of this research to determine the response of the sorghum genotypes on *Striga* emergence and sorghum growth and yield traits.

MATERIALS AND METHODS

Study site: The trials were carried out at Henderson Research Station at an altitude of 1295 m above sea-level, experiencing average daytime summer temperature range of 26-30°C, whereas night temperatures usually average 22-25°C. The area lies at latitude 17.34°S and longitude 30.58°E. The pot experiments were conducted in a greenhouse where temperatures averaged 35 and 15°C during the day and night respectively, and were repeated twice.

Experiment 1

Materials: Diammonium phosphate ($(NH_4)_2HPO_4$) (18% N, 46% P), a straight fertilizer obtained from Zimbabwe Fertilizer Company was used. Two local sorghum cultivars, Macia and Tsweta brown that were sourced from Genebank of the Department of Research and Specialist Services Harare, were used in the experiments. The two sorghum varieties, so chosen were locally used by most smallholder farmers in Zimbabwe as they are better adapted for most sorghum diseases. They are both medium-maturing varieties which are suited for production in medium and low rainfall areas. *Striga asiatica* seed was obtained from the University of Zimbabwe, Crop Science Department. Sandy-loam soil was used in the experiments. The soil was obtained from Domboshava Training centre, which is about 40 km north-east of Harare. Cattle manure was obtained from a cattle pen in Domboshava nearer to the training center. The farmers in the area use cattle manure for sorghum fertilization.

Experimental design: The experiment was a 2×2×3 factorial treatment laid down in a completely randomized design. The three factors were sorghum cultivar with two levels: Macia and Tsweta brown, *Striga* infestation with two levels: *Striga* infested sorghum and *Striga* free sorghum and diammonium phosphate (DAP) with three levels of microdoses of fertilizer of 0, 4 and 8 g which translate to 0, 160 and 320 kg ha^{-1}, respectively. The treatments were replicated three times and the experiment was repeated twice.

Experimental procedure: Plants were grown in 36 9 L pots each containing 7 kg of sandy-loam soil. Each pot had a base diameter of 15 cm, a top diameter of 20 cm and a perpendicular height of 18 cm. Infesting of the soil in pots that contained *S. asiatica* seeds was done. About 10 mg *Striga* seeds (about 3000 seeds) of *S. asiatica* were placed in each pot and mixed with the top 10 cm layer of soil in the pots. The seeds of *S. asiatica* were planted at the same time with five sorghum seeds of Macia and Tsweta brown planted separately in the pots before thinning to one sorghum plant per pot at 2 weeks after crop emergence (WACE).

Watering of pots from the day of planting was done every three days each pot receiving 4 L of tap water. Seven days after sorghum emergence, three microdoses of diammonium phosphate (DAP) were applied to three pots of each of the two sorghum cultivars in *Striga*-infested and uninfested pots at the rates of 0, 160 and 320 kg ha^{-1}.

Experiment II: The second experiment was a 2×2×3 factorial experiment and the only difference with the first experiment was that the fertilizer was cattle manure at the rates equivalent to 2, 4 and 6 t ha^{-1}. Manure was applied and mixed with the top 10 cm of the soil in the pot. For the infested pots 10 mg of *Striga* seeds were mixed with the top 10 cm of the top soil. All the other experimental procedures were the same. This experiment was repeated twice over time. The experiments were done on the same day and under the same conditions with the diammonium phosphate experiment.

Data collection: *Striga* parameters were determined alongside those of the sorghum cultivars. Days to first *Striga* emergence, *Striga* counts were done at 2 week interval from first *Striga* emergence.

Striga attachment on host sorghum roots per treatment was determined. *Striga* plants from each pot were detached from the sorghum roots at the time of harvest. The sorghum roots were washed under running water to remove soil debris and were left to dry in the sun for 30 min. The points of *Striga* attachment on the sorghum roots were counted.

Striga biomass was determined. They were placed in an oven and left to dry at 80°C over a period of 48 h. They were then taken out and their dry mass measured on a digital scale to determine the biomass.

Data analysis: Data from the two repeats of each experiment were pooled together before analysis. This was done after Bartlett's test for homogeneity of variance. All the data was subjected to normality and homogeneity of variance test using Genstat Version 14.0. Data was analyzed using the Generalized Treatment Structure in Randomized Replications. In the case where the data was not normally distributed, a logarithmic transformation was done, before carrying out the analysis of variance. The Fisher's protected LSD at 5% probability was used for mean separation, where the F-test was significant at 5% level of significance.

