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Effects of Nitrogen Levels on *Striga* Infestation and Grain Yield of Extra-early Maize (*Zea mays* L.) in a Nigerian Northern Guinea Savanna

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ABSTRACT

Low soil N and *Striga hermonthica* parasitism limit maize production in the northern Guinea savanna Zone of Nigeria. Field experiments were conducted during 2005 and 2006 rainy seasons to determine the influence of N fertilization on *Striga* infestation and grain yield of an extra-early maize variety (95 TZEE-W). The site was naturally infested with *S. hermonthica* due to sorghum seed multiplication at the site over the years. A randomized complete block design (RCBD) was used with 4 nitrogen levels: 0, 30, 60 and 90 kg ha^{-1}, replicated 4 times. The maize variety 95 TZEE-W was sown at 75 × 50 cm with two plants per stand. The N status of the soil was moderate, but organic matter content and basic cations ranged from moderate to very low. Increase in N levels increased plant height, number of leaves plant^{-1}, leaf area, leaf area index, cob weight and grain yield ha^{-1}, while *Striga* counts ha^{-1} were reduced by the application of 60 and 90kg N ha^{-1}. *Striga* count ha^{-1} was higher in 2005, which recorded lower rainfall than in 2006, while the photosynthetic parameters and grain yield ha^{-1} were higher in 2006 than in 2005. Grain yield ha^{-1} was positively correlated with plant height, number of leaves, leaf area, leaf area index, and cob weight, and negatively correlated with *Striga* count ha^{-1}. *Striga* count ha^{-1} was also negatively correlated with plant height and the leaf parameters. Although the N status of the soil was moderate, application of 60 and 90 kg N ha^{-1} suppressed *Striga* emergence, increased the photosynthetic parameters, and increased grain yield of maize. However, increasing the N level beyond 90 kg N ha^{-1} may further reduce *Striga* infestation and increase grain yield beyond the 5.4 tons ha^{-1} realized in the present study.

Keywords: emergence, maize parameters, *Striga hermonthica* counts, suppression

INTRODUCTION

The northern Guinea savanna (NGS) zone of Nigeria is a high potential area for maize production because of the prevalence of high solar radiation and low night temperatures (Kassam *et al.* 1975). The climate is suitable as there is low likelihood of drought during late June to September. Therefore, it is possible to attain 80% maximum yield (Jagtap 1995), which has resulted in extensive adoption of maize in the region (Smith *et al.* 1994).

However, low soil fertility, particularly N supply, organic matter content and *Striga hermonthica* parasitism limit maize production in the NGS. Between 10 and 100% loss in maize grain yield has been attributed to *Striga* parasitism (Lagoke *et al.* 1996). Berner *et al.* (1996) attributed depletion in soil fertility and an increase in *Striga* infestation to the drastic change in farming systems from prolonged fallow, shifting cultivation and rotation to more or less continuous cropping and frequent cultivation of host plants. A survey of *Striga* species on cereals in the NGS of Nigeria showed that *S. hermonthica* had become a serious problem (Kim *et al.* 1997) as over 77% of 135 maize fields (65 compound and 70 bush fields) surveyed in northeast Nigeria were infested with *S. hermonthica* (Dugje *et al.* 2006).

Several methods have been recommended for improving soil fertility, reducing *Striga* infestation and improving grain yield of maize among the resource-poor farmers in the Nigerian savanna. Kim *et al.* (1997) recommended the use of *Striga*-resistant or -tolerant varieties and N fertilization for reducing *Striga* infestation and improving maize grain yield. N fertilization reduces *Striga* emergence and density and increases host crop tolerance, particularly when high rates (120–150 kg N ha^{-1}) are used (Pieterse and Verkleij 1991; Ransom 1999). However, farmers in the NGS zone of Nigeria are unable to apply the recommended N rate due to high fertilizer costs and unavailability. The average rate of fertilizer use in Nigeria is about 12 kg nutrient ha^{-1} of arable land; figures for other West African countries are lower (FAO 1992).

