African Scientist Vol. 4, No. 4, December 31, 2003
Printed in Nigeria

1595-6881/2003 $12.00 + 0.00

http://www.klobexpublishers.com

AFS 2003039/4403

Comparative growth responses of field- and pot-grown open-pollinated maize varieties to N fertilizer application

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(Received August 4, 2003)

ABSTRACT: Field and screen house experiments were conducted during the 1997 cropping season at the University of Ilorin, Nigeria. The experiments designed as 2 x 5 factorial and laid out in split-plot were to compare responses of field- and pot-grown maize varieties to N fertilizer application. Two open-pollinated maize varieties (DMRSR-Y and TZBP-W) were evaluated at five N levels (0, 30, 60, 90 and 120 kg N ha^{-1}) in both the field and the controlled environment. Data collected included leaf growth measurements, morphological growth characters such as plant height, tassel and silk appearance dates, and physiological growth indices at both vegetative and reproductive stages. Yield components and grain yield were also measured at harvest. Responses of the evaluated varieties to N fertilizer application were similar for both the pot- and field-grown plants. However, the effects of low N levels were greater in the potted plants than in the field-grown ones, due to the adaptation of the field –grown plants to low N application, resulting from large volume of soil available to field-grown plants. Conversely, at the higher N levels, the values of most measured parameters were generally higher in the pot-grown plants than in the field. This was however, attributable to adequate soil moisture resulting from daily watering of potted plants as against the field plants which were rain fed and suffered water stress due to inadequate rainfall for sometime during the growing period, thereby unable to utilize the applied N fertilizer. Conclusively, this study showed that the results of the potted plants did not differ significantly in trends, but rather in magnitude, thereby suggesting that care should be taken in using controlled environment data in modeling for field evaluation of grain yield under rain fed conditions.

Key words: Comparative responses, N fertilizer application, pot- and field-grown maize varieties.

Introduction

A major source of controversy in crop research studies is whether such studies should be conducted solely in the field or under controlled environments. It has been observed that field studies are often subjected to weather vagaries such that many factors influencing crop growth cannot be controlled and this limits the repeatability of field investigation (Day *et al*., 1978). Davidson and Campbell (1984) also observed that it is difficult to obtain accurate data because of the combined influences of temperature, soil fertility and soil moisture under field conditions.

However, controlled environment studies offer the possibility to control these factors and to distinguish individual effects. Moreover, screening can be accomplished in a smaller space and shorter times in green houses and growth rooms, although the rooting media often used distinctively differ from soil and may not be useful in selecting for traits associated with root soil interactions (Shannon, 1984). An essential part of useful research is extrapolation of laboratory, growth chamber and field results to field testing (Christiansen, 1979). However, there is increasing evidence in the literatures that the responses of plant grown in controlled environments differ from those grown in the field (Begg and Turner, 1976). It was therefore the objective of this study to investigate the comparative growth responses of two open-pollinated (OP) maize varieties to N fertilizer application under the controlled environment and field conditions.

Materials and Methods

The experiments were conducted in a screen house and an adjacent field at University of Ilorin main campus during the 1997 cropping season. The study was designed as a 2 x 5 factorial experiment and laid out in split-plot arrangement in both the screen house and the field. Plants were grown in 10 litre capacity pots filled with top soil (pH 6.30; %N 0.11; P 8.45 ppm; OM 3.21; K 0.16 ppm; Ca 6.00 cmol kg^{-1}; Mg 1.20 cmol kg^{-1}; %sand 86.6; %silt 9.7 and %clay 3.7) in the screen house and replicated eight times, while the field-grown plants were replicated four times. Two OP maize varieties (DMRSR-Y and TZBP-W) were given five levels of N fertilizer application in both the field and screen house. Both maize varieties are improved OP types which are widely cultivated in the study area, and constituted the main plots in the experimental layout.

The nitrogen treatments involved factorial application of N fertilizer to the two maize varieties at rates of 0.5, 10, 15 and 20g per pot, equivalent to 0, 30, 60, 90 and 120 kg N ha^{-1} as applied on the field using urea (46% N) in two split applications at 2 and 6 weeks after planting (WAP). Basal applications of P and K at rates equivalent to 60 kg P_2O_5 and K_2O ha^{-1} respectively were made at the time of first N application. Four seeds treated with Apron Plus were planted in each pot or hole in a plot (field) and later tinned to one seedling per pot and two seedlings per hole in the field. All the necessary agronomic management practices were observed in both the pot and field experiments. In the screen house, weed control in the pots was achieved by weekly hand pulling, while in the field, a pre-emergence herbicide, atrazine (500g/Latrazine 6-chloro-N_2-Ethyl-M_4-150 Propyll, 3,5-Triazine, a.i.), was sprayed immediately after planting and this was supplemented by hoe weeding at 7 WAP. In the screen house, all pots were watered every other day until canopy was achieved, and thereafter, pots were watered daily, however, field experiment was rain-fed and no supplementary irrigation was provided.

