Response of maize (*Zea mays* L.) to varied moisture levels under *Striga lutea* (Lour) infestation in Nigeria

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ABSTRACT

Laboratory and glasshouse trials were used to determine the response of maize plants to varied moisture levels under *Striga lutea* infestation. Six moisture levels (1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 ml) were applied to striga seed for germination count in the laboratory, while five moisture levels (300, 600, 900, 1200 and 1500 ml) were applied to two maize varieties infested with *Striga lutea* to assess their tolerance to striga in the glasshouse. The results showed decline in striga germination counts with increased moisture supply in the laboratory and daily moisture application. Supply of 2.00 ml of moisture seemed enough for optimum striga germination. Results from a glasshouse trial also showed significant effects of moisture on striga and maize agronomic characters, except for maize flag leaf length and grain yields. The maize varieties also differed significantly for striga syndrome rating, plant height, and maize grain yield, while variety × infestation as well as variety × moisture differed significantly for almost all the traits assessed. The interactive effects of variety × moisture were significant for all variables except grain yield. Similarly, gradual increase in striga emergence at higher moisture levels from 1.3 (300 m1) to 52.0 (1500 ml) were recorded. Striga syndrome ratings were significantly reduced with increased moisture, thereby enhancing higher grain yield. The use of striga- resistant genotypes in addition to adequate soil moisture will probably boost maize production in striga-endemic areas.

Original scientific paper. Received 30 Oct 02; revised 5 Jul 04.

RÉSUMÉ

OLAKOJO, S. A. & OLAOYE, G.: *Réaction de maïs (*Zea Mays *L.) aux niveaux variés d'humidité sous l'infestation de* Striga lutea *(Lour) au Nigéria.* Les essais de laboratoire et de serre se sont déroulés à l'Institut de Recherche et de Formation Agricole, Université d'Obafemi Awolowo, Plantation de Moor, Ibadan, Nigeria. Le but était de déterminer la réaction des plantes de maïs aux niveaux différents d'humidité sous l'infestation de *Striga lutea*. Six niveaux d'humidité (1.5, 2.0, 2.5, 3.0, 3.5, et 4.0 ml) sous une situation de laboratoire, étaient appliqués aux graines de *Striga* pour le compte de germination, alors que cinq niveaux d'humidité (300, 600, 900, 1200 et 1500 ml niveaux d'humidité) sous condition de serre étaient appliqués aux deux variétés de maïs infestées de *Striga lutea* pour l'évaluation de leur tolérance au *Striga*. Les résultats montraient une baisse des comptes de germination de *Striga* avec une augmentation en provision d'humidité sous condition de laboratoire et d'application d'humidité quotidiennement. Provision de 2.00 ml d'humidité semble être suffisant pour la germination optimale de *Striga*. Les résultats de l'essai d'une serre montraient aussi des effets considérables d'humidité sur *striga* et les caractères agronomiques de maïs sauf l'iris de maïs, longueur de feuille et les rendements de grains. Les variétés de maïs aussi différaient considérablement pour l'estimation de syndrome de *striga*, taille de plante et le rendement de grain de maïs, alors que variété × infestation ainsi que variété × humidité différaient considérablement pour presque tous les traits évalués. Les effets interactifs de variété × humidité étaient considérables pour toutes les variables sauf le rendement de grain. De la même façon, les augmentation graduelles de l'émergence de *Striga* aux niveaux d'humidité plus élevée de 1.3 (300 ml) à 52.0 (1500 ml) étaient enregistrées. Les estimations de syndrome de *Striga* étaient considérablement réduites avec l'augmentation d'humidité améliorant de cette façon le rendement plus élevé de grain. L'utilisation de génotypes résistants au *Striga* en plus d'humidité adéquate du sol pourrait probablement accroitre la production de maïs dans les zones endémique de *Striga*.

Ghana Jnl agric. Sci. **39**, 3-10

Introduction

Maize *(Zea mays* L.) is a popular cereal crop in Africa, and a major staple food that constitutes the main diet of many people and live stock in the tropical and subtropical regions of Africa. Its production in Nigeria cuts across many agroecologies where adequate moisture and soil nutrient can sustain its growth. Production capacity and use potentials are on the increase in Nigeria. Many factors are hindering maize production especially at the commercial level (Olakojo & Iken, 1999). Some of these production constraints include susceptibility to pests and diseases, poor soil nitrogen level, incessant drought, and lack of improved seeds for planting. Recently, striga (a parasitic green plant) has been found to be endemic to many maize-producing belts of Nigeria, reducing grain yield by 30 to 70 per cent (Kim & Adetimirin, 1997).

