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Response of Tobacco Cultivars to Varying Fertiliser Levels in *Striga gesnerioides* Infested Soils in Zimbabwe

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Abstract: The effect of varying fertiliser levels on the response of five tobacco (*Nicotiana tabacum*) varieties to *Striga gesnerioides* infestation was studied for three seasons at a *S. gesnerioides*-infested site. A split-plot design with cultivar as main plot factor and three rates of basal fertiliser (0, 800, 1000 kg ha^{-1}) and three top dressing nitrogen fertiliser rates (0, 25, 50 kg N ha^{-1}) were investigated. Standard tobacco cultural practices were followed. Striga emergence counts were carried out at 3rd week intervals from 9 Weeks After tobacco Planting (WAP). Tobacco infestation by *S. gesnerioides* and tobacco yield were also assessed. Striga emergence was first noted at 12 WAP. Plots with high rates of nitrogen had fewer emerging and maturing Striga plants. Of the five tobacco varieties tested, T66 was the most tolerant to Striga infestation and two landraces, LR11 and 12 were the most susceptible. Yields of the landraces were significantly lower ($p<0.05$) than T66. There was a significant reduction in tobacco yield loss due to *S. gesnerioides* infestation when the variety T66 was grown at recommended basal rate (500 kg ha^{-1}) combined with a higher nitrogen rate (50 kg N ha^{-1}).

Key words: Striga, fertiliser, infestation, variety, nitrogen, Zimbabwe

INTRODUCTION

Striga gesnerioides (family: Scrophulariaceae) is an obligate parasitic flowering plant attacking tobacco, cowpea and other wild legumes (Oswald, 2005). Striga attaches to the host root, invades the host tissues and diverts the host photosynthate for its growth. It utilises the host root system for water and mineral uptake. There is a paucity of information on the economic importance of Striga on tobacco in Zimbabwe. Although, the 1st report of *S. gesnerioides* on tobacco in Zimbabwe was in 1948 (Wild, 1948) no host damage was reported until 2002 in the Mvuma area of the country. *S. gesnerioides* was confined to tobacco, posing a major threat to continued tobacco production in the area (Koga *et al*., 2011). Striga causes up to 75% of its overall damage to the host during its underground stage of development. Control strategies targeted at controlling emerged Striga plants, therefore do not result in increased crop yield (Berner and Winslow, 1997). In other crops, control of *Striga* sp., infestation includes suicidal germination with trap crops, catch cropping, application of high rates of nitrogen fertiliser and the use of organic matter and resistant varieties (Kachelriess *et al*., 2001; Ahonsi *et al*., 2002). Declining soil fertility contributes to increased Striga infestation. Striga has been used as an indicator of the nutritional status of the May 28, 2011 soil (Mbwaga, 2002). The control of *S. gesnerioides* through application of nitrogenous fertilisers and organic matter amendments has been studied often with varying and contradictory results from different geographic locations (Ahonsi *et al*., 2002). Control through the application of optimal levels of nitrogen and the use of resistant varieties has been successful in studies by Akademiai. Optimal nitrogen caused a reduction in number of emerged and maturing Striga plants, resulting in less seed being produced (Kachelriess *et al*., 2001). The severity of Striga infestation is also dependant on the amount of germination stimulants produced by different crop varieties (Haussmann *et al*., 2000) as evidenced by their different tolerance levels.

The selection of tolerant varieties and varieties with reduced capacity to induce the production of the germination stimulant can be a management intervention because there is a positive correlation between the amount of stimulant produced and the susceptibility to Striga infestation (Johnson *et al*., 2000). The present study investigated Striga biology and management in tobacco production in Zimbabwe, specifically the interrelationships between tobacco varieties, varying fertiliser nutrient levels and Striga infestation.

MATERIALS AND METHODS

Study site: The field trials were conducted in Mvuma (19°16'S, 30°30'E), Midlands province, Zimbabwe. The

