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Nitrogen use efficiency of extra early maize varieties as affected by split nitrogen application in two agroecologies of Nigeria

Abstract

Poor yield of maize has been attributed to low soil N since maize requires high Nitrogen for optimum productivity. Field experiments were conducted in the late season of 2014 at IITA, Research Farms, in Ibadan and Mokwa. The research was to evaluate the effects of split N fertilizer on nitrogen use efficiency of extra early maize varieties. Arrangement was 5 x 8 factorial fitted into Randomized Complete Block Design, with four replications. Extra early maturing maize varieties (2013 TZEE-W DT STR, TZEE-Y Pop STR C_4, TZEE-W Pop STR C_5, 2013 TZEE-Y DT STR, and 99 TZEE-Y STR QPM) with Nitrogen fertility rates (0 kg N ha^{-1} (Control), 30 kg N ha^{-1} single, 60 kg N ha^{-1} single, 60 kg N ha^{-1} split (30:30) applied at 2 and 4 weeks after sowing (WAS), 90 kg N ha^{-1} split 60:30 applied at 2 and 4 WAS, 90 kg N ha^{-1} split (30:30:30) applied at 2, 4 and 6 WAS, 120 kg N ha^{-1} split (60:60) applied at 2 and 4 WAS and 120 kg N ha^{-1} split (30:60:30) applied 2, 4 and 6 WAS). Data collected were subjected to Analysis of Variance procedure and significant means were separated using Duncan's Multiple Range Test at $p<0.05$. Results showed that maize variety 2013 TZEE-W DT STR produce highest number of leaves, plant height, leaf area, cob yield (3.33, 3.15 t ha^{-1}), grain yield (2.57, 2.38 t ha^{-1}) and Nitrogen use efficiency (33.03, 28.95%) at Mokwa and Ibadan respectively. Split application of 90 kg N ha^{-1} as (60:30) at 2 and 4 WAS produce significantly ($p<0.05$) higher 1000 grain weight, cob yield (3.90, 3.73 t ha^{-1}) and grain yield (2.99, 2.80 t ha^{-1}) at Mokwa and Ibadan respectively. The control produced significantly reduced dried cob and grain yield by (85, 81%) and (84.4, 80.4%) in Mokwa and Ibadan respectively, compared to the best rate of 60:30 split N application. The N application of 30 kg N ha^{-1} as single dose had the highest Nitrogen use efficiency (51.3, 43.0 %) in both Mokwa and Ibadan, which was significantly different ($p<0.05$) from the rest treatments. Across the varieties used in both locations, Mokwa agro-ecology zone proved to be a favourable location for higher yield of extra early maize varieties. The study concluded that application of 30kgN/hectare at two weeks after sowing efficiently improved Extra early maize varieties and is thus recommended as low input package for resource poor farmers.

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Olaiya AO,[1] Oyafajo AT,[1] Atayese MO,[1] Bodunde JG[2]

[1]Department of Crop Physiology and Crop Production, Federal University of Agriculture, Nigeria
[2]Department of Horticulture, Federal University of Agriculture, Nigeria

Correspondence: Olaiya A.O, Department of Crop Physiology and Crop Production, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria,
Email olaiyaabideen@yahoo.com, olaiyaao@funaab.edu.ng

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Introduction

Maize (*Zea mays L.*) is the most important cereal crop in Nigeria in terms of production and consumption.[1] Maize accounts for 15-20% of the total daily calories in the diets of more than 20 developing countries found in Latin America and Africa.[1,2]

It is grown for energy-rich grains and its production is increasingly gaining wider acceptability over other traditional cereal crops in the savanna of West and Central Africa (WCA).[3,4] It has high yield potential, wide adaptation, relative ease of cultivation, storage and transportation. These desirable attributes of maize have increased the potential of the crop for combating food security challenges posed by population increase in WCA. Average productivity of maize is 6.7 t ha^{-1} in developed countries and 2.4 t ha^{-1} in developing countries.[5] Maize is usually considered to have a high soil fertility requirement to achieve optimal yields[6] and thus large quantities of N is required. Poor soil fertility is one of the principal factors that limit maize productivity in maize in Nigeria and nitrogen being the most yield limiting nutrient, its stress reduces grain yield by delaying plant growth and development.[7] According to Sowers et al,[8] the application of high N rates may result in poor N uptake and low nitrogen use efficiency due to excessive N losses. Similarly N fertilization and management practices remain significant agronomic practices for maize to produce high yield[9,10] Nitrogen use and demand is continuously increasing day by day.[11] Since it is highly mobile, it is subject to greater losses from the soil-plant system.[11] According to Sowers et al,[8] the application of high N rates may result in poor N uptake and low nitrogen use efficiency due to excessive N losses. Ali and Raouf,[12] reported positive effect of rate and timing of N application on nitrogen use efficiency while Amanullah,[13] reported effect of source and application mode on NUE and harvest index. In view of the rapidly expanding population in Nigeria and the general acceptability of maize as a popular staple food among small scale farmers, there is the need to increase production through the use of appropriate nitrogen fertilizer rate to ensure optimal productivity. Therefore this has necessitated the need to evaluate the effect of split N application rates on growth and yield of extra early maize varieties at two Agro ecological zones of Nigeria.

