

Effect of rate and time of nitrogen fertilizer application on *Striga hermonthica* infestation in field-grown maize

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SUMMARY

The effects of urea and sulphate of ammonia applied at 0, 90, 120, 150 and 180 kg N ha⁻¹ (from 1989 to 1992) and the time and rate of N application (1992) on the severity of *Striga hermonthica* infestation and maize yield were studied in order to compare the two sources of N fertilizer, commonly available to farmers in Ghana, in reducing *S. hermonthica* infestation, and to determine the rate and time of application that would minimise the deleterious effect of *Striga* on maize. The experiments were carried out under natural field infestations on farmers' fields (6-10 locations each year) in the Guinea Savanna zone of Ghana and replicated three times at each location on plots 5 m long and 3.6 m wide. In 1989 and 1992, higher *S. hermonthica* population density was recorded when urea was applied compared to sulphate of ammonia. However, there were no differences in *Striga* population density between the two sources of nitrogen from 1990 to 1991. Applying N at either 4 or 6 weeks after planting (WAP) maize did not affect the number of emerged *Striga* shoots. The rate of nitrogen applied did not influence the emergence of *Striga* from 1989 to 1991 as compared to 1992 when *Striga* population declined with increased rate of nitrogen fertilizer. Maize grain yield was unaffected by the source of nitrogen applied from 1989 to 1991. Similarly, applying N fertilizer at 4 or 6 WAP did not affect maize grain yield in 1992. However, the application of sulphate of ammonia resulted in higher maize yield compared to urea in 1992. Maize grain yield increased with increased nitrogen rate up to 90 kg ha⁻¹ beyond which no appreciable increase was observed. A minimum of 90 kg N ha⁻¹ is therefore required for any meaningful reduction in the deleterious effects of *Striga* on maize. In addition, to reduce the population of *Striga* in maize, it is essential to apply N fertilizers early.

RÉSUMÉ

AFLAKPUI, G. K. S., BOLFREY-ARKU, G., ALLOU, P. B., DAKURAH, A. H. & ADU-TUTU, K. O.: *L'effet de la fréquence et le temps de l'application des engrais d'azote sur l'infestation de Striga hermonthica du maïs cultivé-au-terrain.* Les effets d'urée et de sulfate d'ammoniac appliqués à 0, 90, 120, 150 et 180 kg N ha⁻¹ (de 1989 à 1992) et le temps et la fréquence de l'application d'N (1992) sur la sévérité de l'infestation de *Striga hermonthica* et le rendement de maïs étaient étudiés afin de comparer les deux sources d'engrais N, communément disponible aux cultivateurs au Ghana, en réduisant l'infestation de *S. hermonthica* et pour déterminer la fréquence et le temps d'application qui pourrait minimiser l'effet délétère de *Striga* sur le maïs. Les expériences se sont déroulées sous les infestations de terrain naturel sur les terrains des cultivateurs (6-10 emplacements chaque année) dans la zone Savano-guinéenne du Ghana et se reproduisaient trois fois à chaque emplacement sur des lots longs de 5 et 3.6 m de large. En 1989 et 1992, une densité de plus élevée était enregistrée lorsque l'urée était appliquée en comparaison de sulfate d'ammoniac. Cependant il n'y avait pas de différences dans les densités de population de *Striga* entre les deux sources d'azote 1990 à 1991. Appliquant N à 4 ou 6 semaines après la plantation (SAP) de maïs n'affectait pas le nombre de pousse qui émergeait de *Striga*. La fréquence d'azote (N) appliqué n'influçait pas l'émergence de *Striga* de 1989 à 1991 en comparaison de 1992 lorsque la population de *Striga* déclinait avec l'augmentation en fréquence de l'engrais d'azote. Le rendement de grain de maïs n'était pas affecté par la source d'azote appliquée de 1989 à 1991. De la même façon, appliquant l'engrais A à 4 ou 6 SAP n'affectait pas le rendement de grain de maïs en 1992. Toutefois, l'application de sulfate d'ammoniac aboutissait à un rendement de maïs plus élevé en comparaison d'urée en 1992. Le rendement de grain de maïs augmentait avec l'augmentation de la fréquence d'azote jusqu'à 90 kg ha⁻¹ au-delà de quoi aucune augmentation appréciable n'était observée. Un minimum de 90 kg N ha⁻¹ est donc exigé pour une réduction significative quel conque dans les effets

Original scientific paper. Received 12 Feb 97; revised 26 Sep 97.

délétères de *Striga* sur le maïs. De plus, pour réduire la population de *Striga* dans le maïs, il est essentiel d'appliquer les engrais A tôt.