Several measures had been suggested for controlling striga. These include cultural practices, use of inorganic and organic fertilizers, use of chemicals and stimulants, and planting of striga-resistant crop varieties. Also, increase in soil moisture supply to maize plants in striga-infested soil was suggested by Ray & Sinclair (1997). They reported that maize genotypes varied in their response to soil water transpiration. This may imply that genotypes with reduced water transpiration may be ideal in striga-endemic areas for conserving moisture to balance up for the losses caused by striga infestation. It was believed that striga cannot thrive in areas with high rainfall, but Musselman & Ayensu (1984) had shown that *Striga asiatica* occurred in areas such as South Africa and North and South Carolina (USA) with 45.72 and 50.80 cm annual rainfall, respectively.

Also, in Nigeria, Omidiji *et al.* (1993) reported that *S. asiatica* was widespread in the Southern Guinea Savanna (SGS) with high and bimodal rainfall pattern. Kim & Tanimonure (1993), therefore, studied the relationship between watering regime and S. *hermonthica* in the laboratory and glasshouse to establish a trend. Their results showed that maximum watering of 3.5 ml daily recorded the highest striga germination count in the laboratory study, while increase in moisture from 300 to 1200 ml weekly enhanced higher striga emergence in the glasshouse.

An understanding of the reaction of various striga species to different eco-physiological factors, therefore, calls for testing of different striga species under varied moisture levels for crop growth and development. The objectives of this study, therefore, were (1) to evaluate the striga germination count at varied moisture levels in the laboratory, (2) assess the response of maize to varied moisture levels in a glasshouse maize trial under *Striga lutea* artificial infestation, and (3) to determine the appropriate moisture requirement for optimum striga emergence for effective crop screening.

Materials and methods

The study comprised two sets of experiments:

Laboratory study

The study was at the Maize Breeding and Physiology Laboratory of the Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria, in 1996. Before planting, the viability of striga seeds was tested using the tetrazolium red test (Elpee & Norris, 1987). Clean Petri dishes were lined with 9.0-cm diameter filter paper for each sample which contained 50 viable striga seeds from the previous year's collections. The seeds were sprinkled on each plate and watered daily using 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0 ml of moisture, respectively, as treatments. The samples were covered with aluminum foils to exclude light and were incubated for 14 days at room temperature and humidity.

A completely randomized design (CRD) was used with four replications. Striga germination count was determined under the binocular light dissecting microscope. The experiment was repeated two times and the data sets were pooled for analysis. Striga germination counts were recorded at varied moisture levels. Therefore, mean and percentage striga emergence counts were computed for this trait.

Glasshouse trial

Plastic pots containing 5 kg top soil were placed in the glasshouse. The soil was an alfisol with loam-sand and slightly acidic. The cation exchange capacity was fairly low, while the total nitrogen and available phosphorus were moderately adequate. Each pot was inoculated with about 44,000 viable striga seeds (infested), and a corresponding set of uninfested pots served as control. Two maize varieties, Tzpi 97 (striga-resistant) and Tzpi 9 (striga-susceptible), were planted 14 days after inoculation to allow striga seeds to acclimatize to the new environment. Weekly 300, 600, 900, 1200 and 1500 ml of water were supplied to the potted plants as treatments. The experiment was 2 × 2 × 5 factorial with moisture level (A) as main plot, infestation (B) as sub plot, and variety (C) as sub-sub plot, respectively.

Data collected included striga emergence count and striga syndrome rating (1-9)[where 1 =Normal growth, no visible symptoms; 2= Small and vague, purplish-brown leaf blotch; 3=Mild leaf blotching, with some purplish-brown necrotic spot; 4=Extensive blotching and mild wilting; slight but noticeable stunting and reduced ear and tussel size; 5=Extensive leaf blotching, wilting, and some scorching; moderately stunting, ear and tussel reduction; 6= Extensive leaf scorching with mostly gray necrotic spots; some stunting and reduction in stem diameter, ear size and tassel size; 7=Definite leaf scorching, with gray necrotic spots, and leaf wilting and rolling; severe stunting and reduction in stem diameter, ear size, and tassel size, often causing stalk lodging, brittleness, and husk opening at the late-growing stage; 8= Definite leaf scorching with extensive gray necrotic spots; conspicuous stunting, leaf wilting; rolling, severe stalk, lodging, and brittleness; reduction in stem diameter, ear size and tassel size; 9=complete scorching of all leaves, causing premature death or collapse of host plant and no ear formation], according to Kim (1995). Other parameters included flag leaf length (cm), grain row/cob, number of kernels/row, and maize grain yield (t/ha). Data were analysed using the SAS 1998 model to compute Analysis of Variance (ANOVA), while pertinent means were separated using the New Duncan Multiple Range Test [NDMRT] according to Duncan (1955).