RESULTS

Days to first *S. asiatica* emergence: For cattle manure it took significantly less time for *Striga* to emerge at all the three rates compared to DAP (Fig. 1) for both sorghum

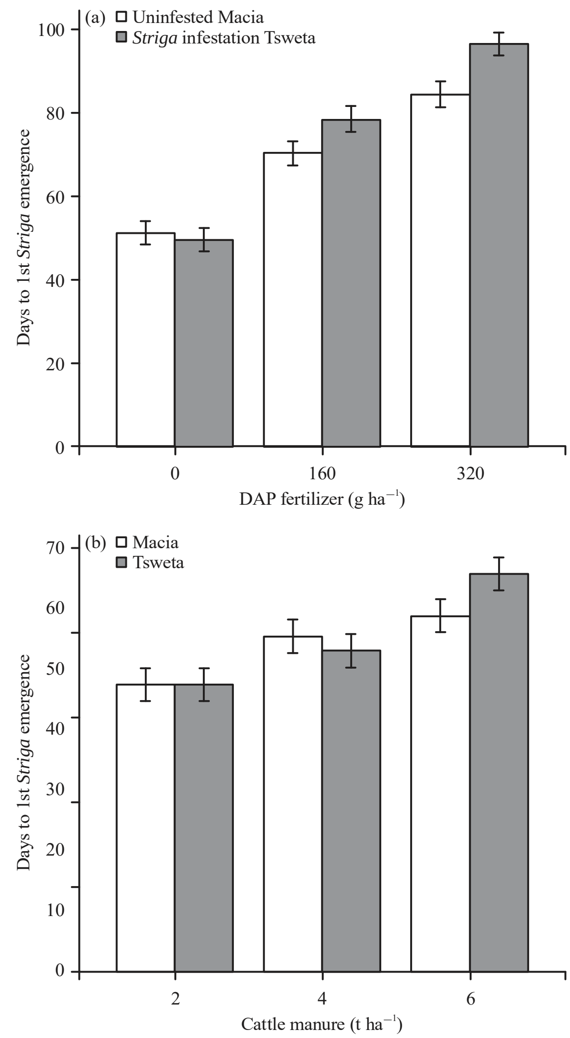

Fig. 1(a-b): Effect of (a) DAP fertilizer and (b) Cattle manure quantity on number of days to first *Striga* emergence

varieties. Application of manure at 2 t ha^{-1} gave the least number of days to *Striga* emergence compared to 4 and 6 t ha^{-1} (Fig. 1).

***Striga* attachment to sorghum roots:** *Striga* attachment to Macia roots was significantly greater ($p<0.05$) than to Tsweta brown (Fig. 2). Higher rate of DAP application resulted in significantly lower numbers of *Striga* attached to sorghum roots than in sorghum roots deficient of DAP (Fig. 2). Tsweta brown showed lower *Striga* attachment to its roots at each level of DAP application than in Macia (Fig. 2).

For manure increasing the rate of application did not affect *Striga asiatica* attachments to the sorghum roots (Fig. 2).