Introduction

Striga (witchweed) species are angiosperm root hemiparasites of cereals and legumes in the semi-arid tropics. The most agriculturally important species are *S. hermonthica* (Del.) Benth., *S. asiatica* (L.) Kuntze and *S. densiflora* Benth. which parasitize crops such as sorghum, millet, maize, upland rice and sugarcane; and *S. gesnerioides* (Willd) Vatke., which attacks cowpea and tobacco (Musselman & Ayensu, 1984). *Striga* occurs in both the Coastal and Guinea Savanna zones of Ghana (Laing, 1984). *Striga* is recognized by farmers as an important constraint to crop production. In Ghana, *S. hermonthica* is more widespread than *S. gesnerioides* (Willd) Vatke, and infestation levels as high as 98 per cent and yield losses of 78 to 100 per cent have been reported (GGDP, 1988). Apart from the direct yield losses, there are other socio-economic losses; for instance, locating farms at increasingly longer distances from settlements in an effort to locate *Striga*-free fields. The occurrence of *Striga* in the field is often negatively correlated with soil fertility in general and nitrogen status in particular (Pieterse & Verkleij, 1991; Bebawi, 1981). Other factors that predispose fields to *Striga* infestation are continuous cropping of host crops and pressure on land (GGDP, 1988).

Pearson (1913) (cited by Farina, Thomas & Channon, 1985) observed that NaNO_3 applications reduced *Striga* infestation under field conditions. Subsequently, in both pot and field studies, the ameliorative effects of manure and other nitrogenous fertilizers on crop damage due to various *Striga* species have been reported. However, reports of the effect of added nitrogen fertilizer on the infestation of *Striga* are inconclusive. Pieterse & Verkleij (1991) reviewed soil conditions affecting *Striga* development and summarized several experiments conducted from 1913 to 1989 to investigate the role of nitrogen fertilizer on

infestation of *Striga* (assessed as the number of emerged *Striga* plants). Their summary showed that applied nitrogen decreased *Striga* infestation in 16 reported cases, had no effect in four and in eight cases, and *Striga* infestation increased with N application. Published work after Pieterse & Verkleij's review in the period from 1990 to 1997 have shown that N application did not give clear trends in the level of *Striga* infestation. Thus, from 1913 to 1997, N application decreased *Striga* infestation in 19 reported cases, had no effect in six and in 11 cases, and *Striga* infestation increased with N application.

The objectives of this study were to compare the effect of two sources of nitrogen commonly available and used by farmers in Ghana on the infestation of *S. hermonthica* in maize, to determine the rate of nitrogen that would minimize the deleterious effects of *S. hermonthica* on maize, and to investigate whether the time of applying nitrogen fertilizer would affect the severity of *S. hermonthica* infestation.

Materials and methods

Field experiments were carried out under natural field infestation on farmers' fields in the Guinea Savanna zone of Ghana (Dokpong, Kpongo, Tumu, Bugubelle, Ping, Kong, and Sakai, all in the Upper West Region; Yendi and Kpalsi, in the Northern Region) from 1989 to 1992. The physical and chemical properties of the top 15 cm of soil of some of the typical locations (Dokpong, Tumu, Sakai, Kpongo and Ping) were percent sand: 70.5-80.5; percent clay: 4.0-9.0; percent silt: 10.5-25.5; pH (in water): 5.1-5.8; percent C: 0.35-0.53; percent N: 0.04-0.06; P (mg kg^{-1}): 6.6-14.3 and K (cmol kg^{-1}): 0.12-0.55 (Aflakpui et al., 1994). The two types of experiments conducted were source by rate of N application (Dokpong, Kpongo, Tumu, Bugubelle, Ping, Kong, Yendi, Kpalsi, and Sakai), and time by rate of N application (Tumu and Ping). A

randomized complete block design in a 2×5 factorial arrangement was used for both types of experiments at all locations.

Sulphate of ammonia and urea were applied at five rates of 0, 90, 120, 150 and 180 kg N ha⁻¹. Phosphorus was applied at 50 kg P₂O₅ ha⁻¹ as single superphosphate and potassium at 60 kg K₂O ha⁻¹ as muriate of potash in 1992. In the other years no extra potassium was applied but phosphorus was applied at the same rate. Each rate of N was divided into two equal halves and was applied in two split doses in the source by rate of N application experiment. The first was applied between germination and up to 10 days after planting and the second at 4 weeks after planting in all years at all locations. All fertilizers were buried at about 3-5 cm depth with a dibbling stick. Dobidi, a 120-day white dent streak-susceptible maize variety, was planted in 5 m long plots, 4 rows wide at 90 cm \times 40 cm spacing in 1989 and 1990. Dobidi was replaced by Okomasa, a 120-day streak-resistant white dent variety, in 1991 and 1992 but planted at the same density. In the time by rate of N experiment in 1992, N was applied as sulphate of ammonia at 4 and 6 weeks after planting but at the same rates as in the source by rate of N application experiment. All the experiments were carried out between June 10 and 20 each year, and the maize harvested just after physiological maturity (when the black layer at the base of 50 per cent of the kernels was visible).