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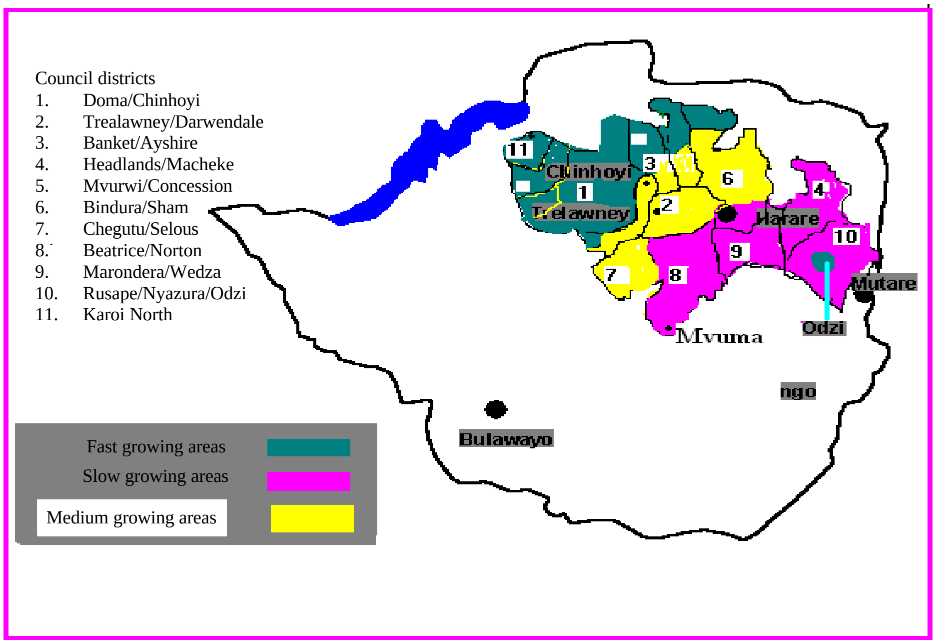

Fig. 1: Tobacco growing areas of Zimbabwe

study area has an altitude of 920-1475 m above sea level with soils of medium-heavy in texture and poorly-drained with high clay content and high water-holding capacity. Mvuma is within the slow growing area of tobacco production in Zimbabwe (Fig. 1) and receives a mean annual rainfall ranging from 650-800 mm. Tobacco production was initiated in the area in 1997. Prior to that the area was predominantly for cattle ranching.

Field activities: The trial was established and managed following standard recommendations for tobacco production. Tobacco is grown on 20-30 cm ridges to avoid water logging. The plant spacing used in the study was 1.2×0.56 m. Soil samples were taken from the field for chemical analysis and fertiliser recommendations according to the method of Juo (1981). Differing levels of nitrogen, phosphorus and potassium were applied according to treatment specifications. A split-split plot design with cultivar as the main plot and fertiliser rates as the sub-plot was used in the study. There were three ammonium nitrate levels (0 kg N ha^{-1}), recommended rate (25 kg N ha^{-1}) and higher rate (50 kg N ha^{-1}). Basal fertiliser (Tobacco-fert, 6:15:12) rates were applied at 0 kg ha^{-1}, recommended rate (800 kg ha^{-1}) and higher rate (1000 kg ha^{-1}).

Measurements of Striga haustorium and emergence counts were taken at 9, 12, 15 and 18 Weeks After Planting (WAP). After 18 weeks, the tobacco crop had completed its life cycle and assessments were terminated. In Zimbabwe, tobacco is harvested at 2 leaves week^{-1} and cured leaf mass was determined at each reaping. Three commercial cultivars: KRK 26 [RW Parentage]; T61 [KM10 Parentage]; T66 [XM Parentage] and two land races (Landrace 11; 12) were evaluated in the Striga-infested fields. The data were analysed using GenStat Release 7.2 DE.

RESULTS

Soil test: The pH of the soils (pH 5.12-5.68) and Electrical Conductivity (EC) were within acceptable levels (<1500 µS cm^{-1}) for tobacco production and other nutrient levels were in ranges normally acceptable for tobacco production (Table 1).

Tobacco yield response to increased nutrient levels under Striga infestation: Increased fertiliser rates (both basal and nitrogen levels) significantly increased tobacco yield ($p<0.05$). The variety T66 had the highest mean yield of 2, 467 kg ha^{-1} (Fig. 2) compared to 564 and 662 kg ha^{-1} obtained from the two landraces (LR11 and 12, respectively).