Results and discussion

Table 1 shows the effects of varied moisture levels on *S. lutea* germination count. The percentage striga count declined with increased moisture. For example, 1.0 ml of daily application of moisture resulted in a 74 per cent striga germination as against 2.0 per cent at 4.0 ml of water daily. A moisture level of 2.0 ml, however, seemed enough and probably ideal for optimum striga germination. Olakojo *et aI.* (2001) reported significant differences in striga growth characteristics (emergence count and rating) under varied moisture levels. Hence, screening for striga tolerance materials should, among other factors, ensure 2.0 ml of daily watering for optimum striga emergence.

TABLE 1

Effects of Varied Water Levels on Striga lutea *Germination Count in the Laboratory*

Water level (ml)	*Percentage striga germination*
1.0	74.00
1.5	52.00
2.0	78.00
2.5	8.00
3.0	32.00
3.5	14.00
4.0	2.00
Mean	37.17
SE	2.11

Values in the same column not followed by the same letter are significantly different at $P<0.05$.

Table 2 presents mean square (MS) from the analysis of variance. Differences in moisture regime significantly affected all parameters except flag leaf length and grain yield. Flag leaf length was earlier reported to be positively correlated with grain yield under striga infestation by Olakojo (2001). The two maize varieties, however, differed significantly for striga syndrome rating, plant height, kernel rows per ear, and maize grain yield. Adeosun *et aI*. (2001) also reported significant differences in striga rating in sorghum. They associated this with erratic rainfall distribution and pattern in 1988 at Zaria, Nigeria. Therefore, varied moisture levels influence striga rating in many cereal crops and should be considered for effective crop screening for striga tolerance.

The first order interaction variety × infestation (B × C) and variety × moisture levels (A × C) differed significantly for striga parameters and maize agronomic characters. The interactive effect of moisture levels × infestation (A × B) was also significant for striga count and rating as well as maize agronomic traits such as kernel rows per ear. The interaction between ABC had a significant effect on all variables except grain yield. Variety was also significant for striga rating, plant height and kernel rows per ear, suggesting that the interactive effects of the three factors significantly affect these traits (Table 2).

Table 3 presents character means for striga-related traits. Under infestation, plant height in the resistant hybrid increased with increased moisture levels, while no definite trend was observed in the susceptible hybrid. Under both infestation conditions, plant height increased with increased moisture levels in the susceptible hybrid. The differences were significant under both infestation conditions for flag leaf length at different moisture levels, except at 1500 ml week^{-1}. Fig. 1a and 1b present the bar charts showing relationship between striga infestation parameters and moisture levels. Fig. la shows a gradual increase in striga emergence count with increased moisture levels up to 900 ml of weekly water. Maximum striga emergence (52 m^{-2}) was recorded at 1200 ml of water in the susceptible maize hybrid. This showed that additional application of moisture significantly enhanced

TABLE 2

Analysis of Variance (ANOVA) of Agronomic Characters of Maize Infested With Striga lutea *Under Varied Moisture Conditions*

Sources of` variation	*Df*	*Striga count*	*Striga rating*	*Plant height*	*Ear height*	*Flag leaf length*	*Seed rows ear^{-1}*	*Kernels row^{-1}*	*Grain yield*
Replication	3	0.79	0.03	4556.4	0.83	8.37	0.64	1.51	2.04
Moisture (A)	4	7.78*	3.34**	8660.86	2.95**	104.29	1.12**	7.78**	2.96
Error A	12	0.81	0.02	225.39	0.20	63.65	`0.28`	1.57	2.26
Infestation (B)	1	0.012	0.08	540.8	1.83	12.97	2.51	0.01	2.48
A × B	4	10.28**	3.51**	2055.86**	3.80**	54.54	0.67	4.521*	1.94
Error B	15	0.75	0.03	360.70	0.41	10.06	0.61	1.77	4.27
Variety (C)	1	1.89	3.67**	274.54**	1.61	64.12	0.30	5.32*	58.95**
B × C	1	9.04**	0.80**	2951.06**	9.52	173.02	0.27	0.22	1.00
A × B × C	4	9.04**	0.80**	2951.06**	9.52**	173.02*	2.21*	11.43*	5.07
Error C	30	2.56	0.01	11.28	0.38	21.85	0.27	0.22	1.00
Total	82								

* ** Significant at *P*< 0.05 and 0.01.

