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Full Length Research Paper

Striga asiatica growth and seed production in response to organic and inorganic P - fertilizers

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The measures for *Striga* management are hindered by a unique survival strategy of the weed, whereby it produces large amount of seeds. Therefore, prevention of further build up of the *Striga* seed bank through control measures remains an essential component in *Striga* control. The influence of fertilizers on *Striga* seed production was studied for two consecutive years (2009/2010 and 2010/2011) at Hombolo Research Station-Dodoma, Tanzania. Farmyard manure (5.9 tons/ha equivalent to 50 kg N/ha), chicken manure (2.5 tons/ha equivalent to 50 kg N/ha), urea (50 kg N/ha) and triple superphosphate (TSP) (40 kg P/ha) were tested on sorghum variety Macia in a randomized complete block design replicated four times. *Striga* plants supplied with chicken manure, urea and TSP had significantly fewer *Striga* capsules per plant than farmyard manure treated and control (without fertilizer application) plants. However, the mechanism by which phosphorus application reduced *Striga* reproduction in the current study is yet unclear. Based on this study, fertilizers have the potential to reduce *Striga* reproduction. Even though fertilizers play a significant role in *Striga* reproduction, calculations of the seed production per *Striga* plant indicated that considerable amounts of seeds were still added to the soil.

Key words: *Striga asiatica*, growth, organic, inorganic, P- fertilizer.

INTRODUCTION

The witchweed (*Striga asiatica*) is a parasitic weed that affects cereals including sorghum (Kabambe et al., 2007). This weed competes for water and nutrients as a root parasite. In so doing, crop growth is stunted and yields are generally reduced (Ayongwa et al., 2010). Despite many years of research, *Striga* still remains a weed of economic importance affecting livelihoods of millions of people in Africa (Franke et al., 2006). The weed is responsible for keeping crop productivity in many regions of Africa below subsistence levels (Dudje et al., 2008). *Striga* occurs in Sub-tropical areas with an annual rainfall ranging from 300 to 1200 mm. However, it may be able to adapt to agro-climatic conditions outside its current distribution range and to other crop species (Mohamed et al., 2006). The measures for *Striga* management are hindered by a unique survival strategy of the weed, whereby it produces large amount of seeds (Kudra et al., 2012).

A number of studies found that *Striga* infestation decreased with application of organic or inorganic fertilizers (Lagoke et al., 1991; Kwacha, 2001; Ahonsi et al., 2002, 2004; Patil, 2007; Avav et al., 2009; Hassan et al., 2006). However, all these studies did not provide any insight into the influence of fertilizers on *Striga* reproduction and long term effect on the *Striga* seedbank. In a study by Lagoke et al. (1991), it was observed that application of high fertilizer dosages of up to 120 kg N/ha resulted in 93% reduction in *Striga* incidence. Plots treated with poultry manure had significantly higher *Striga* emergence than urea treated and the non-treated control plots (Ikie et al., 2007). Parker (1984) reported that nitrogen tended to reduce the production of stimulants (strigol) by the host crop and delay *Striga* emergence. Riches (1998) reported that the timing of fertilizer applications even in small doses was effective on the plant's ability to cope with *Striga*.

Van Mourik (2007) reported that application of 2 ton/ha, organic manure did not have a significant effect on *Striga* seed production and long-term effect on *Striga* seed bank. However, one study of a single fertilizer type cannot be used to generalize the influence of fertilizers on *Striga* reproduction and long-term effect on seed bank. Therefore, the current study was conducted to determine the influence of both organic and inorganic P-fertilizers on *Striga* reproduction.

MATERIALS AND METHODS

Experimental site

Two years' (2009/2010 to 2010/2011) field trials were conducted at Hombolo Research Station, situated 40 km off Dodoma town, the capital city of Tanzania. The site is semi-arid, characterized by erratic and unreliable rainfall with the annual average rainfall ranging from 400 to 750 mm and a mean annual temperature of 30°C (URT, 2002).

The unreliability of rainfall and its high intensity over a short period of time (December to February) is an important factor in determining the land use pattern. The rainy season is from November to April with a long dry season from May to October. The soil type of the area can be described as thin stony soils with predominantly sand or sandy clay (URT, 2002). Figure 1 represents the cumulative rainfall (mm) during the cropping season of 2010 and 2011 at Hombolo Research Station.

Prior to manure application, samples of organic manures were collected and analyzed for pH, organic carbon, N and P at Sokoine University of Agriculture Soil Laboratory (Table 1).

Treatments and experimental design

The host species in this study was sorghum (*Sorghum bicolor*), because it is the most important host for *Striga* reproduction (Rodenburg, 2005). Sorghum, variety Macia was planted in a field naturally infested with *Striga asiatica* at Hombolo Research Station. Sorghum was hand planted at a distance of 0.8 × 0.3 m with four to six seeds per hole. Sorghum plants were then thinned to one plant per hole at two weeks after planting (WAP).