Most of the studies on effects of N rates on *Striga* infestation on maize have been reported for early, intermediate and late maturing maize varieties as reported by several groups: Mumera and Below (1993), Kim and Adetimirin (1997), Kim *et al.* (1997), and Oswald and Ransom (2004). The recent release and adoption of extra-early and short stature maize varieties in the savanna zones of northern Nigeria require further assessment of synergy between extra-earliness and N fertilization for suppressing *Striga* infestation and improving grain yield of maize. Oswald and Ransom (2004) also reported a lower *Striga* population in maize varieties with short growth cycles. Ransom and Oswald (1995) attributed a low *Striga* population in small stature, early maturing maize genotypes to production of less extensive root systems which provide fewer sites for *Striga* parasitism.

Carsky *et al.* (2000) reported that increasing N fertilization suppresses *Striga* emergence by causing suicidal germination of *Striga* seeds. Since *S. hermonthica* seeds germinate 2 weeks after sowing the host crop in response to root exudates, and emerge 4 weeks after attaching to the root of the host (Parker and Riches 1993), application of N within the first 3 weeks of sowing maize may disrupt the parasite-

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host interaction, suppress *Striga* emergence and improve grain yield of maize. The objective of this study was to determine the influence of N fertilization on *Striga* infestation and performance of extra-early maize variety in the savanna.

MATERIALS AND METHODS

Field experiments were conducted at the Seed Multiplication Farm of the Ministry of Agriculture in Michika (10° 37′ N and 13° 22′ E) in Adamawa State, north eastern Nigeria during 2005 and 2006 rainy seasons. The aim of the experiment was to determine the effect of N levels on *Striga* infestation and growth and yield of extra-early maize. The experimental site was thus located in northern Guinea savanna characterized by unimodal rainfall distributed between April and October.

The site was naturally infested as there has been a large build up of *S. hermonthica* population due to sorghum seed multiplication over the years. A randomized complete block design (RCBD) was used with 4 N levels: 0, 30, 60 and 90 kg N ha^{-1}, replicated 4 times. The experimental field was ploughed and harrowed with a tractor-driven disc. The maize variety 95 TZEE-W was sown on 27th June 2005 and 29th June 2006 at a spacing of 75 × 50 cm with 2 plants stand^{-1} (53, 333 plants ha^{-1}) in 4 × 4 m (16 m^2) plots each year.

The first fertilizer dose of 30:30:30 was applied to the N treatment plots at one week after sowing (WAS) using NPK (15:15:15) incorporated by side placement 8–10 cm away from the stand. The 0 kg N ha^{-1} treatment was applied 0:30:30 at one week after sowing using single superphosphate (18% P_2O_5) and muriate of potash (60% K_2O), also by incorporation. The balance of 30 and 60 kg N ha^{-1} was applied to the 60 and 90 kg N treatment plots, respectively, as a second N dose at 3 weeks after sowing using urea (46% N) by side incorporation 10–15 cm away from the stand. All treatment plots were manually hoe-weeded twice at 2 and 4 weeks after sowing.

Soil samples were taken from a 0–30 cm depth from each plot before planting for analysis of physical and chemical properties, each year. The soil samples were bulked and mixed to form composite samples. The samples were air-dried, crushed, screened through a 2 mm sieve and stored in tightly sealed polythene bags. Soil samples used for analysis of organic carbon and total N were finely ground to pass through a 0.5 mm sieve. The soil samples were analyzed for texture (IITA 1982), pH in water (1:2.5) organic C by dichromate oxidation (Walkley and Black 1934) and total N by Kjeldhel digestion (Bremner and Mulvaney 1982). Available P, K, Na, Ca and Mg were extracted with Mehlich-3 extracting solution containing 0.02 M acetic acid + 0.25 M ammonium nitrate + 0.01 M ammonium fluoride + 0.01 M nitric acid + 0.00 1 M EDTA (Mehlich 1984). Potassium was determined by flame photometry as described by Black (1965) using Sherwood model No. 410 and phosphorus by a spectrophotometer as described by Bray and Krutz (1945) using Spectrumlab model 22PC.

Measurement of quantitative traits started at 4 weeks after sowing (WAS). Single leaf area was determined following a modified method of estimating the product of leaf length, maximum width and a multiplying factor as reported by Pal and Murari (1985) and Dugje and Odo (2006). Leaf area index (LAI) was estimated from values of the number of leaves plant^{-1} and single leaf area and computed using the formula described by Dugje and Odo (2006) [$LAI = (P \times L \times A)/(10^7)$] where P = plant population ha^{-1}, L = number of fully expanded green leaves plant^{-1} and A = single leaf area (cm^2).