The response variables measured included *Striga* population at 50 per cent tasselling of maize, at harvest and 10 days after harvest, maize plant population after emergence and at harvest, plant height at harvest, and grain yield. Data were recorded on bordered plants within the two central rows of each plot and maize grain yield calculated at 15 per cent moisture. All measured responses were tested for homogeneity of variance and data subjected to statistical analyses. *Striga* count data were subjected to square root [$\sqrt{(x + 0.5)}$] transformation before analyses. Orthogonal polynomials were used to partition nitrogen effects into linear and quadratic components (Snedecor

& Cochran, 1980). For the purposes of this paper, *Striga* population at tasselling and maize grain yield were presented for the source by rate of N application experiment while *Striga* population at tasselling, harvest, and 10 days after harvest (10 DAH), and maize grain yield were presented for the rate by time of N application experiment.

Results

Effect of source of nitrogen on *S. hermonthica* population

Fig. 1 shows the effect of the source of nitrogen

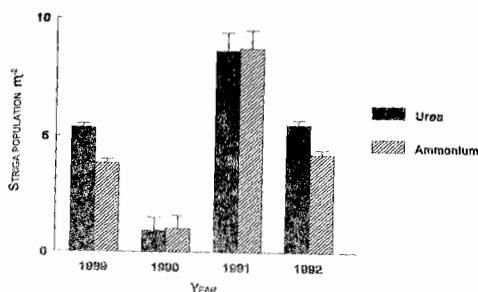


Fig. 1. Effect of the application of urea and sulphate of ammonia on *Striga hermonthica* population under natural field infestation in field-grown maize in the Guinea Savanna zone of Ghana from 1989 to 1992. Data are means (with standard errors) from a 2×5 factorial experiment with three replicates across five locations.

fertilizer on *S. hermonthica* population in maize. In 1989 and 1992, applying sulphate of ammonia to maize reduced the population of *S. hermonthica* more than applying urea ($P < 0.05$). In 1990 and 1991, however, there were no significant differences in *S. hermonthica* population irrespective of the source of nitrogen fertilizer applied.

Effect of time of N application on *S. hermonthica* population

Fig. 2 shows the effect of the time of applying N on *S. hermonthica* population in 1992. Though there was a trend of higher *S. hermonthica* population in maize at tasselling and harvest when nitrogen was applied to maize at 6 WAP than at 4 WAP, the difference was not significant. The *S. hermonthica* population for both times was the

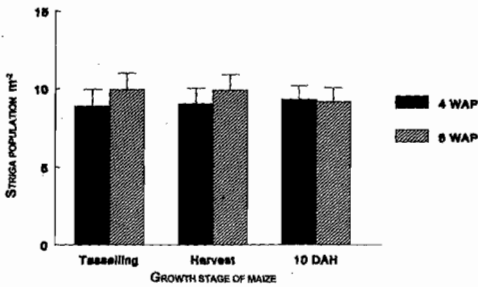


Fig. 2. Effect of the time of nitrogen application on *Striga hermonthica* population under natural field infestation in field-grown maize in the Guinea Savanna zone of Ghana in 1992. Data are means (with standard errors) from a 2×5 factorial experiment with three replicates across two locations.

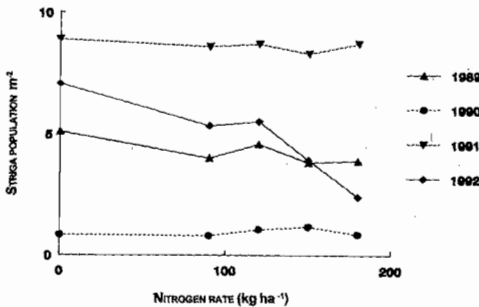


Fig. 3. Effect of the rate of nitrogen application on *Striga hermonthica* population under natural field infestation in field-grown maize in the Guinea Savanna zone of Ghana from 1989 to 1992. Data are means (with standard errors) from a 2×5 factorial experiment with three replicates across two locations.

same at 10 days after harvest.