Leaf growth measurements in six leaf insertions (nodes 5, 7, 9, 11, 13 and 15) were taken as described by Abayomi (1992) and leaf growth parameters including, leaf extension rate (LER), leaf extension duration (LED) and final leaf length (FLL) were calculated according to Gallagher (1979). Leaf area index (LAI) was measured as described by Watson (1947), at weekly intervals. Other measurements included plant height, days to tassel and silk emergence, physiological growth indices at both vegetative and reproductive stages (Duncan and Hesketh, 1968), grain yield components and grain yield at harvest. Analyses of variance were conducted separately for the screen house and field experiments to evaluate the effects of N fertilizer and variety on various parameters measured using GENSTAT 5.2 statistical package. Mean separation was done using Duncan's Multiple Range test at 5% probability level.

Results and Discussion

Effects on leaf growth parameters:

Nitrogen shortage reduced leaf appearance rate (LAR) thereby resulting in reduced number of leaves that appeared under both the controlled and field conditions (Table 1). This result was in consonance with the observation of McCullough *et al*., (1994) and Uhart and Andrade (1995) who showed greater effect of N deprivation on leaf appearance rate, although, Muchow (1988) had earlier reported that N shortage reduced leaf expansion rate more than leaf appearance rate. The results of this study corroborated the later observation, as the effect of N shortage was larger on LER than on leaf emergence. While leaf appearance was decreased by 36%, leaf extension rates at various nodes was decreased by an average of 61%. LER and leaf size generally increased with increasing N, although significant difference was first obtained in leaf 7 (Tables 2, 3, 4 and 5), presumably because soil reserves of N were adequate for the extension of the first six leaves. Many workers have shown that increasing N supply generally increased LER (Thomas, 1983; Alabi, 1999; Mustapha, 1999). The results of this study therefore suggest that higher rates of N uptake result in faster LER in both the field and controlled environment.

In this study, the responses of LER (Tables 2 and 3) and leaf length (Tables 4 and 5) to N application increased with leaf position irrespective of variety or whether pot- or field-grown maize. Similar observations had also been reported for wheat (Gallagher, 1979), barley (Maan, *et al*., 1989), and maize (Alabi, 1999; Mustapha, 1999). This trend was purely ontogenetic since it occurred at all N levels irrespective of variety or pot- or field-grown maize plants. Kirby *et al*., (1982) noted similar trend in LER with leaf position in winter barley.

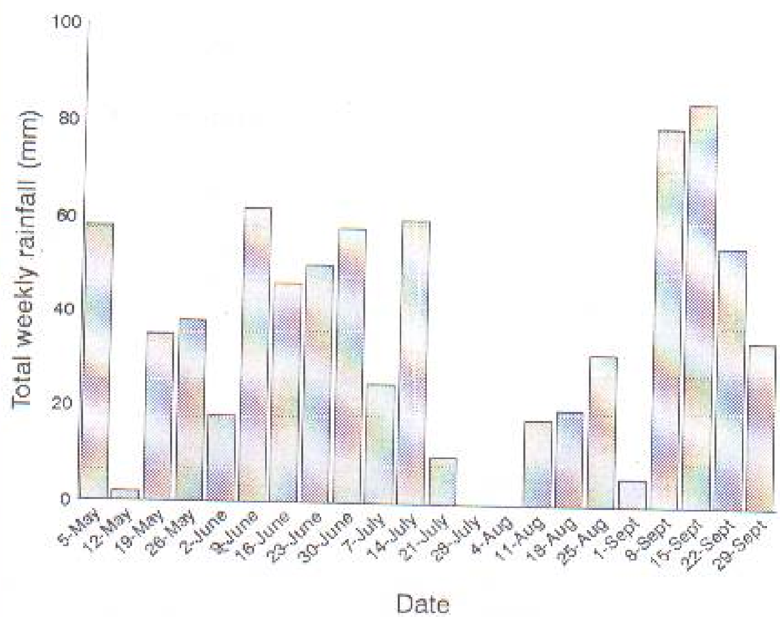

Fig. 1: Total weekly rainfall distribution during 1997 cropping season.

Results of this study show that LERs at most leaf positions were significantly higher in the field-grown than in the potted maize at lower N levels (0-30 kg N ha^{-1}) and vice versa at higher N levels (60-120 kg N ha^{-1}), thereby resulting in significant decreases in LER (Fig. 2) and final leaf length (Fig. 3) by non application of N fertilizer in the pot, but not in the field. This was evidently due to a large soil volume available to field-grown plants to explore as against the restricted soil in potted plants in the screen house. This was similar in principles to the adaptation of field-grown plant to water stress as earlier reported by Ludlow and Ng (1977). Field-grown plants can have their roots penetrating lower horizon and laterally to adjacent plots to obtain nutrients, thereby resulting in improved plant growth at lower N than in the pot-grown plants which were confined to smaller volume of soil. However, applied N at higher levels was not well utilized in the field due to inadequate soil moisture resulting from scanty rainfall (Fig. 1). A declined soil moisture has been shown to be associated with a decrease in diffusion rate of nutrient from the soil matrix to the absorbing root surface (Barber, 1962). Results of this study showed significant positive relationships between LER and final leaf length in maize as was reported for sugar beet (*beta vulgaris*, L.) (Abayomi and Wright, 2002). These results indicate that irrespective of the environmental conditions under which individual leaves are growing, variation in LER was the most important factor influencing final leaf length. Therefore, nitrogen and water affected leaf area mainly by affecting LER.