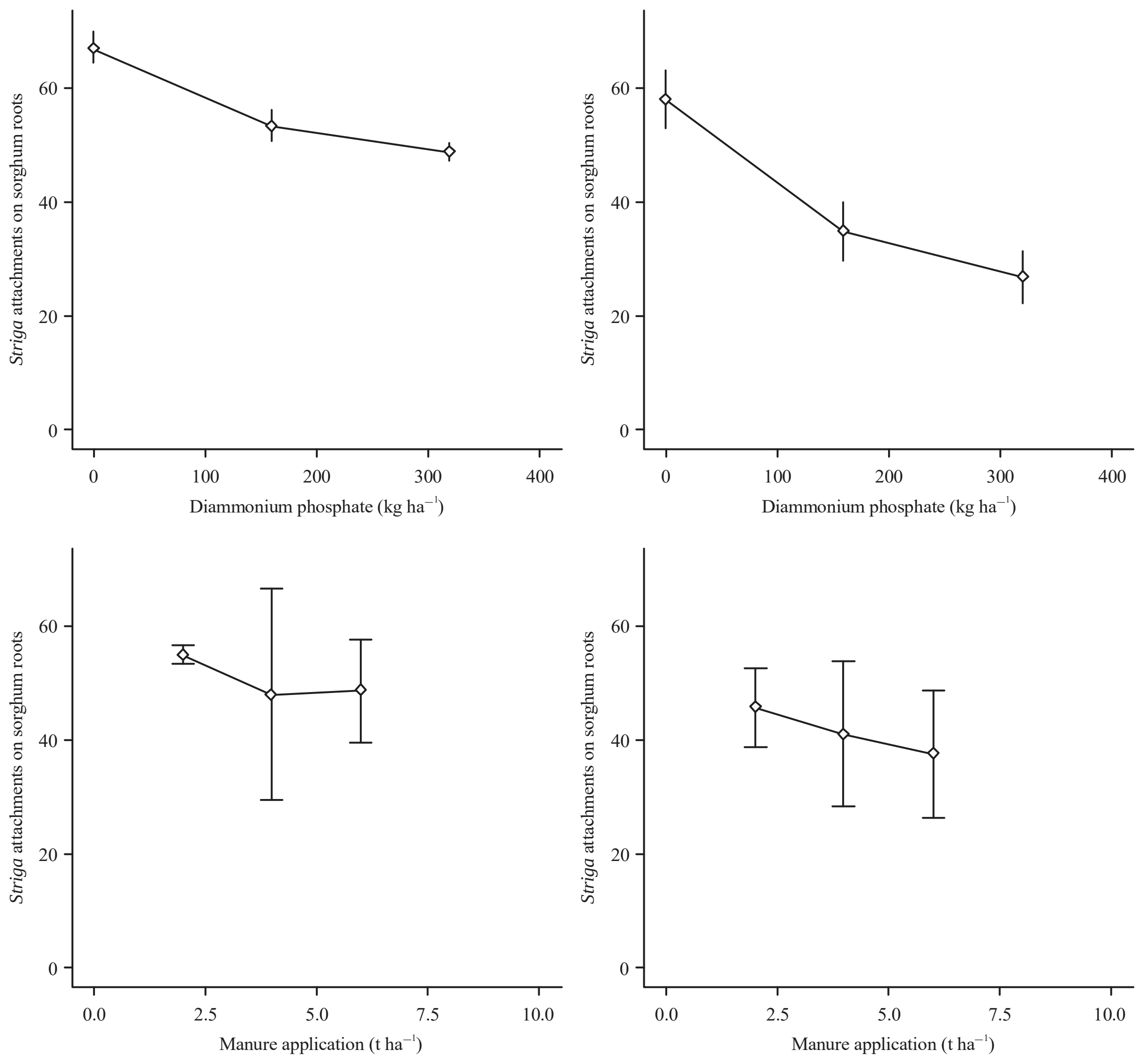

Fig. 2: Effect of the application of DAP and manure on *Striga* attachments on the roots of the sorghum cultivars Macia and Tsweta brown

Sorghum biomass: The DAP significantly ($p<0.05$) increased biomass for leaves, stems, roots and total biomass at each level of the three application rates (Table 1). For cattle manure, application rates of 2 t ha^{-1} gave less dry matter compared to 4 and 6 t ha^{-1} which were not different from each other for leaf, stem, root and total dry matter (Table 1). Yield significantly increased with increase in fertiliser rates.

DISCUSSION

The *S. asiatica* emergence took about 7 weeks from sorghum emergence in control pots while emergence was delayed by 11 and 13 weeks at application rates of 160 and 32 0 kg ha^{-1} of DAP, respectively. This was an indication that host sorghum plants in control pots readily released more host-root chemical stimuli called strigolactones which are the signaling compounds that trigger the germination of *Striga* seeds and subsequent emergence. *Striga* emergence was delayed by increased DAP quantities, implying that diammonium phosphate effectively suppressed early emergence of *S. asiatica.* Since phosphorus has greater proportion (46% P_2O_5) in relation to nitrogen (18% N) in diammonium phosphate, it has greater impact on delaying first *Striga* emergence than nitrogen. In contrast, addition of cattle manure at rates of 2, 4 and 6 t ha^{-1} delayed *Striga* emergence by 6, 7 and 9 weeks, respectively. For manure, phosphorus content is low and there is reduced mineralisation. This agreed with Esilaba *et al.*[10], whose research study revealed that the nitrogen level had little effect on *Striga* during the early stages of crop development

Table 1: Effect of cultivars, DAP and cattle manure on sorghum biomass and grain yield

Parameters	Leaf dry biomass (g plant^{-1})	Stem dry biomass (g plant^{-1})	Root dry biomass (g plant^{-1})	Total dry biomass (g plant^{-1})	Grain yield (g plant^{-1})
DAP(kg ha^{-1})					
0	10.82^{a}	10.67^{a}	48.00^{a}	69.50^{a}	6.53^{a}
160	18.69^{b}	16.29^{b}	125.80^{b}	160.70^{b}	15.57^{b}
320	22.44^{c}	19.39^{c}	167.70^{c}	209.50^{c}	22.45^{c}
p-value	<0.001	<0.001	<0.001	<0.001	<0.001
LSD (5%)	1.693	3.035	31.04	33.88	2.449
CV (%)	11.50	23.20	32.20	27.30	19.50
Cattle manure (t ha^{-1})					
2	10.14^{a}	11.61^{a}	53.07^{a}	74.80^{a}	5.11^{a}
4	12.84^{b}	16.50^{ab}	77.27^{b}	106.60^{b}	9.53^{b}
6	14.16^{b}	20.02^{b}	72.77^{b}	106.90^{b}	16.17^{c}
p-value	0.005	0.013	0.039	0.005	<0.001
LSD	2.294	5.39	19.42	20.54	1.744
CV (%)	21.90	39.70	33.90	25.20	20.10