Materials and methods

The experiment was conducted during late season of 2014 planting season in Ibadan (forest-savanna transition) and Mokwa (southern guinea savanna) zones. Land preparation was done mechanically, first and second ploughs, harrowed and marked with mechanical marker of 0.75m inter-row spacing. A factorial experiment fitted into randomized complete block design was used for both locations. The treatment were 5 varieties x 8 fertilizer rates making 40 treatment combinations replicated four times; three row planting of 5m long with inter and intra-row spacing of 0.75m x 0.25m . The plot size was 5m x 2.25m with total experimental area of 90m x 27.5m (2475m^2).

Basal application of P and K at rates equivalent to 30 kg P_2O_5 and K_2O ha^{-1} respectively were made at time of first N application.

The following parameters were collected for, plant height, number of leaves, leaf area, stem girth, cob yield (t ha-1), 1000 seed weight (g) and grain yield (t ha-1). Growth parameters were taken at 4 and 8 weeks after sowing (WAS).

Grain yield per heactare (t ha^{-1}):

Grain yield was estimated using the formula:

$$\frac{Field\,Weight(kg\,/\,plot)X(100-GMC)X80/100}{85}X\frac{10,000}{0.25X0.75X21}$$

Where:[14]

Fw = field weight of ears at harvest

Gmc = grain moisture content (%)

0.8 = shelling coefficient of maize

(100-15)= 15% moisture in grain at dry state

10,000m^2 = harvested area conversion into standard unit (ha)

Nitrogen use efficiency: Expressed as grain production per unit of Nitrogen applied

The agronomic nitrogen use efficiency (NUE_A) was calculated using the formulae:[13]

$$NUE_A = \frac{Grain\ yeild\ with\ N - Grain\ yeild\ without\ N}{N\ rate}$$

The planting materials used were five cultivated extra early maize varieties comprising of striga tolerant maize varieties obtained from maize breeding unit (DTMA), International Institute of Tropical Agriculture, Ibadan, (IITA).

Data collected was subjected to analysis of variance (ANOVA) procedures according to the methods described by Steel et al. Treatment means were separated using the Duncan Multiple Range Test (DMRT) at 5% level of probability.

Results and discussions

Pre-cropping soil physiochemical properties analysis; the result showed that the field trials for both agro-ecology is sandy soil in texture, medium to slightly acidic soil, low in total Nitrogen (N), medium in available phosphorus (P). As result of its low essential macronutrients the soil can be regarded as a poor soil for maize production. The pH of 5.7 and 6.0 was moderate for maize production (Table 1). Very low in total Nitrogen (N of 0.09, 0.04kg-1 of soil is less than the critical level of 1.5kg-1 (Enwezor et al, 1998), while the available phosphorus (P) of 8.7, 10.3mgkg-1 exceeds the critical level of 8.10mgkg-1 (Agboola, 1982). The pH of 6.0 was moderate for maize production (Table 1). The data presented in Table 2 showed that maize varieties respond differently to Nitrogen fertilizer rates in both locations. Split N application greatly enhanced the performance of extra-early maize varieties in the various growth parameters measured. Application of nitrogen fertilizer produced significantly higher number of leaves, taller plants height, wider leaf area and thicker stem girth when compared with 0 kg N/ha. Application of 120kgN/ha split (60:60) applied at 2 and 4 WAS produced the highest number of leaves and widest leaf area when compared to other treatments in both locations. The tallest plant height and thickest stem girth was produced with the application rate of 90kgN/ha split (60:30) applied at 2 and 4 WAS. This result is an indication that higher levels of nitrogen fertilizer promote the vegetative growth in maize and its deficiency reduces the vegetative growth of maize. This agrees with[15] who reported higher application rate of 120 kgN/ha to produced the highest number of leaves. Also,[16,17] reported that higher nitrogen rate promotes vegetative growth in maize. Similar results that plant height increases with increasing levels of fertilizers were reported by Maqsood et al, [18] Ayub et al,[19] and Sharar et al.[20] But these results are contrary to those of[21] who reported that time of application of N had no significant effect on maize plant characters. The least value for leaf area, number of leaves, plant height and stem girth was recorded in the control plot with 0kgN/ha. This result agrees with Tweneboah[22] who earlier established that nitrogen deficiency retarded growth of maize and resulted into stunted growth and poor root development.