Emerged *S. hermonthica* plants were counted from each plot as described by Kim (1994) and Dugje *et al.* (2003). A 1.0× 1.0 m quadrat was randomly marked out with a stick in each plot along a diagonal transect. All *Striga* plants that appeared within the quadrat were counted. The emerged *Striga* plant count m^{-2} was converted per ha and transformed using square root transformation. Grain yield was determined from three middle rows leaving out two border rows and one stand at the two ends of each row and converted per hectare.

Statistical analysis

All quantitative plant parameters and transformed *Striga* counts were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedures of the statistical analysis systems (SAS) package (SAS 1990). Differences between variable means were compared using a standard error of difference ($P < 0.05$). Linear relationships among the agronomic parameters and *Striga* counts were determined by calculating Pearson's correlation coefficient using PROC CORR of SAS, SAS (1990).

RESULTS AND DISCUSSION

Soil and rainfall characteristics

The soil reaction at the experimental site was strongly acid (pH 5.3) in 2005 and moderately acid (pH 5.6) in 2006, organic matter content was low (0.40–0.54%), but total N was high (0.32–0.38%) in both years (**Table 1**). The type of vegetation on a soil is likely to have a marked influence on the soil reaction due to the inherent differences in the composition of the vegetation. Jones and Wild (1975) attributed low organic matter content to bush fires and high N content to high rainfall. Exchangeable bases present in the soil ranged from moderate to very low. Available P, K, and Na were moderate, while available Ca and Mg were very low.

Decrease in soil pH is generally associated with a decrease in the amount of basic cations and *vice versa*. Similar trends in the occurrence of exchangeable bases in Nigeria Savanna soils have been reported by Malgwi (1979). The low soil reaction decreased the presence of Ca and Mg but the low organic matter content had little effect on the presence of soil N. The soil texture was sandy clay loam and therefore medium textured. The clay proportion was higher than the silt proportion. Both clay and organic matter content constitute the soil cation exchange capacity which in turn determine the retention capacity for Ca, Mg, K, NH_4^+, H^+ and water (Tarfa *et al.* 2004). From the results of soil analysis, it can be observed that the soil chemical and physical properties did not vary significantly during both years. The performance of the parameters measured was therefore mainly due to the treatment effects and difference in rainfall amount between the seasons.

Rainfall started in April and became fully established by the end of May each year (**Table 2**). The rains were not

Table 1 Physico-chemical characteristics of soil at the experimental site in Michika, Nigeria in 2005 and 2006.

Soil characteristics	2005	2006	Mean
pH in water	5.3	5.6	5.5
Organic C (%)	0.3	0.34	0.32
Organic matter (%)	0.54	0.4	0.47
Total N (%)	0.32	0.38	0.35
Available P (ppm)	87	91	89
Available K (ppm)	35.4	37.2	36.2
Available Na (ppm)	70	78	74
Available Ca (%)	0.21	0.2	0.21
Available Mg (%)	0.07	0.08	0.08
Mechanical analysis (0–30 cm)			
Sand (%)	47.4	46.9	47.2
Silt (%)	23.5	22.8	23.2
Clay (%)	30.6	31.7	31.2
Textural class	Sandy clay loam	Sandy clay loam	Sandy clay loam

Table 2 Average monthly rainfall (mm), in Michika, Nigeria in 2005 and 2006.

Month	2005	2006	Mean
April	32.0	17.0	24.5
May	77.0	110.0	93.5
June	285.5	256.5	257.5
July	468.5	377.0	422.8
August	402.0	497.0	449.5
September	253.0	374.0	313.5
October	162.5	136.0	149.3
Total	1653.5	1767.5	1710.5

Table 3 Effect of year and nitrogen levels on maize plant height and number leaves plant^{-1} at 6 and 8 WAS in Michika, Nigeria in 2005 and 2006.