as there were no significant nitrogen effects on *Striga* emergence in the first 10 weeks after planting. Tsweta brown responded more in the suppression of *S. asiatica* emergence than the Macia cultivar. The nitrogen and phosphorus in diammonium phosphate reduced the levels of the germination stimulants in the cultivar Tsweta brown during the early stages of growth that resulted in reduced *S. asiatica* emergence in the pots containing the sorghum cultivar.

Initial *S. asiatica* counts were lower at application rates of 160 kg ha^{-1} of DAP but after 12 weeks up to 16 weeks from sorghum emergence, counts out-numbered those in control pots by an average of 17.4% in Macia and 6.6% in Tsweta brown. This could be related to the availability of the nitrogen and phosphorus nutrients in the soil which later became depleted to account for the high production of the strigolactones by the sorghum hosts. These findings concurred with Jamil *et al.*[11], who suggested that the combined depletion of both nitrogen and phosphorus also gave a lower strigolactone secretion than in the case of just phosphorus deficiency. The rate of production of these strigolactones was lower in Tsweta brown than in Macia variety in later periods of sorghum growth. It entails that the production of strigolactones by the sorghum cultivars is considered to be proportional to *S. asiatica* germination and emergence[12]. For cattle manure, the rates did not affect *Striga* counts again reflecting reduced release of nutrients which suppress strigolactones production. The benefits of manure with respect to *Striga* counts were not apparent in this study

More *Striga* attachments were recorded on Macia roots than on Tsweta brown. This showed that Tsweta brown cultivar supported few attachments of the *Striga* parasites to the host roots and this could possibly be explained by a delay in the onset of parasitic attachments as elicited by low *Striga* emergence in the early stages of sorghum growth. DAP fertilizer significantly affected *Striga* attachment. The higher the DAP rate then the lower numbers of *Striga* attached on sorghum roots. This was because of the presence of both N and P in DAP that had the inhibitory effects on the production of the haustorium initiation factors that lead to *Striga* attachment[13].

Tsweta brown showed significantly higher root and total biomass than Macia and plants grown in 320 kg ha^{-1} DAP gave significantly larger root and total biomass. However, *S. asiatica* had no impact on root and total biomass even in interactions with other factors such as cultivar and/or DAP. This could be explained by the fact that nutrient supply to the root components was not affected by the presence or absence of *S. asiatica* where root biomass was a larger contributor to total sorghum biomass. This finding agreed with Timko *et al.*[14], who postulated that the partitioning of the food components to root tissues was similar in sorghum plants under *Striga* or no *Striga* parasitic infestation.

In contrary to biomass yields of sorghum explained above, Macia exhibited tolerance to *Striga* infestation as it out-yielded Tsweta brown by 26 and 35.6% in grain in conditions of medium and high DAP dosages, respectively. The system that would improve soil condition to increase crop yield as well as reduce *Striga* seed production will be of double advantage[9]. Macia variety elicited more bias to accumulation of photo-assimilates to harvestable products, that is grain, than Tsweta brown at the expense of bio-accumulation of dry matter in plant parts. These findings agreed with Gurney *et al.*[15] who noted that the highest *Striga* infestation did not necessarily translate into the least yield but indicated that the level of *Striga* biomass on a host influences host productivity but the relationship is non-linear, that is, a point is reached where host grain production is independent of parasite biomass.

CONCLUSION

Cattle manure reduces days to *Striga* emergence by 7, 8 and 9 weeks for 2, 4 and 6 t ha^{-1}. The application of DAP reduced *Striga* attachments to sorghum roots where this reduction was higher in Tsweta brown than in Macia cultivar. Farmers operating in areas threatened by the *S. asiatica* parasites should apply the DAP fertilizer at the rates of between 160 and 320 kg ha^{-1} to ensure late emergence of the *Striga* parasites. Higher DAP rate of 320 kg ha^{-1} is recommended in the growing of Macia cultivar in *Striga*-infested conditions and can maintain its stem biomass and grain yield even under infestation.

SIGNIFICANCE STATEMENT

The DAP is better in delaying *Striga asiatica* emergence compared to cattle manure. Increasing DAP from 160-320 kg ha^{-1} reduces *Striga asiatica* attachments to both varieties whilst cattle manure did not. Both fertilisers increased yield of sorghum despite infestation by *Striga asiatica*.

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