Throughout the growing season, experimental plots were kept free of weeds other than *Striga asiatica* using hand hoe and hand pulling methods. The phosphorous treatments consisted of 40 kg P_2O_5 ha^{-1} applied as triple superphosphate (TSP), urea at 50 kg N/ha, while the sources of organic manure were chicken and farmyard manure (FYM). Based on the analysis (Table 1), chicken manure was applied at a rate of 2.5 tons/ha while farmyard manure was applied at a rate of 5.9 tons/ha. Each of these rates provided an equivalent of 50 kg N/ha. Organic fertilizers were incorporated into the experimental plots three weeks prior to planting while 30% of inorganic fertilizers were applied at sowing and the remaining 70% were applied three weeks after crop emergence. All treatments were laid out in a randomized complete block design replicated four times. Experimental plot size was 5 × 3.2 m. In 2010/2011 cropping season, the treatments were placed in the same plots they were during the 2009/2010 season.

Data collection

Striga plant counts were done every two weeks in each experimental plot after *Striga* emergence. Total dry weight of *Striga* plants/m^2 was determined by harvesting all *Striga* plants per plot and drying in an oven at 80°C for 48 h in paper bags. *Striga* reproduction was determined by sampling 10 mature but unopened, green seed capsules from five randomly selected *Striga* plants in each plot (that is, two seed capsules/plant) just before the harvest and packed separately in paper envelopes. These seed capsules were air dried for one week, weighed and the final weight determined by deducting 10% of the weight as a correction factor for unremovable trash. The average weight per capsule was divided by 5 × 10^{-6} (average *Striga* seed weight, Berner et al., 1997) to get an estimate of the seed production per capsule. The number of capsules per plant was counted for estimation of seed production per plant.

Data analysis

The data collected were subjected to analysis of variance (ANOVA) using GenStat (12^{th} edition). Treatment mean comparisons were done using the least significant difference test at 5% probability level. Correlation analyses between *Striga* numbers, *Striga* biomass, *Striga* capsules/plant, were done using SPSS software package (Version 15). Prior to analysis, values of emerged *Striga* plants were square root $(x + 0.5)^{1/2}$ transformed to normalize data (Gomez and Gomez, 1984).

RESULTS

Effect of fertilizers on *Striga* numbers

Fertilizers had a significant ($P \leq 0.05$) effect on *Striga*

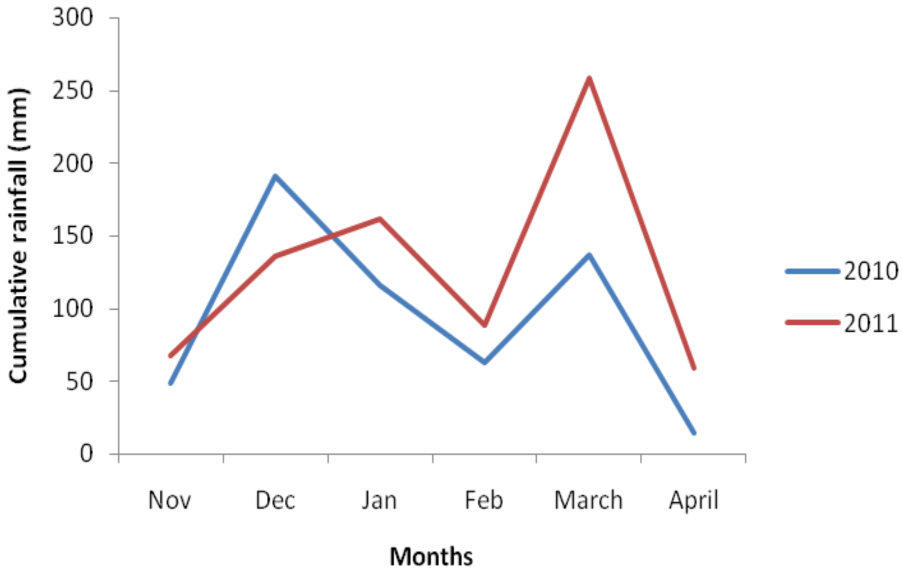

Figure 1. Cumulative rainfall (mm) at Hombolo during 2010 and 2011 cropping seasons.

Table 1. Composition of major nutrients in organic manures used in the trial.