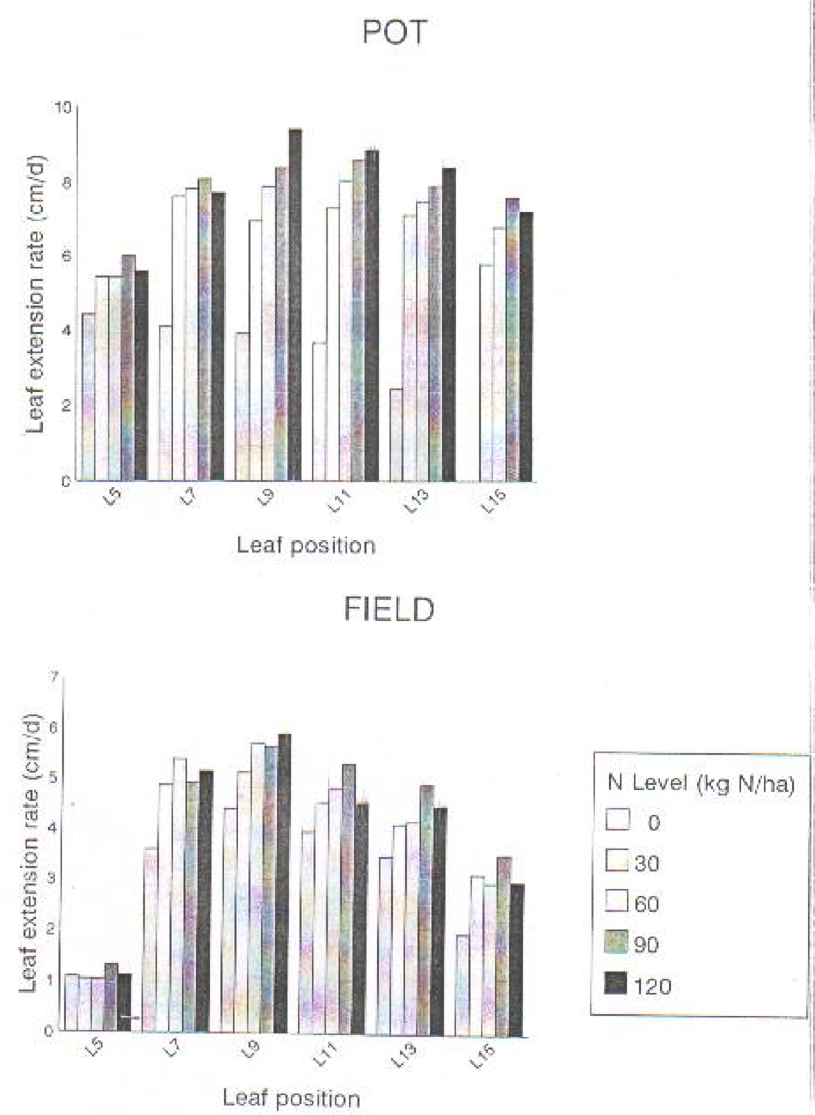

Fig. 2: Effects of N fertilizer application on LER of pot- and field-grown maize.

Leaf area index (LAI) significantly increased with increased n application in both the pot- and field-grown maize. However, the magnitudes of reduction in leaf growth due to N shortage was greater in the potted plants (Figs. 4) possibly due to the adaptability of field-grown plants resulting from larger volume of soil as earlier mentioned. The general trends of all LAI and all N levels including the control were increases from 18 DAP to 60 DAP, in both the potted and field-grown plants (Fig. 4), with significant differences in LAI among N levels occurring from 32 DAP, indicating early responses to N shortages in both the field and screen house plants. This was in line with the report of Uhart and Andrade (1995) who showed an early sensitivity of leaf expansion to N shortage. However, Muchow and Davis (1994) and Cox, *et al.*, (1993) have shown that LAI was not affected by early N shortages. Generally, LAI increased with increasing N application with increasing magnitude with time after planting, thereby resulting in significant differences among N levels.

Table 1: Main effects of variety and N fertilizer application on leaf appearance in pot- and field-grown maize.

	POT			FIELD		
Treatment	LAR	LAD	FNL	LAR	LAD	FNL
Variety:						
DMRSR-Y	0.32a	56.4a	17.5a	0.27a	70.1a	18.9a
TZBP-W	0.33a	59.0a	18.7a	0.28a	68.5a	17.9a
s.e.d	**0.005**	**1.31**	**0.32**	**0.005**	**1.30**	**0.231**
Nitrogen Levels (kg N ha^{-1}):						
0	0.21c	75.3a	16.0b	0.21c	75.6a	16.7a
30	0.33b	57.1b	18.9a	0.25bc	65.9abc	16.7a
60	0.37a	53.2bc	19.2a	0.25bc	69.1ab	17.0a
90	0.37a	49.5c	18.3a	0.29ab	61.2bc	17.5a
120	0.36ab	53.4bc	18.4a	0.30a	55.0c	16.5a
s.e.d	**0.017**	**2.94**	**0.80**	**0.021**	**5.40**	**0.49**

Figures followed by the same letter(s) in each column are not significantly different by DMRT at 5% probability level.