Table 1 Pre-cropping soil physico-chemical properties for both locations, 2014

Soil properties	Ibadan	Mokwa
Sand(%)	92	90
Silt(%)	3	5
Clay(%)	5	5
Textural class	sandy	sandy
pH	6.0	5.7
Ca(cmol kg^{-1})	21.4	13.4
O.C(%)	1.2	0.35
Mg(cmol kg^{-1})	1.9	0.8
Na(cmol kg $^{-1}$)	0.4	0.3
K(cmol kg $^{-1}$)	0.2	0.2
AL + H(cmol kg $^{-1}$)	0.1	0.1
ECEC(cmol kg $^{-1}$)	30	20.1
Base Sat(%)	99.7	99.5
Total N	0.09	0.04
Av.P(ppm)	8.7	10.3
Cu(ppm)	1.6	0.9
Mn(ppm)	57.5	180
Fe(ppm)	136	59
Zn(ppm)	4.7	9.5

Table 2 Effect of split N application rate on growth parameters of maize

	NL		PH		LA		SG	
Treatments	**Mokwa**	**Ibadan**	**Mokwa**	**Ibadan**	**Mokwa**	**Ibadan**	**Mokwa**	**Ibadan**
Varieties (V) 2013 TZEE-W DT STR	11.8a	13.4a	178.3a	184.8a	524.3a	550.5a	2.47	2.57a
2013 TZEE-Y DT STR	10.5c	12.1c	172.7b	178.7b	448.6c	471.1c	2.31	2.39b
TZEE-W Pop C_5	11.0b	12.5b	170.7b	176.5b	463.6c	486.7b	2.40	2.47ab
TZEE-Y Pop C_4	11.1b	12.7b	173.3b	179.3b	463.2b	486.3b	2.42	2.52a
99 TZEE-Y STR QPR	10.9bc	12.5b	165.6c	171.1c	460.3bc	483.3bc	2.45	2.53a
S.E (±)	0.12**	0.13**	1.68**	1.82**	4.24**	4.45**	NS	0.06*
Urea rate (R)								
0kgN	6.8f	8.4f	115.3g	119.2g	361.7f	379.8f	1.69e	1.74e
30kgN	8.9e	10.5e	149.6f	156.0f	431.1e	452.7e	2.02d	2.10d
30:30kgN	11.8c	13.3c	179.6c	185.9c	490.4c	514.9c	2.67b	2.76b
60kgN	9.5d	11.0d	170.6d	176.7d	468d	491.4d	2.79b	2.89b
60:30kgN	13.0b	14.3b	217.5a	223.7a	508.1b	533.5b	3.13a	3.24a
30:30:30kgN	12.0c	13.6c	176.7c	183.3c	470.3d	493.8d	2.66b	2.76b
60:60kgN	13.7a	15.3a	205.5b	211.6b	540.5a	567.5a	2.20c	2.28c
30:60:30kgN	12.9b	14.5b	162.2e	168.3e	505.9b	531.2b	2.13cd	2.21cd
S.E (±)	0.16**	0.17**	2.13**	2.30**	5.36**	5.62**	0.05**	0.07**
Varieties x Rate								
S.E (±)	0.38*	0.38*	4.76*	5.15*	11.98*	12.58*	0.11*	0.11*

WAS = Weeks after sowing, *, ** = Significant at 0.05 and 0.01 level of probability, respectively Mean followed by the same letter(s) within the same column and treatments are not significantly different. NL, number of leaves; PH, plant height; LA, leaf area; SG, stem girth