				Nutrient compositions	
Cropping season	**Type of manure**	**pH**	**OC (%)**	**N (%)**	**P (mg/kg)**
2009/2010	Chicken manure	7.4	32.58	2.02	0.74
	Farmyard manure	6.7	12.65	0.84	0.14
2010/2011	Chicken manure	7.6	32.62	0.04	0.69
	Farmyard manure	6.9	12.63	0.82	0.16

numbers at 9 and 11 WAP for 2010/2011 (Table 2). Addition of fertilizers did not have a significant effect on the *Striga* numbers in 2009/2010 season at all sampling periods and in 2010/2011 season at 13 and 15 WAP. In 2010/2011, at 9 WAP farmyard manure treated plots had significantly higher *Striga* counts/m^2 than all other treatments. At 11 WAP, farmyard manure had significantly higher *Striga* counts/m^2 than urea treated plots. The overall mean number of *Striga* plants/m^2 ranged from 2.15 (9 WAP) to 4.62 (15 WAP) in 2009/2010 season and from 3.43 (9 WAP) to 7.90 (15 WAP) in 2010/2011 season (Table 2).

Effect of fertilizers on *Striga* biomass, capsule numbers and fecundity

There were significant ($P \leq 0.05$) differences in *Striga* biomass between treatments in both seasons (Table 3). Urea treated plots had significantly lower *Striga* biomass than farmyard and chicken manure treated plots in 2009/2010 season. Farmyard manure had significantly higher *Striga* biomass than urea. In 2010/2011 season, the control plots had significantly higher *Striga* biomass than plots supplied with chicken manure. Mean *Striga* biomass ranged from 16.3 to 45.5 g/m^2 in 2009/2010 and 30.68 to 67.85 g/m^2 in 2010/2011.

Fertilizer application had a significant ($P \leq 0.05$) effect on the number of capsules/plant only during the 2010/2011 season. Plants supplied with chicken manure, urea and TSP had significantly fewer capsules per plant than farmyard manure treated and control (without fertilizer application) plants. The overall mean number of capsules/plant ranged from 55.14 in 2009/2010 season to 94.79 in 2010/2011 season. No differences were noted on *Striga* fecundity (seeds/plant) among all the treatments in 2009/2010 season. However, mean *Striga* fecundity ranged from 35988 to 64390. In 2010/2011 season, farmyard manure, chicken manure, urea and TSP treated plots had significantly lower *Striga* fecundity relative to the control. During this season, chicken manure, urea and TSP treated plots

Table 2. The effect of fertilizers on *Striga* counts per m^2 at Hombolo in 2009/2010 and 2010/2011 cropping seasons.

2009/2011				
Treatment	**9 WAP**	**11 WAP**	**13 WAP**	**15 WAP**
Control	1.93	2.78	3.82	4.21
Farmyard manure	2.22	3.80	4.96	5.68
Chicken manure	2.91	4.06	5.09	5.02
Urea	1.13	1.72	2.46	2.73
TSP	2.58	3.33	4.81	5.48
LSD (P ≤ 0.05)	NS	NS	NS	NS
CV (%)	37.90	37.50	30.70	33.20
2010/2011				
Control	2.77	5.19	7.89	8.63
Farmyard manure	5.76	7.26	8.63	8.63
Chicken manure	3.31	5.17	6.22	6.36
Urea	1.84	3.78	6.11	6.46
TSP	3.46	6.99	9.15	9.40
LSD (P ≤ 0.05)	2.19	3.16	NS	NS
CV (%)	41.50	36.10	31.70	31.10

*Control = zero application of fertilizer; * WAP = weeks after planting; *TSP = Triple-superphosphate.

Table 3. Effect of fertilizers on *Striga* biomass, number of capsules and fecundity at Hombolo in 2009/2010 and 2010/2011 cropping season.

	2009/2010			**2010/2011**		
Treatment	**Biomass (g/m^2)**	**Capsule/plant**	**Fecundity (seeds/plant**	**Biomass (g/m^2)**	**Capsules/plant**	**Fecundity (seeds/plant)**
Control	30.81	68.68	64390	67.85	137.57	93826
FYM	40.36	69.68	63683	47.10	117.10	58784
CHM	45.44	42.62	37723	30.68	66.35	33241
Urea	16.31	41.25	35988	49.83	81.85	38961
TSP	22.45	53.45	46127	52.70	71.07	39162
LSD (P ≤ 0.05)	19.18	NS	NS	35.57	32.21	18618.5
CV (%)	40.1	40.9	39.7	46.4	22.1	22.9

*Control = zero application of fertilizer, FYM = farmyard manure, CHM = chicken manure. *TSP = Triple-superphosphate.

had significantly lower *Striga* fecundity than farmyard manure treated plots (Table 3).