LAR = leaf appearance rate (no d^{-1}), LAD = leaf appearance duration (d) ;FNL = final number of leaves (no).

Table 2: Effects of variety and N fertilizer application on leaf extension rates of leaves at selected nodes in pot-grown maize.

	Leaf positions					
Treatment	L5	L7	L9	L11	L13	L15
Variety:						
DMRSR-Y	5.07a	5.76a	6.13a	6.81a	9.63a	5.92a
TZBP-W	5.31a	6.24a	6.11a	6.73a	8.96a	5.78a
s.e.d	**0.138**	**0.207**	**0.264**	**0.217**	**0.345**	**0.448**
Nitrogen level (kg N ha^{-1}):						
0	4.49c	2.52b	3.66d	4.43d	4.63c	3.18b
30	5.27b	6.44a	5.79c	6.37c	8.85b	5.77a
60	5.29b	6.45a	6.51bc	7.26b	10.43ab	6.53a
90	6.73a	6.95a	7.18ab	7.85ab	11.07a	6.97a
120	5.21b	6.66a	7.46a	7.96a	11.50a	6.81a
s.e.d	**0.219**	**0.328**	**0.417**	**0.343**	**0.546**	**0.709**

Figures followed by the same letter(s) in each column are not significantly different by DMRT at 5 % probability level.

Table 3: Effects of variety and N fertilizer application on leaf extension rates of leaves at selected nodes in field-grown maize.

	Leaf position					
Treatment	L5	L7	L9	L11	L13	L15
Variety:						
DMRSR-Y	0.99a	4.14b	5.54a	4.93a	4.67a	3.80a
TZBP-W	1.27a	5.43a	5.21a	4.37a	3.83b	2.04b
s.e.d.	**0.179**	**0.276**	**0.319**	**0.293**	**0.169**	**0.255**
Nitrogen Level (kg N ha^{-1}):						
0	1.09a	3.60b	4.42b	3.97b	3.49c	1.96b
30	1.04a	4.87a	5.14ab	4.56ab	4.13b	3.14a
60	1.03a	5.39a	5.73a	4.83ab	4.19b	2.97a
90	1.32a	4.93a	5.65a	5.33a	4.93a	3.54a
120	1.17a	5.16a	5.92a	4.55ab	4.49ab	3.00a
s.e.d	**0.283**	**0.436**	**0.504**	**0.463**	**0.268**	**0.404**

Figures followed by the same letter(s) in each column are not significantly different by DMRT at 5% probability level.

Table 4: Effects of variety and N fertilizer application on final leaf length of leaves at selected nodes in pot-grown maize.

	Leaf position					
Treatment	L5	L7	L9	L11	L13	L15
Variety:						
DMRSR-Y	51.6a	72.6a	87.6a	92.0a	88.0a	68.8a
TZBP-W	55.3a	78.3	90.9a	91.8a	83.5a	64.6a
s.e.d	**1.32**	**2.21**	**3.18**	**2.73**	**3.18**	**3.68**
Nitrogen Level (kg N ha^{-1}):						
0	47.1b	49.1b	41.4d	32.8d	24.4d	12.7c
30	55.9a	79.6a	90.4c	95.2c	86.1c	67.5b
60	53.4a	81.9a	98.3bc	103.9b	99.1b	80.4a
90	57.2a	85.7a	107.7ab	113.0a	106.7ab	84.7a
120	53.7a	81.0a	108.4a	114.6a	112.4a	88.2a
s.e.d	**2.09**	**3.50**	**5.04**	**4.32**	**5.02**	**5.82**

Figures followed by the same letter(s) in each column are not significantly different by DMRT at 5% probability level.

Nitrogen supply had a much larger effect on the area of individual leaves. There were significant differences among N levels in the area of upper leaves with reduction of as much as 53 and 55% of N-stressed plant in the two maize varieties respectively. These results were in agreement of Muchow (1988) and Uhart and Andrade (1995). Although, the trends in LAI at all N levels were initial increases up to various peaks at 60 DAP, the decline thereafter was slower at higher N levels than when no N was applied resulting in longer leaf area duration which may have profound effect on canopy photosynthesis (Okeleye and Alofe, 1995). The results of this study also confirm the reports of Ellen and Spietz (1980) who showed that higher LAI through large leaf area can be maintained through application of adequate N fertilizer which delayed senescence.