The most common variety grown in the Mvuma area (KRK26) had a mean yield of 2,048 kg ha^{-1}. Significant differences ($p<0.05$) were noted among the basal fertiliser levels, nitrogen levels, cultivars, the interaction of basal

Table 1: Soilan alysis results of Mvuma soils

		(µS cm^{-1})	Results (meq/100 g)				Results (µg g^{-1})					
Block	pH ($CaCl_2$)	EC	Ca	Mg	Na	K	MinN	P	Mn	Zn	Cu	Fe
1	5.12	33	9.78	10.85	0.05	0.51	40	2	402	2	13	275
2	5.68	46	18.46	21.66	0.08	0.47	70	<1	539	2	10	177
3	5.39	22	7.09	8.56	0.05	0.37	40	<1	195	2	6	249
4	5.52	26	2.15	0.53	0.03	0.33	40	38	42	5	2	77
5	5.42	34	13.62	13.96	0.08	0.36	30	<1	382	2	11	233

Table 2: Statistical data on cultivar mean yield with different basal and nitrogen fertiliser levels

	Means with different levels of cultivar			Means with same levels of cultivar	
Fertilisers	F-prob	SED	LSD	SED	LSD
Cultivar (C)	<0.001	232.00	505.40	-	-
Basal (B)	<0.001	84.20	172.00	-	-
Nitrogen (N)	<0.001	38.80	77.00	-	
C×B	<0.001	278.30	575.60	188.30	384.60
C×N	0.013	242.50	519.00	86.70	172.20
B×N	<0.001	100.50	201.20	-	-
C×B×N	0.846	304.10	619.00	224.70	449.90

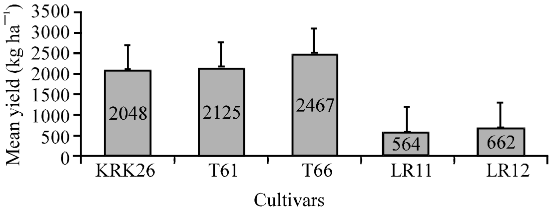

Fig. 2: Tobacco yield per cultivar at combined basal and nitrogen fertiliser levels

and nitrogen, basal and cultivar, nitrogen and cultivar but there was no overall significant interaction (p>.05) among basal, nitrogen and cultivar (Table 2).

Tolerance and susceptibility of different cultivars in Striga-infested soils: The cultivars exhibited visual differences for Striga damage symptoms, especially with the two landraces (LR11 and 12) succumbing more to Striga than the other cultivars (T61, T66 and KRK26). At 12 and 15 WAP, no damage to the tobacco crop was observed but at 18 WAP, the two land races (LR11 and 12) had up to 50% leaf damage as a result of the effects of the parasitic weed.

The other varieties still had no symptoms of Striga leaf damage at 18 WAP. Figure 3-8 shows 20 WAP and the two land races (LR11 and 12) had close to 100% leaf damage whilst the other varieties (KRK26, T61 and 66) had moderate levels of leaf damage.

Effect of basal fertilizer rates on Striga emergence counts: There were no significant differences in Striga counts at various basal fertiliser rates and the interaction

Fig. 3: LR12 severely infested

Fig. 4: LR11 severely infested

Fig. 5: KRK26 showing some tolerance

Fig. 6: T61 moderately infested

Fig. 7: T61 showing high tolerance

Fig. 8: Striga infested tobacco roots

between cultivar and basal fertiliser levels was also not significant ($p>0.05$). The trend was similar at all the assessment times (12, 15 and 18 WAP). In most cases, higher Striga counts were recorded in high basal fertiliser treatments. Figure 9 shows the mean Striga counts per cultivar with increased basal fertiliser rates. Generally, T66 had fewer Striga plants emerging compared to all cultivars, although not statistically different.

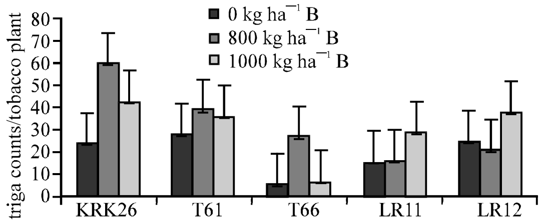

Fig. 9: Effect of basal fertiliser levels on Striga counts per cultivar (18 WAP) (LSD = 13.2, F. prob. = 0.12)

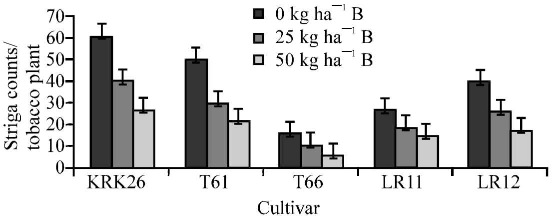

Fig. 10: Effect of nitrogen fertiliser levels on Striga counts (18 WAP) (LSD = 5.56, F. prob.<0.01)