	Plant height						**Number of leaves plant^{-1}**					
	6WAS			**8WAS**			**6WAS**			**8WAS**		
Kg N ha^{-1}	**2005**	**2006**	**Mean**	**2005**	**2006**	**Mean**	**2005**	**2006**	**Mean**	**2005**	**2006**	**Mean**
	70.7	65.7	68.2	135.2	139.9	137.5	8.1	8.0	8.0	10.2	9.5	9.8
30	76.9	81.1	79.0	151.5	150.9	151.2	8.2	8.2	8.2	10.3	10.1	10.2
60	80.0	83.4	81.7	158.5	167.7	163.1	9.1	9.0	9.0	11.2	11.5	11.3
90	85.4	84.6	84.9	168.9	171.2	170.1	9.7	9.4	9.5	11.2	11.6	11.4
Mean	78.3	78.7	-	153.5	157.4	-	8.7	8.7	-	10.7	10.7	-
SED Year		1.46			2.37			0.12			0.13	
SED N Levels		2.15***			4.22***			0.17***			0.25***	
SED Yr. x N		2.98			5.40			0.24			0.32*	

*F–test significant (P<0.05), *** F–test significant (P<0.01)

Table 4 Effect of year and nitrogen levels on leaf area and leaf area index at 6 and 8 WAS and number of days to 50% tasseling in Michika, Nigeria in 2005 and 2006.

	Leaf area						**Leaf area index**			**No. Days to 50% tasselling**		
	6WAS			**8WAS**			**6WAS**					
Kg N ha^{-1}	**2005**	**2006**	**Mean**	**2005**	**2006**	**Mean**	**2005**	**2006**	**Mean**	**2005**	**2006**	**Mean**
0	435.9	453.8	444.9	492.4	474.5	483.4	1.8	1.8	1.8	51.8	50.3	51.0
30	488.7	536.1	512.4	494.1	489.0	491.6	2.0	2.2	2.1	53.0	55.0	54.0
60	595.7	586.8	591.2	608.8	627.3	618.1	2.7	2.7	2.7	52.5	54.0	53.3
90	547.1	582.3	564.7	638.5	638.6	638.6	2.6	2.8	2.7	52.5	51.8	52.1
Mean	516.8	539.7	-	558.5	557.4		2.3	2.4	-	52.4	52.8	-
SED Year		8.84**			11.68			0.05			0.52	
SED N Levels		12.51***			16.51***			0.08***			0.73**	
SED Y.r x N		17.68			23.36			0.11			1.04	

** F – test significant (P<0.01), ***F – test significant (P<0.001)

evenly distributed since about 50% of the rains were recorded between July and August. The total amount of rains received in 2006 was 6.4% higher than 2005. The mean rainfall for the two years was also 3.3% higher than the mean rainfall received in 2005.

Effect of N levels on maize growth and development

Maize plant height did not significantly (P>0.05) differ between the two seasons (**Table 3**). Higher N levels significantly (P < 0.001) produced taller plants at 6 and 8 WAS than control. The tallest plants were observed for 90 kg N ha^{-1} while the shortest were observed for control (0 kg N ha^{-1}). The effect on number of leaves plant^{-1} was also significantly (P<0.001) higher for higher N treatments than control at 6 and 8 WAS. However, there was no significant difference between 0 and 30 kg N on the one hand and between 60 and 90 kg N on the other at 8 WAS in 2005. Aluko and Fischer (1987), Gungula *et al.* (2005) also reported that higher N rates enhanced the vegetative growth of maize and increased the source capacity of the plants by increasing the number of leaves produced per plant.

There was a significant (P<0.05) Year × N level interaction effect on the number of leaves plant^{-1} at 8 WAS in 2006. Significantly higher numbers of leaves plant^{-1} were observed with 30, 60 and 90 kg N than the control. Although a relatively higher number of leaves were observed for 60 and 90 kg N, there was no significant difference with 30 kg N ha^{-1}. Values for leaf area were significantly (P<001) higher in 2006 than in 2005 at 6 WAS (**Table 4**). The relatively higher amount of rain and lower *Striga* emergence observed in 2006 than 2005 probably increased the availability of nutrients and moisture thus increasing leaf expansion during the season. Although there were significant differences among the N levels in the expression of leaf area, 60 kg N significantly (P<0.001) produced higher leaf area than 0 and 30 kg N at 6 WAS in 2005 and 2006, 90 kg N at 6 WAS in 2005 and 8 WAS in 2006. The relatively higher values of leaf area in 2006 may be due to the higher rainfall amount as reported by Grabau (1995) and Ottman and Welch (1988): rainfall affects soil moisture which in turn affects N up take and the distribution of N in plants.