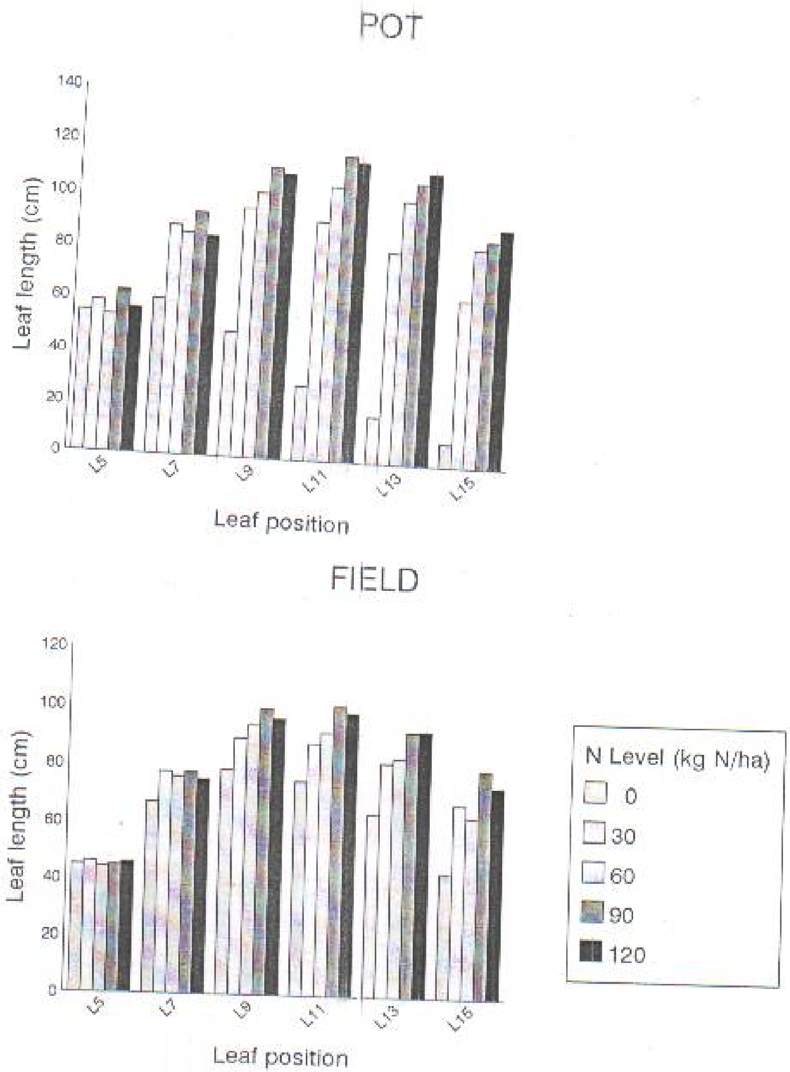

Fig. 3: Effects of N fertilizer application on leaf length of pot- and field-grown maize.

Morpho-physiological growth responses

Plant growth parameters were generally higher in pot-grown plants than in the field-grown ones. There was a linear relationship between plant height and N fertilizer for the two maize varieties in both the field and screen house. However, the effect of no N treatment was greater in the potted plants than in the field-grown plants (Fig. 5). This result is attributable to the confined environment of the pot-grown plants which were adequately watered, resulting in proper or efficient utilization of the applied nutrients for faster and better growth and development than in the field-grown plants The plants attained a maximum height at 90 kg N ha^{-1} and then reduced at 120 kg N ha^{-1}across the two varieties in both experiments. This result is in agreement with those obtained by El-Kholy (1987) in their reports on plant height. Lucas (1986) reported significant increase in plant height with increase in N fertilizer as observed in the present study. The difference in the plant height between the field and screen house plants is attributable to water deficit experiences by the field-grown plants. Abrecht and Carberry (1993) demonstrated that plant height in maize showed a gradual reduction with increasing water deficit especially when it occurred at the early vegetative growth stage. .Similar observation was reported earlier by Moss and Downey (1971).

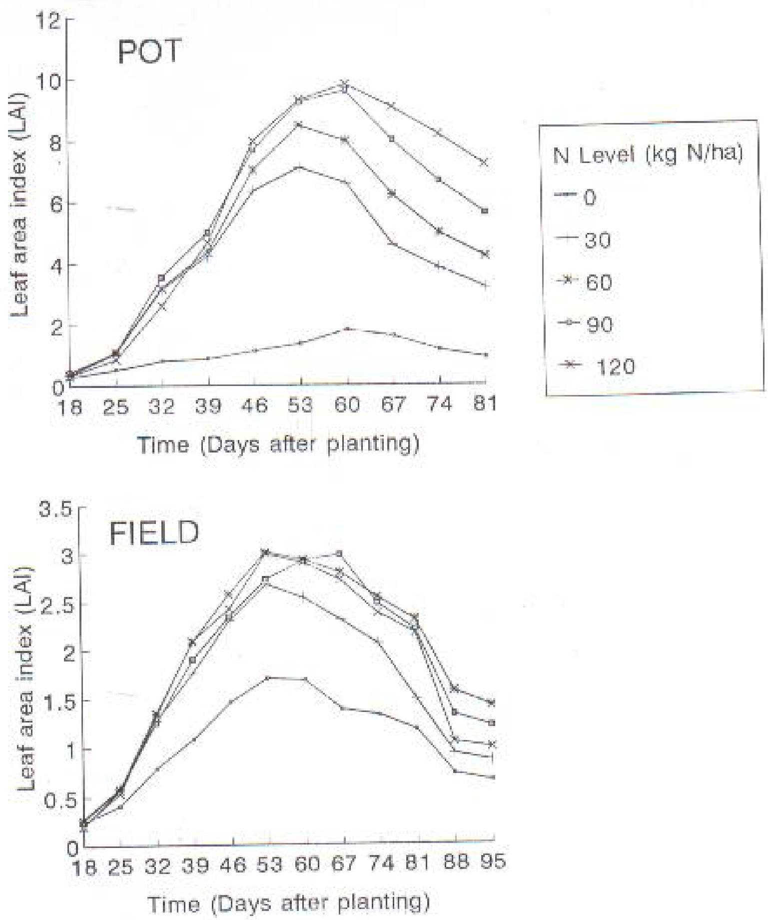

Fig. 4: Effects of N fertilizer on leaf area index of maize.