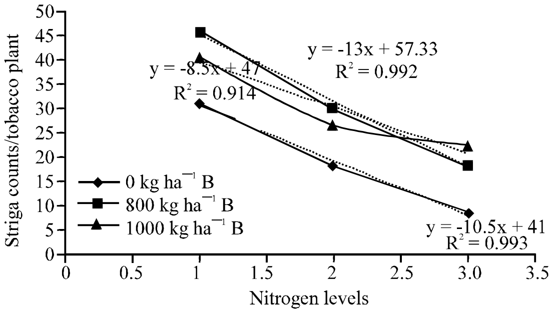

Fig. 11: Nitrogen effect on Striga counts

Effect of Nitrogen fertilizer rates on Striga emergence counts: There were significant differences in Striga counts among nitrogen rates ($p<0.05$). Increasing nitrogen levels from 0-50 kg N ha^{-1} resulted in significant ($p<0.05$) reduction in Striga emergence counts across all the varieties (Fig. 10). Generally, the number of emerged Striga counts increased between 12 and 18 WAP. At 18 WAP, the variety KRK26 was heavily infested with 60 parasitic weeds recorded in non-fertilised plots compared to 5 Striga plants in T66 plots with 50 kg N ha^{-1}. Generally, T66 variety had the least Striga counts recorded from the onset of assessments and the counts were low in all the three nitrogen fertiliser levels.

Nitrogen levels and Striga counts: A regression analysis to determine the relationship between nitrogen fertiliser rates and Striga counts showed a very strong relationship (Fig. 11). A more linear relationship in Striga counts was found in plots where increased nitrogen levels (0-50 kg N ha^{-1}) were applied to plants with no basal fertiliser with the R^2 value of the best-fitted joint regression equations of 0.993. However, the trend was similar among all the cultivars and at all assessment times with increased nitrogen rates resulting in reduced Striga counts (Fig. 11).

DISCUSSION

Previous research by Osman *et al.* (1991) showed that nitrogen did not reduce Striga incidence but neutralised the harmful effects of the parasite. However, severity of infestation showed that the Striga is negatively correlated with soil fertility (Ahonsi *et al.*, 2002; Parker and Riches, 1993; Louise *et al.*, 2001). The results of the present study corroborate these findings. The mechanisms by which high nitrogen levels suppress Striga have not been fully established (Avav *et al.*, 2009; Kureh *et al.*, 2003; Adagba *et al.*, 2002). In some studies, Striga-tolerant genotypes permitted and supported as many Striga plants as susceptible genotypes but did not show a concomitant reduction in grain production or overall productivity (Hess and Ejeta, 1992). The differential susceptibility of studied tobacco genotypes to Striga infestation presents an opportunity to screen more material for tolerance to *S. gesnerioides*. In this study, a yield loss of close to 100% in the two landraces LR11 and 12 with the minimum damage observed in the commercial cultivars KRK26, T66 and 61 could be a result of different cultivar tolerance levels to Striga infestation. Local landraces were often described as having tolerance to Striga (Hess and Haussmann, 1999) but in terms of stimulant production, no differences were noted among different cultivars in laboratory studies (Koga *et al.*, 2011). However, the moderate level of tolerance exhibited by landraces was found not to provide protection at higher levels of infestation (Haussmann *et al.*, 2000). Local landraces have been found to behave similarly to susceptible cultivars at high infestation levels supporting more Striga and allowing more parasitic plants to set seed further enriching the soil seed bank (Kling *et al.*, 2000). Where the Striga infestation is high, only cultivars with high levels of Striga resistance would provide protection from infestation and help diminish the seed bank. If a susceptible host is frequently cultivated, the seed bank in the soil increases and continuous cropping of this host crop becomes more uneconomical (Kroschel, 2001). Crop and varietal differences to infestation by *Striga* species (Hess and Haussmann, 1999; Koga *et al.*, 2011) have led to the initiation of breeding programmes for resistance. Research has shown that Striga control requires an integrated approach (Berner and Winslow, 1997; Mohammed *et al.*, 2001), probably because of the genetic plasticity of Striga.

CONCLUSION

To ensure the continued tobacco production in Mvuma, Zimbabwe, a combination of a tolerant variety such as T66 and higher nitrogen application rates may be recommended. In this study however, the effect of basal fertiliser was not apparent as in other studies, perhaps because of the inherent soil fertility in studied soils. Further investigations could be initiated using different soil types.

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