DISCUSSION

Fertilizer effects on *Striga* numbers and *Striga* biomass

Application of farmyard manure, chicken manure, urea and TSP fertilizers did not significantly affect *Striga* numbers at all sampling periods in 2009/2010 presumably due to the low organic carbon and nitrogen supply of the soil. These results were also observed by Smaling et al. (1991) and Kamara et al. (2007) who found that fertilizer application did not significantly affect *Striga* infestation. The reduction of *Striga* numbers at 9 and 11 WAP with application of urea in 2010/2011 could be due to the higher level of nitrogen supplied by urea that could have affected the production of stimulants. Ikie et al. (2007) found that urea significantly lowered *Striga* emergence in the field, compared to an equivalent N dose of organic manure due to the faster release of N from the former than the latter.

The reduction in *Striga* biomass in plots treated with chicken manure in 2010/2011 is probably due to the higher quantity of nitrogen supplied by the chicken manure applied which affected *Striga* growth. It is not the quantity but the rate of release of the nitrogen that is essential for the negative effect that N has on *Striga*

(Kranz et al., 1998). Ayongwa et al. (2011) observed that timing of fertilizer application is more important than the amount applied. While various authors showed that N application significantly suppressed *Striga* in cereal production, Bebawi (1991) noted that there was no consistent host plant response to N fertilization with regard to reduced *Striga* infestations and biomass. Such inescapable problems in N fertilizer application could explain inconsistencies on the effect of farmyard manure and chicken manure applied at the same rates in controlling *Striga* infestations. Sometimes high rates of N fertilizer produce high infestation levels and biomass in the farmers' fields (Ayongwa, 2006).

Fertilizer effects on the number of capsules per *Striga* plant and fecundity

Reduction in the number of capsules per *Striga* plant in 2010/2011 due to application of chicken manure and urea and the reduction in fecundity due to urea, chicken manure and farmyard manure application could be attributed to their nitrogen release in the soil. The N release could have improved sorghum N status and thereby adversely affected *Striga* growth and reproduction. An earlier study by Riches (1998) reported that N fertilizers reduced *Striga* reproduction and the load of attached parasites through their effect on the sorghum root. Nitrogen somehow modified the host's root stimulants by either considerably reducing the quantity or making exudates less active in eliciting *Striga* seed stimulation (Matusova et al., 2005). Negative effects of TSP application on the number of capsules/plant and fecundity were observed in the current study. According to the available literature, this study may be the first one that observed such a relationship. Studies by Raju et al. (1990) and Farina et al. (1985) demonstrated no effect of phosphorus on *Striga* seed germination and infestation. However, none of these authors studied the relationship between phosphorus application and *Striga* reproduction. Therefore, the mechanism by which phosphorus application reduced the *Striga* reproduction in the current study is yet unclear. Evidently, there is a need for further study on the effect of P application on *Striga* reproduction.

Relationship between *Striga* numbers, biomass and capsule production

Striga numbers and biomass are good indicators for capsule production as indicated by the positive and significant correlations between these variables. Reduction in *Striga* numbers led to low biomass and consequently low number of seed capsules. These observations are in agreement with the findings by Haussmann et al. (2001) and Rodenburg et al. (2006) who reported highly significant correlations between *Striga* biomass and *Striga* seed capsules. Carsky et al. (1994) concluded that the reduced number of capsule forming plants was related to *Striga* above-ground biomass rather than below-ground suppression. In the present study, it can be concluded that any fertilizer sources that reduce *Striga* numbers and biomass will cause a proportional reduction in seed production.

Long-term effect of fertilizers on *Striga* seed bank

Van Mourik et al. (2005) reported average densities of *Striga* seed bank to range from 1800 to 414600 seeds/m^2 based on a literature search. In this study, *Striga* seed number per plant ranged from 35988 (urea) to 64390 (control) in 2009/2010 and from 33241 (chicken manure) to 93826 (control) in 2010/2011. It would appear that for an initial seedbank of 414600/m^2, only about 5 *Striga* plants/m^2 (in 2010/2011) would be enough to completely replace the original seedbank if farmers were to continue planting without using fertilizers. In situation where farmer were to use fertilizers like chicken manure as in 2010/2011, about 13 *Striga* plants/m^2 would be enough. In fact, these values of *Striga* number/m^2 are very common in infested fields. Based on these observations, it is concluded that just the use of fertilizers alone is not enough to reduce the *Striga* seed inputs. Integrating fertilizers with other control measures is an important approach to preventing seed inputs into the soil.

Conclusion

The application of fertilizers has a potential for the control of *S. asiatica* through reduced seed inputs in the soil. However, the tested treatments showed little scope for effective elimination of the *Striga* seed bank with the use of only fertilizers. This strategy will not avoid *Striga* damage to cereal crops after a single year because considerable amounts of seeds will persist in the soil. It is suggested that integrating different control options such as fertilizer application with weeding of any *Striga* plants before they flower may achieve nearly complete prevention of seed bank input through shedding.

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