The study revealed that the application of N fertilizer at any amount reduced times to tassel and silk emergence particularly in the field (Table 6). This is in line with the report of Jacobs and pearson (1991) who demonstrated that N stress delayed tasseling and silking from 5 – 8 days. Girardin *et al*., (1987) also found that time to silk appearance was strongly affected by N shortages. Reduced N fertilizer application is known to delay silking time in maize (Lemcoff and loomis, 1986; Giradin *et al*., 1987). The study also showed that TZBP-W silked earlier than DMRSR-Y. This confirmed the early maturity of the former variety when compared to the latter.

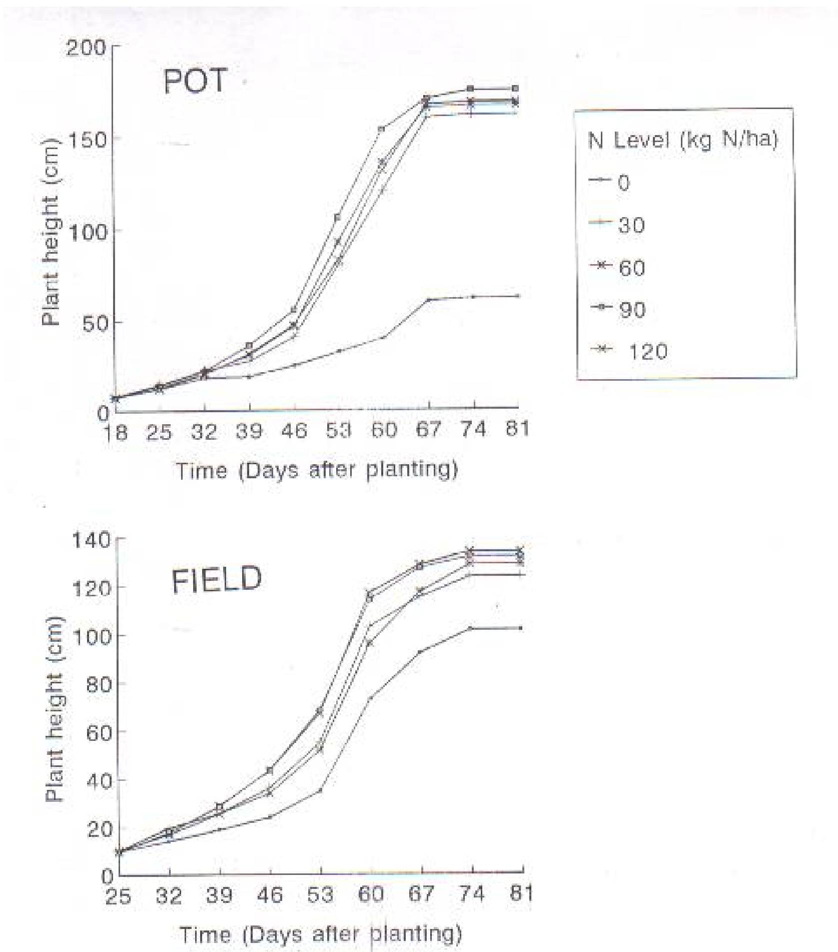

Fig. 5: Effects of N fertilizer on plant height of maize.

Most physiological growth indices such as crop growth rate (CGR), net assimilation rate, (NAR) relative growth rate (RGR) measured in this study showed measurable responses to N fertilizer application (Tables 7 and 8). A positive linear responses to increased N application were observed in all parameters at both the vegetative and reproductive stages. This result was in line with the report of Raghip(1979) who showed that increased N supply increased NAR and CGR. Similarly, Akintoye (1995) has observed that CGR increased with increased N application. Results of this study show that the physiological growth indices were generally higher in the potted plants than in the field-grown plants (Tables 7 and 8). This effect can be attributed to the direct effect of water stress on the leaf area index (LAI). Watson (1952) has attributed variations in CGR to variations in leaf area (LA) and/or NAR. Reduced NAR as a consequence of water stress obtained in the field-grown plants in the present study was in agreement with the report of Viets (1972).

Table 5: Effects of variety and N fertilizer application on the final leaf length in leaves at selected nodes in field-grown maize.