TABLE 3

Means for Striga lutea *Parameters and Maize Agronomic Traits of Tolerant and Susceptible Hybrid Maize Grown Under Different Levels of Moisture and Striga Infestation*

Moisture level (ml)	*Striga count*	*Striga rating (1-9)*	*Plant height (cm) infested*	*Uninfested*	*Ear height (cm) infested*	*Uninfested*	*Flag leaf (cm) infested*	*Uninfested*
300	8.93b	6.00c	61.00c	52.75e	0.0e	0.00e	10.13	4.13c
	(1.37c)	(8.50c)	(41.75c)	(40.25e)	(0.0c)	(0.0c)	(5.15b)	(3.75c)
600	6.87b	5.75a	92.5c	61.75d	5.50b	0.00c	18.62a	10.63b
	(1.68)	(7.50b)	(13.25c)	(74.5d)	(0.00c)	(0.00c)	(18.00a)	(9.13c)
900	2.87b	3.75a	117.75b	117.5c	12.75a	10.63a	28.38a	14.30ab
	(13.75b)	(7.50b)	(107.75b)	(119.5a)	(0.00c)	(7.50b)	(15.83a)	(16.75b)
1200	9.56b	3.75a	131.50a	136.75b	13.50a	14.63a	20.70a	23.78a
	(18.31b)	(7.57b)	(137.25)	(171.25a)	(0.00c)	(9.75b)	(20.50a)	(16.13a)
1500	29.15a	2.50a	145.5a	153.0a	12.75a	12.50a	22.20a	12.57ab
	(51.37a)	(4.75a)	(125.50a)	(206.0a)	(15.6a)	(15.63a)	(20.07a)	(29.63a)
SE	8.19	0.76	0.15	0.16	3.29	1.71	11.94	7.18

Values in parenthesis are for the susceptible maize variety.

higher striga emergence, especially in the susceptible maize varieties.

Striga syndrome ratings were better in the resistant variety, with reduced rating of 2.2 to 5.8 compared to the susceptible variety with high ratings of 5.2 to 8.5 (Fig. 1b). Ogunbodede & Olakojo (2001) have reported the usefulness of striga syndrome rating in assessing maize for tolerance to *Striga asiatica.* In striga tolerance breeding, the lower the syndrome rating, the more tolerant is such a material. Hence, the significant influence of moisture on striga rating should be considered for enhanced grain yield. Similarly, Fig. 2a and 2b show the trend of maize grain yield as soil moisture increases under *S. lutea* infestation. For the striga-resistant and susceptible maize varieties, maize grain yield increased with increase in soil moisture. Although yield under non-striga infestation increased with increase in moisture levels, no yield data were recorded at 300 to 900 ml of weekly moisture application for striga-artificially infested maize genotypes. The moisture levels were too low to sustain maize plants till maturity under parasitic influence of striga. However, optimum grain yield was recorded at 1500 ml (Fig. 2b). Bouker, Hess & Payne (1996), however, reported a significant decrease in transpiration ratio because of striga infestation, and a significant increase in transpiration ratio with reduced water availability.

Conclusion

The trend in this trial showed that striga count in the susceptible maize variety increased with increased moisture, while reduced striga syndrome rating correspondingly increased maize grain yield. In the resistant maize hybrid, the higher the moisture level, the lower the striga emergence count (900 ml of moisture). Farmers should, therefore, increase soil moisture where irrigation is available to control striga and to increase maize grain yield. Combination of striga-resistant genotypes and supply of adequate soil moisture will no doubt boost maize productivity in striga-infested areas of South Western Nigeria.

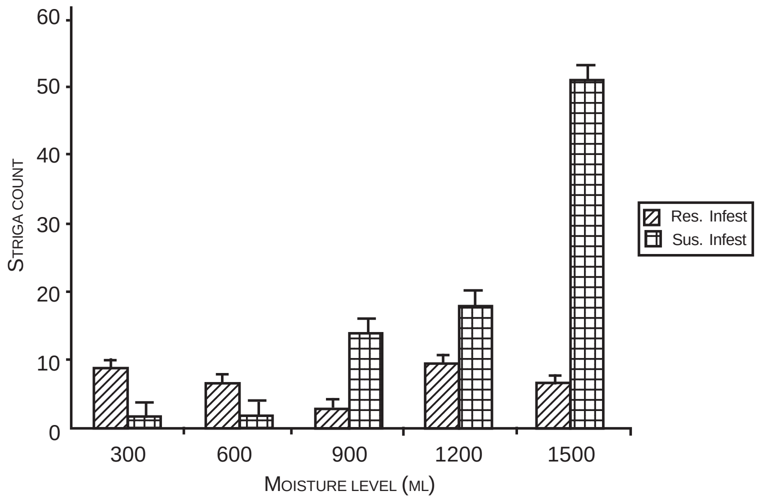

Fig. 1a. Effects of varied moisture levels on *Striga lutea* emergence count in maize (*Zea mays* L.) under artificial infestation.