Consequently LAI was significantly (P<0.001) higher for 30, 60 and 90 kg N than the control at 6 WAS in 2005 and 2006. Higher LAI occurred at 60 kg N than at 90 kg in 2005, but the 90 kg N was significantly superior to all N levels in 2006. It is apparent that LAI values were generally higher in 2006 than 2005 as a consequence of an increase in rainfall, number of leaves and leaf area. Dugje and Odo (2006) reported a direct relationship between LAI with number of leaves and leaf area. Aluko and Fischer (1987) reported increased source capacity with an increase in N levels.

The number of days to 50% tasselling was significantly (P < 0.01) delayed by higher N levels than control. The control treatment significantly tasseled earlier than 30, 60 and 90 kg N during both years. The delay in period to tasselling ranged from 0.7–1.2 days in 2005 and 1.5–4.7 days in 2006. The delay in tasselling may be attributed to luxurious growth at higher N levels in the presence of high moisture as indicated by higher plant height and photosynthetic parameters.

Effect of N levels on *Striga* count

Striga plants started emerging at 8 WAS and the emergence was significantly (P<0.001) reduced by 60 kg N ha^{-1} than 0, 30 or 90 kg N ha^{-1} at 10 WAS in 2005 (**Table 5**). N at 30 kg ha^{-1} significantly (P<0.001) promoted *Striga* emergence than 0, 60 or 90 kg N during the same period. In 2006, N at 30, 60 and 90 kg N ha^{-1} significantly reduced the *Striga* count more than the control. Thus, lower *Striga* counts were observed for 60 and 90 kg N treatments, respectively, in both years. This finding corroborates those of Kim *et al.* (1997) who reported higher *Striga* emergence at low rates of between 30 and 60 kg N ha^{-1} than 0 kg N ha^{-1}. This implies that the practice of applying low amounts of N by farmers in West Africa promote *Striga* infestation. Pieterse and Verkleij (1991) and Dugje *et al.* (2008) reported higher stimulation and *Striga* emergence at low N doses in low fertility soils in farmers' fields in the savannas. There was significant (P < 0.01) Year × N level interaction effects on *Striga* count at 10 and 12 WAS. At 10 WAS *Striga* count was signi-ficantly (P<0.001) lower for the control and 60 kg N ha^{-1} in 2005 than 2006. The reverse was observed for 30 and 90 kg N ha^{-1}, which significantly promoted *Striga* emergence in 2005 more than in 2006. However, mean *Striga* counts

Table 5 Effect of year and nitrogen levels on *Striga* count ha^{-1} at 10 and 12 WAS in Michika, Nigeria in 2005 and 2006.

	***Striga* count ha^{-1}(x000)**					
	10 WAS			**12 WAS**		
Kg N ha^{-1}	**2005**	**2006**	**Mean**	**2005**	**2006**	**Mean**
0	60.2	62.2	61.2	64.9	64.0	64.5
30	64.2	60.4	62.3	67.8	61.2	64.5
60	49.2	54.7	51.9	58.1	61.0	59.5
90	55.2	52.4	53.8	602	56.9	58.6
Mean	57..2	57.4	-	62.8	60.8	-
SED Year		0.84			0.49***	
SED N Levels		1.18***			0.69***	
SED Yr. x N		1.68**			0.98***	

**F – test significant (P<0.01), ***F – test significant (P<0.001)

did not significantly (P>0.05) differ between 2005 and 2006. At 12 WAS, *Striga* count was significantly (P<0.001) higher in 2005 than 2006. Similar to the trends observed at 10 WAS, *Striga* count was significantly (P<0.0) higher at 30 and 90 kg N in 2005 than in 2006. Application of 60 kg N ha^{-1} reduced (P<0.001) *Striga* counts in 2005 than in 2006. There was no significant difference between the two seasons in the promotion of *Striga* infestation at 0 kg N ha^{-1}. However, values were relatively higher in 2005 than 2006. The early establishment and higher rainfall recorded in 2006 probably suppressed *Striga* emergence. Ogborn (1987) reported that early continuous rains delay S. *hermonthica* infestation, and excessively wet soils are not favourable for *Striga* damage to crops.