	Leaf position					
Treatment	**L5**	**L7**	**L9**	**L11**	**L13**	**L15**
Variety:						
DMRSR-Y	44.3a	75.0a	96.5a	98.4a	95.0a	87.2a
TZBP-W	45.9a	73.7a	86.2b	92.5b	90.0a	73.6a
s.e.d	**1.85**	**2.26**	**3.04**	**2.77**	**3.31**	**5.70**
Nitrogen Level (kg N-ha^{-1})						
0	44.9a	66.8b	78.2c	74.7c	63.8c	43.5b
30	46.0a	77.3a	89.2b	87.5b	81.4b	67.6a
60	44.2a	75.6a	93.7ab	91.5ab	83.1ab	63.0a
90	44.8a	77.4a	99.4a	100.6a	92.2ab	79.3a
120	45.6a	74.7a	95.9ab	98.1a	92.4a	73.6a
s.e.d	**2.92**	**3.57**	**4.81**	**4.39**	**5.25**	**9.01**

Figures followed by the same letter(s) in each column are not significantly different by DMRT at 5% probability level.

Table 6: Effects of variety and N fertilizer application on tassel and silk emergence times in pot- and field-grown maize.

	POT		FIELD	
Treatment	Tasseling	Silking	Tasseling	Silking
Variety:				
DMRSR-Y	55.4a	65.5a	64.2a	68.3a
TZBP-W	56.2a	67.6a	53.7b	58.9b
s.e.d	**0.93**	**2.23**	**0.50**	**0.65**
Nitrogen Level (kg N ha^{-1})				
0	62.5a	88.5a	60.0a	66.9a
30	54.0b	64.0b	59.1bc	63.8b
60	53.6b	60.7b	59.4b	63.8b
90	53.3b	59.1b	57.8c	61.6c
120	55.6b	60.5b	58.3bc	61.8bc
s.e.d	**1.46**	**3.53**	**0.78**	**1.02**

Figures followed by the same letter(s) are not significantly different by DMRT at 5% probability level.

Table 7; Effects of variety and N fertilizer application on physiological growth parameters in pot-grown maize

	Vegetative stage				Reproductive stage			
Treatment	NAR	CGR	RGR	LAD	NAR	CGR	RGR	LAD
Variety:								
DMRSR-Y	3.74a	0.54b	0.08a	2.00b	5.76a	1.65a	0.12a	4.02b
TZBP-W	3.96a	0.87a	0.09	2.42a	4.44b	1.44a	0.06b	4.56a
s.e.d	**0.737**	**0.121**	**0.012**	**0.08**	**0.658**	**0.200**	**0.026**	**1.190**
Nitrogen Level (kg N ha^{-1}):								
0	1.60c	0.31c	0.05b	0.58b	3.73b	0.23b	0.05b	0.93c
30	3.37b	0.53b	0.07ab	2.31b	5.85a	1.78a	0.08a	4.30b
60	4.51a	0.74b	0.08a	2.71a	6.82a	2.14a	0.07a	5.32a
90	4.75a	0.99a	0.11a	2.70a	5.11a	1.87a	0.07a	5.28a
120	5.01a	0.96a	0.11a	2.77a	4.01ab	1.71a	0.16a	5.65a
s.e.d.	**0.702**	**0.123**	**0.016**	**0.107**	**1.059**	**0.282**	**0.054**	**0.230**

Figures followed by the same letter(s) in each column are not significantly different by DMRT at 5% probability level.

Table 8: Effects of variety and N fertilizer application on physiological growth parameters in field-grown maize

	Vegetative stage				Reproductive stage			
Treatment	NAR	CGR	RGR	LAD	NAR	CGR	**RGR**	LAD
Variety:								
DMRSR-Y	3.72a	0.44a	0.049a	2.02a	9.45a	1.74a	**0.085a**	2.61a
TZBP-W	3.72a	0.28a	0.053a	1.71a	12.86a	1.86a	0.095a	1.83b
s.e.d.	**0.368**	**0.114**	**0.006**	**0.201**	**1.929**	**0.189**	**0.006**	**0.211**
Nitrogen Level (kg N ha^{-1}):								
0	3.07a	0.25a	0.058a	1.28ab	4.73c	0.49c	0.052ab	1.38ab
30	4.68a	0.47a	0.060a	1.84a	10.09b	1.40b	0.085a	2.07a
60	3.87a	0.22a	0.030a	1.99a	12.02b	1.87b	0.108a	2.20a
90	3.46a	0.30a	0.045a	1.88a	13.18b	2.03b	0.098a	2:59a
120	3.52a	0.56a	0.062a	2.34a	15.75a	3.22a	0.107a	2.86a
s.e.d	**0.602**	**0.127**	**0.0147**	**0.302**	**1.153**	**0.345**	**0.022**	**0.432**

Figures followed by the same letter(s) in each column are not significantly different By DMRT at 5% probability level.

Table 9: Effects of variety and N fertilizer application on yield parameters and grain yield in pot-grown maize.