Effect of rate of nitrogen on *S. hermonthica* population

Fig. 3 shows the effect of the rate of nitrogen fertilizer on *S. hermonthica* population in the source by rate of N application experiment. There was no clear trend of the effect of the rate of nitrogen fertilizer applied on the emergence of *Striga* from 1989 to 1991. In 1992, however, *Striga* population declined in response to increased rate of N fertilizer. In the time by rate of N application experiment, *Striga* population declined in response

to increased N with no appreciable difference in response beyond 90 kg N ha^{-1} at all the three sampling periods (Fig. 4).

Maize grain yield under *S. hermonthica* infestation

Fig. 5 and 6 show the effect of the source and rate of N fertilizer application on maize grain yield. The source of nitrogen fertilizer applied did not affect maize grain yield from 1989 to 1991, although there was a trend towards a higher grain yield with

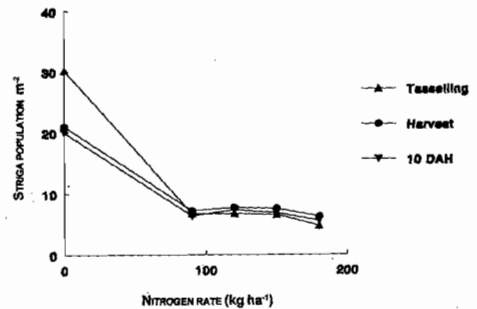


Fig. 4. Effect of the rate of nitrogen application on *Striga hermonthica* population under natural field infestation in field-grown maize (at tasselling, harvest and 10 days after harvest) in the Guinea Savanna zone of Ghana in 1992. Data are means (with standard errors) from a 2×5 factorial experiment with three replicates across two locations.

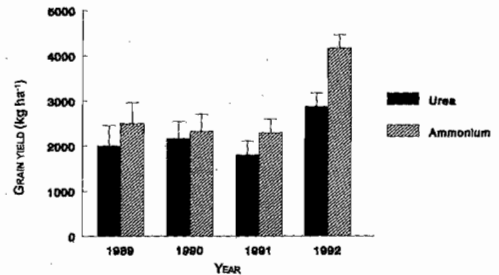


Fig. 5. Effect of the application of urea and sulphate of ammonia on maize grain yield under natural field infestation of *Striga hermonthica* in field-grown maize in the Guinea Savanna zone of Ghana from 1989 to 1992. Data are means (with standard errors) from a 2×5 factorial experiment with three replicates across two locations.

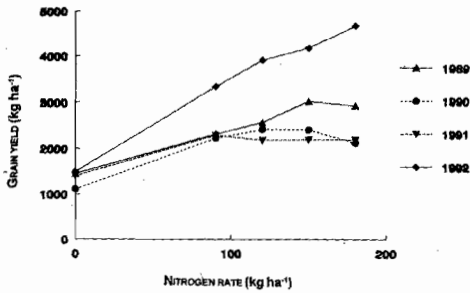


Fig. 6. Effect of the rate of nitrogen application on maize grain yield under natural field infestation of *Striga hermonthica* in field-grown maize in the Guinea Savanna zone of Ghana from 1989 to 1992. Data are means (with standard errors) from a 2 × 5 factorial experiment with three replicates across two locations.

the application of sulphate of ammonia (Fig. 5). In 1992, however, maize grain yield was higher ($P > 0.05$) with the application of sulphate of ammonia than with urea.

There were no clear trends in maize grain yield

TABLE I

Effect of the Rate and Time of Application of Nitrogen on Maize Grain Yield under *Striga hermonthica* Infestation at Ping and Tumu in the Guinea Savanna Zone of Ghana in 1992

	Grain yield (kg ha ⁻¹)	
	Tumu	Ping
Time		
4 WAP	2950	3400
6 WAP	2820	3640
SE	258	219
N rate (kg ha ⁻¹)		
0	1660	2100
90	2960	3580
120	3040	3860
150	3260	3960
180	3490	4110
SE	408	346
Contrasts (N rate)		
Linear	**	**
Quadratic	NS	NS

Data are means from a 2 × 5 factorial experiment with three replicates.

WAP - weeks after planting; ** - contrasts differ at $P < 0.01$; NS - not significant.

as the rate of nitrogen fertilizer was increased in 1989, 1990 and 1991 (Fig. 6). The trend in grain yield was clearer in 1992 with a linear response of grain yield to the rate of nitrogen fertilizer applied.

Applying N fertilizer at either 4 or 6 WAP did not affect maize grain yield (Table 1). As in the source by rate experiment, increased rates of N application increased maize grain yield in the time by rate of N application experiment, though the response to increased N declined beyond 90 kg N ha⁻¹ (Table 1).