Effect of N levels on grain yield

An increase in N levels significantly (P<0.001) increased cob weight (**Table 6**). The highest cob weight was observed for 60 kg N, while the lowest value was recorded for 30 kg N ha^{-1} in 2005. However, there was no significant difference between the 60 and 90 kg N ha^{-1}. In 2006, the control produced the lowest (P<0.001) cob weight than 30, 60 or 90 kg N, and the highest value was observed for 90 kg N ha^{-1}. There were significant (P<0 .001) Year × N level interaction effects as cob weight was significantly higher for 0 kg N ha^{-1} in 2005 than in 2006, and 90 kg N ha^{-1} in 2006 than in 2005. The higher cob weight expressed at higher N levels than control was probably due to efficient utilization of N as a nutrient and the apparent reduction of *Striga* population by N fertilization.

Grain yield ha^{-1} was significantly higher (P<0.01) in 2006 than in 2005 (**Table 6**). The value was 7.0% higher in 2006 than in 2005. The higher photosynthetic parameters and lower *Striga* emergence observed during the year enhanced grain yield during the season. An increase in N level significantly (P<0.001) increased grain yield. Grain yield was relatively higher for the control in 2005 than in 2006. Thus grain yield ha^{-1} was higher by 8.6, 35.2, and 44.7% for 30, 60, and 90 kg N ha^{-1} than control, respectively. In 2006, the values were higher for 30, 60 and 90 kg N than control by 17.2, 36.3 and 43.6%, respectively. Similarly Akintoye *et al.* (1999), Oikeh *et al.* (2003) and Kamara *et al.* (2005) reported that N fertilization significantly increased maize grain yield in the Nigerian savanna.

Although the N status of the soil in the experimental area was high (**Table 1**), grain yield may increase further if N levels are increased beyond 90 kg N ha^{-1} as used in the present experiment. This inference is based on the continuous increase observed in grain yield up to the highest N level applied. The 100-seed weight was significantly (P< 0.001) higher in 2005 than in 2006 (**Table 6**). The early period to flowering experienced in 2005 may have prolonged the grain-filling period which enhanced grain weight, as N levels had no significant effect on grain weight. Slightly higher grain weight was observed at 60 kg in 2005 and 2006, and the lowest value was observed for 0 kg N in 2006.

Effect of N levels on linear relationships

The effect of N levels on linear relationships showed that grain yield ha^{-1} was positively correlated with plant height (r = 0.78), number of leaves plant^{-1} (r = 0.83), leaf area (r = 0.74), leaf area index (r = 0.85), and cob weight (r = 0.77), and was negatively associated with *Striga* count ha^{-1} (r = -0.70) (**Table 7**). Similarly, cob weight was positively associated with plant height (r = 0.63), number of leaves plant $^{-1}$ (r = 0.63), leaf area (r = 0.59), and leaf area index (r = 0.69) and was negatively associated with *Striga* count (r = -0.64)

Striga count ha^{-1} was negatively associated with plant height (r = -0.43), number of leaves plant^{-1} (r = -0.63), leaf area (r = -0.69) and leaf area index (r = -0.72) (**Table 7**). Plant height increased with increase in number of leaves plant^{-1} (r = 0.67), leaf area (r = 0.74), leaf area index (r = 0.77), and number of days to 50% tasseling (r = 0.36). Number of leaves plant^{-1} was positively correlated with leaf

Table 6 Effect of year and nitrogen levels on cob weight (g), grain yield ha^{-1} (kg) and 100 seed weight (g) in Michika, Nigeria in 2005 and 2006.