Treatment	EHT	TBY	EWT	ELH	NKR	NG	SPT	HI	GY
Variety:									
DMRSR-Y	63.3a	101.1a	51.7a	9.23a	9.93a	172.5a	73.8a	0.311a	43.5a
TZBP-W	67.0a	99.8a	41.7b	9.68a	10.40a	143.4a	73.3a	0.310a	32.8b
s.e.d	**4.05**	**2.23**	**2.65**	**1.009**	**0.696**	**15.18**	**4.54**	**0.034**	**2.91**
Nitrogen Level (kg N ha^{-1}):									
0	32.9c	11.0d	1.5c	3.53c	3.83b	6.3b	56.2b	0.073c	0.9c
30	66.4b	70.1c	18.7b	7.75b	7.83b	46.2b	65.6a	0.188b	12.3b
60	69.0b	115.0b	60.5a	12.08b	13.50a	234.2a	85.0a	0.452a	51.0ab
90	85.8a	157.7b	82.9a	11.92b	12.50a	266.0a	81.6a	0.438a	66.4a
120	71.6b	148.5a	70.0a	11.98a	13.17a	237.0a	79.2a	0.402a	60.2a
s.e.d	**6.16**	**12.85**	**8.62**	**0.996**	**1.333**	**24.66**	**8.88**	**0.048**	**7.18**

Figures followed by the same letters in each column are not significantly different by DMRT at 5% probability level
EHT = ear height (cm); TBY = total biomass yield (g); EWT = ear weight (g); ELH = ear length (cm); NKR =no of kernel row (no); NG = no of grains per cob (no); SPT = shelling percentage (%); HI = harvest index; GY = grain yield per plant (g).

Table 10: Effects of variety and N fertilizer application on yield parameters and grain yield of field-grown maize.

Treatment	EHT	TBY	EWT	ELH	NKR	NG	SPT	HI	GY
Variety:									
DMRSR-Y	60.7a	121.6a	60.0a	12.65a	12.7b	330.6a	78.3a	0.36a	47.1a
TZBP-W	58.0a	119.0a	58.5a	10.22a	13.7a	271.0b	76.1a	0.32b	48.8a
s.e.d	**2.48**	**2.04**	**1.01**	**0.335**	**0.411**	**9.42**	**1.25**	**0.005**	**1.37**
Nitrogen level (kg N ha^{-1}):									
0	34.7b	46.4d	19.2c	7.17c	11.8b	112.8c	68.6b	0.27b	13.7c
30	48.0a	84.8c	43.5b	10.22b	13.2a	279.0d	77.8a	0.37a	33.3b
60	48.3a	104b	50.0b	10.25b	13.1a	329.7c	78.0a	0.34a	36.5ab
90	58.6a	122.5a	57.2a	11.85b	13.9a	374.2b	84.1a	0.37a	47.6a
120	57.1a	158.4a	73.9a	15.18	13.9a	408.3a	77.5a	0.37a	58.6a
s.e.d	**5.69**	**10.93**	**9.53**	**1.100**	**0.547**	**11.76**	**5.72**	**0.036**	**6.72**

Figures followed by the same letter(s) in each column are not significantly different by DMRT at 5% probability level.
EHT = ear height (cm); TBY = total biomass yield (g); EWT = ear weight (g); ELH = ear length (cm); NKR = no of kernel rows per war; NG = no of grains per cob; SPT = shelling percentage (%); Hi = harvest index; GY = grain yield per plant (g).

Yield Responses

The main effects of N fertilizer was highly significant for grain yield and yield components. N supply increased grain yield as much as 3 – 8 folds in both experiments. N fertilizer applications increased yield in both the pot- and field-grown plants up to 90 kg N ha^{-1} then decreased at 120 kg N ha^{-1} in the two evaluated varieties (Tables 9 and 10). The same trends were obtained for ear height, total biomass yield, ear weight and number of grains per ear. These results are in agreement with the findings of Tanaka *et al* (1972); Jesmanonicz (1973) and Shafshak and El-Debaby (1981) who reported that nitrogen fertilization significantly increased number of ears per plant, ear weight and consequently grain yield. The grain yield was slightly higher in DMRSR-Y than in the TZBP-W variety probably due to more efficient utilization of water and nutrient applied in the former than in the latter variety. The study further revealed that there were linear relationships between grain yield and leaf extension rate and final leaf length which indicate the importance of leaf production in determining yield. The results showed highly positive correlation between grain yield and leaf growth which were enhanced by N supply thereby suggesting that N shortage reduced percentage of radiation interception and radiation use efficiency and dry matter storage in the reproductive sink (seed), and therefore in line with the report of Uhart and Andrade (1995). There were no appreciable yield differences between pot-grown maize compared with those of the field (Tables 9 and 10). However, most yield parameters and grain yield were better in the field than in the pot at lower N fertilizer (0-30 kg N ha^{-1}), and vice versa at 60 – 120 kg N ha^{-1}, thereby suggesting greater adapatability of field-grown crops to low N.

The results of present study show that the trends of varietal responses to N application were similar for both the pot- and field-grown plants, suggesting good correlation between the two experiments. However, the magnitudes of the effects were greater with the pot experiment possibly due to smaller growth medium which did not allow for adapatability to low N levels as in the field-grown plants. It was also observed that values of most measured parameters at higher N levels were greater in the potted plants than in the field-grown plants. The differences in the growth of the pot-grown and field maize were due mainly to adequate water supply to the potted plants which allowed for the effective and efficient usage of the applied nutrient by the assimilatory apparatus for good growth and development of the plants in the screen house. This suggests that care must be taken in using screen house data in modeling for field evaluation of grain yield in maize under rain-fed conditions. Nevertheless, the results of the two experiments were in close correlation, indicating the usefulness of both the field and controlled room experiments in crop improvement programmes.

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