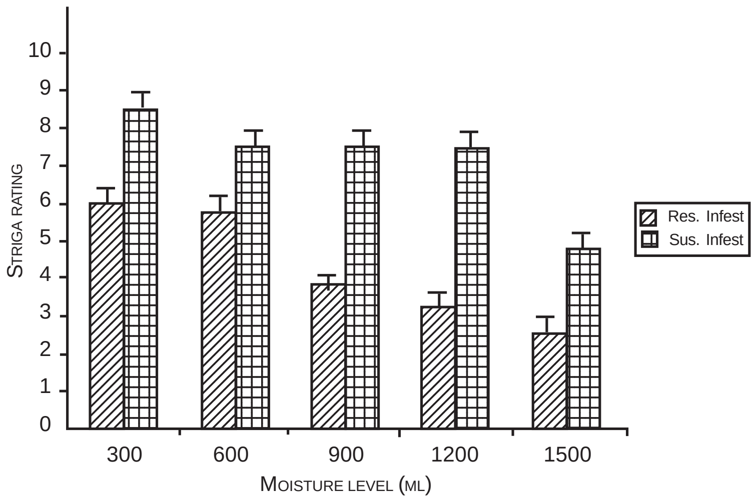

Fig. 1b. Effects of varied moisture levels on *Striga lutea* syndrome rating in maize (*Zea mays* L.) under artificial infestation.

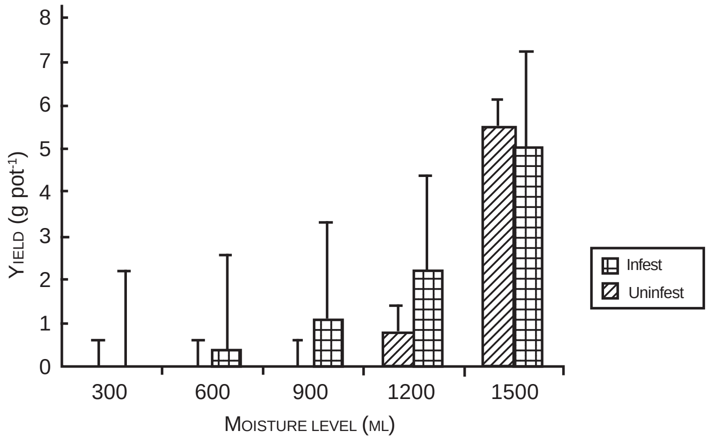

Fig. 2a. Effects of varied moisture levels on grain yield of maize resistant to *Striga lutea* under artificial infestation.

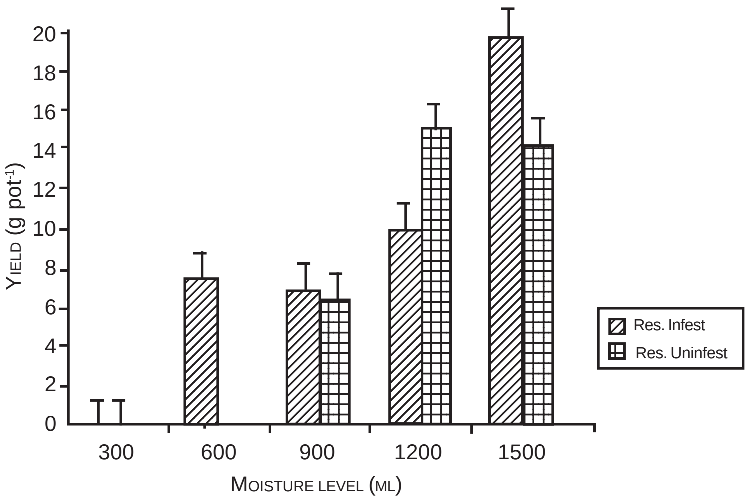

Fig. 2b. Effects of varied moisture levels on grain yield of maize susceptible to *Striga lutea* under artificial infestation.

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