	Cob weight			**Grain yield ha^{-1}**			**100 – seed weight**		
Kg N ha^{-1}	**2005**	**2006**	**Mean**	**2005**	**2006**	**Mean**	**2005**	**2006**	**Mean**
0	120.3	103.5	111.9	2927.6	3088.9	3008.3	21.5	19.0	20.2
30	115.5	122.0	118.8	3205.7	3734.9	3470.3	21.5	19.4	20.4
60	135.3	132.5	133.9	4514.3	4847.6	4680.9	23.9	20.4	22.2
90	133.3	154.5	143.9	5294.9	5473.9	5384.4	22.1	19.4	20.8
Mean	126.1	128.1	-	3985.6	4286.4		22.2	19.6	-
SED Yr		3.01			113.32**			0.61***	
SED N Levels		4.56***			160.25***			0.87	
SED Yr. x N		6.25***			226.63			1.23	

**F – test significant (P<0.01), ***F – test significant (P<0.001)

Table 7 Linear correlation coefficient (r) among maize agronomic parameters at four N levels in Michika, Nigeria in 2005 and 2006 combined.

Maize parameter	**Plant height**	**No. leaves plant^{-1}**	**Leaf area**	**Leaf area index**	**Days to 50% tasselling**	***Striga* count ha^{-1}**	**Cob weight**	**Grain yield ha^{-1}**
Plant height	-	0.67***	0.74***	0.77***	0.36*	-0.43*	0.63***	0.78***
No. leaves plant^{-1}	-	-	0.94***	0.88***	0.01	-0.63***	0.63***	0.83***
Leaf area	-	-	-	0.94***	0.29	-0.69***	0.59**	0.74***
Leaf area index	-	-	-	-	0.18	-0.72***	0.69***	0.85***
Days to 50% tasselling	-	-	-	-	-	-0.01	0.10	0.13
Striga count ha^{-1}	-	-	-	-	-	-	-0.64***	-0.70***
Cob weight	-	-	-	-	-	-	-	0.77***
Grain yield ha^{-1}	-	-	-	-	-	-	-	-

*Significant (P<0.05), **Significant (P<0.01), ***Significant (P<0.001).
Values without asterisk(s) have no significant linear correlation.

area (r = 0.94) and leaf area index (r = 0.88), while leaf area was also positively correlated with leaf area index (r = 0.94).

The reduction in *Striga* infestation at higher N levels in the present study corroborates similar findings by previous authors. Mumera and Below (1993) and Kim *et al.* (1997), reported that adequate N, especially urea, and cereal–legume rotation are effective in reducing *Striga* emergence, damage, and dry weight in maize and sorghum. The maize cultivars used in both studies were early, intermediate and late maturing hybrids that took a longer time in the field. The effect of N fertilization was not evident until 42 days after planting (Mumera and Below, 1993), unlike extra early maturing varieties that could have matured 30 days latter, and hence enabling some level of escape from *Striga* damage.

Thus, increase in N level in the present study reduced *S. hermonthica* infestation and increased the photosynthetic parameters and cob weight, which were the major contributors to grain yield. According to Kamprath *et al.* (1982), the increase in maize grain yield after N application is largely due to an increase in the number of ears per plant, increase in total dry matter distribution to the grain and increase in average ear weight. The significantly higher *Striga* population observed in 2005 at 0 and 30 kg N ha^{-1} reduced the expression of the photosynthetic parameters and subsequently reduced grain yield of maize. Ransom and Oswald (2004) reported that short cycle varieties (such as 95 TZEE W used in this study); had the lowest *Striga* densities but produce acceptable yields only in low stress environments in Kenya. It is apparent that increasing N fertilization of the short cycle maize varieties would further reduce *Striga* infestation and increase grain yield in low – stress environments such as the northern Guinea savanna in Nigeria and similar ecologies in the tropics.

CONCLUSION

Although the N status of the soil at the experimental site was high, application of between 60 and 90 kg N ha^{-1} suppressed *Striga* infestation, increased the photosynthetic parameters, and consequently increased grain yield of maize. The 60 kg N was the most promising dose for promoting leaf production and expansion, while both 60 and 90 kg N suppressed *Striga* infestation and increased grain yield. Resource-poor farmers in the NGS would therefore achieve an appreciable level of *Striga* control and improve grain yield of the extra-early maize by application of 60–90 kg N ha^{-1}. However, increasing the N level beyond 90 kg may further suppress *Striga* infestation and increase grain yield of the open-pollinated maize variety (95 TZEE W) beyond the 5.4 tons ha^{-1} realized in the present study.

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