Discussion

This study showed that in 2 out of 4 years, the application of urea resulted in higher *S. hermonthica* population in maize than with sulphate of ammonia. The population of *S. hermonthica* observed on the plots varied from year to year. Pieterse & Verkleij (1991) observed similar variations in emergence of *Striga* due to the application of different sources of nitrogen. They suggested that these variations in the field can be connected with the transfer of ammonium to nitrate due to bacterial activity which is affected by ecological conditions in the soil. The study also showed no consistent trend in *Striga* population due to increased rate of nitrogen from 1989 to 1991. Published results of the effect of increasing the rate of nitrogen fertilizer on *Striga* have led to varying conclusions and the results from this study do not help to clarify the situation.

In field studies, Agabawi & Younis (1965), Bebawi (1981) and Farina, Thomas & Channon (1985) reported that increasing the rate of nitrogen fertilizer reduced the infection of *Striga* and increased host yield. In contrast, the present study has shown that high levels of nitrogen in the soil enhanced the growth of both host and parasite (Egley, 1971; Parker, 1984). In a rice-*S. hermonthica* association, Cechin & Press (1993) observed that the number of *S. hermonthica* shoots per host was similar for both 1 and 3 mol N m⁻³ but the final biomass per host at 3 mol N m⁻³ was more than twice at 1 mol N m⁻³. A study by Gurney, Press & Ransom (1995) showed that nitrogen neither

affected cereal growth nor photosynthesis, nor did it influence the response of maize and sorghum to *Striga*. Similarly, Kim & Adetimirin (1997) reported that the application of N fertilizer at 60 and 120 kg N ha⁻¹ did not affect the emergence of *S. hermonthica* in maize. In addition, Kim, Adetimirin & Akintunde (1997) applied N at a range of 0-150 kg ha⁻¹ and observed that the emergence of *S. hermonthica* was significantly reduced only at 120 and 150 kg N. It is noteworthy that grain yields of more than 1000 kg ha⁻¹ were obtained in the 0 kg N ha⁻¹ plots, indicating that the latent fertility of the soils of the selected sites was not terribly low. This latent fertility may have contributed to the reduction in the emergence of *Striga* shoots. It is speculated that the main role of applied N is to prevent successful establishment of host-parasite union. If this host-parasite union is not prevented, then any applied N would enhance growth of both host and parasite. Maize grain yield from this study did not show any clear trends in most years. In 3 out of 4 years, grain yield obtained at 90 kg N ha⁻¹, the recommended economic optimum for maize in Ghana (GGDP, 1990) was comparable to grain yield at the higher levels of N used in this study.

The lack of response in maize grain yield to higher levels of N contrasts with the results of Raju *et al.* (1990) and Cechin & Press (1993) in which sorghum biomass under *Striga* infestation increased with increased N application. The results from the study are, however, consonant with the work by Gurney, Press & Ransom (1995) in which cereal yield under *Striga* infestation was not affected by nitrogen. It is possible that a combination of intermittent drought and heavy rains which were experienced during the course of the experiments may have made the applied N unavailable to the plants through volatilization and leaching respectively, even though N was applied in two split doses in the source by rate of N experiment. Indeed, Yaduraju, Hosmani & Probhakara (1979) and Mumera & Below (1993) found repeated applications of N more effective in depressing *Striga* infestation and stimulating host productivity than a single initial application.

Alternatively, the N applied may have been bound to soil particles in such a way that it was unavailable to the plants. Wong, Hughes & Rowell (1990) reported that some soils from the tropics (with pH ranging between 4.2 and 5.9) are capable of retaining high concentrations of nitrate ions which are recalcitrant to leaching. Addition of N to such soils may, therefore, have little effect on plant growth. The consistent increase in maize grain yield in 1992 in response to increased N fertilizer application, in the source by rate experiment, may be attributed to a removal of N-K nutrient imbalance beyond 90 kg N which consequently reduced *Striga* populations (Farina, Thomas & Channon, 1985). The contrast, though, is the declined response of grain yield in the rate by time experiment which may be attributed to biophysical differences in locations and differences in crop management practices of cooperating farmers.

Although the source of N applied did not affect maize grain yield significantly, the higher concentration of N (46 per cent) in urea may make urea a better economic proposition than sulphate of ammonia if it is properly applied.

Acknowledgement

The authors wish to thank all personnel who conducted the field experiments and the donors of research facilities, namely the Ghana Grains Development Project of the Crops Research Institute (CSIR), Grains and Legumes Development Board, and the Ministry of Food and Agriculture.

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