For maize varieties, the highest plant height, widest leaf area and the thickest stem girth recorded for variety 2013 TZEE-W DT STR at 8 WAS could be attributed to their genetic make-up. It was also reported by Msarmo and Mhango[23] that cultivars grown under the same conditions may have differences in their performance based on the genetic characteristics. Amendment of soil by nitrogen fertilizer, irrespective of rates or period of application produced significantly better yield than 0kgN/ha. The data presented in Table 3, showed higher number of cobs at 60kgN/ha single applied ($55.20x10^3$ and $51.60x10^3$) in both Mokwa and Ibadan respectively, while the lowest number of cobs produced was in the control plot ($28.13x10^3$ and $29.2x10^3$) for both locations respectively. This result indicate that increase in N application do not show increase in number of cobs produced and environment did not have any effect on number of cobs produced in both locations, though mokwa agroecology brought about higher number in cob produced. The higher number of cobs experienced with N fertilizer application over the control may be due to the availability of Nitrogen nutrients throughout the growing season which is essential for optimum maize growth. This finding agrees with the earlier report of Bangarwa et al,[24] and Khan et al.[25] that the number of cobs produced by maize did not increase with the increase in nitrogen rates. Maize cob yield was greatly enhanced by varietal differences and split N application rates. Variety 2013 TZEE-W DT STR produced the best cob yield (3.33, 3.15 t ha^{-1}) for both mokwa and Ibadan.

Varieties had no significant (p>0.05) effect on grain moisture content among the maize varieties at both locations. TZEE-Y Pop C_4 had the highest grain moisture of (13.99 %) while the least grain moisture content was produced in 2013 TZEE-Y DT STR. Split N application rates showed significant effect on maize grain moisture content at Mokwa. The 90 kg N/ha split (60:30) applied at 2 and 4 weeks after sowing produced the highest cob yield (3.91 and 3.73 t ha^{-1}), grain yield (2.99 and 2.80 t ha^{-1}) and 1000 grain weight (432.2 and 414.9 g) in both Mokwa and Ibadan respectively. The least cob yield, grain yield and 1000 grain weight was recorded in the control plot with 0 kg N/ha in both locations. Cob yield of extra early maize was increased linearly with increase in N rates up to 90 kg N/ha. Split N application rate enhanced grain yield produced by extra early maize. This result agrees with Sanjeev and Bangarwa[24] that grain yield increased with increasing nitrogen rates. Similar, findings was reported by Samira et al,[26] Torbert et al.[27] that found that yield and yield component of maize were increase by increasing the rate of nitrogen application rates. Increase in maize grain yield with an increase in the rates of nitrogen was also reported by Luschinger, Sabir et al,[28] and

Younas et al.[29] in their investigations on nitrogen levels and maize grain yield. For 1000 grain weight, the data in Table 3 reveals that the treatments were significantly different from one another. The different rates of nitrogen fertilizer and time of application influenced the size of maize seed produced. All the treatments where N was applied resulted in higher 1000 grain weight compared with the control (Table 4).

Varietal difference had no significant ($p<0.05$) effect on 1000 grain weight produced by the extra early maize materials. The 1000 grain weight produced was comparable for both agro-ecologies. 1000 grain weight were increased as N application rate increases up till 90 kg N/ha split (60:30) applied at 2 and 4 weeks after sowing and started decreased at 120 kgN/ha split (30:30:30) applied. Nitrogen Use Efficiency (NUE), expressed as grain production per unit of N applied, indicated that, there were significant differences among the maize varieties tested on Nitrogen Use Efficiency (Table 5).

Table 3 Effect of split N application rate on plant stand at harvest, cob number and cob yield of maize

	Number of cobs x 10^3 ha^{-1}		Cob yield (t ha^{-1})	
Treatments	**Mokwa**	**Ibadan**	**Mokwa**	**Ibadan**
Varieties (V)				
2013 TZEE WDT STR	48.25a	45.33a	3.33a	3.15a
2013 TZEE YDT STR	48.00a	44.58ab	2.96b	2.72b
TZEE W POP C5	47.83a	46.42a	2.95b	2.81b
TZEE Y POP C4	48.17a	46.33a	2.69b	2.56b
99 TZEE Y STR QPR	43.42b	41.83ab	2.37c	2.30c
S.E (±)	1.02*	0.99**	0.94**	0.88**
Urea rate(R)				
0kgN	28.13c	29.2c	0.59d	0.71d
30kgN	52.80a	49.33a	2.59c	2.42c
30:30 kgN	52.67a	49.6a	3.31b	3.07b
60kgN	55.20a	51.6a	2.65c	2.55c
60:30kgN	52.40a	48.8a	3.91a	3.73a
30:30:30kgN	45.47b	44.13b	3.30b	3.13b
60:60kgN	45.33b	43.2b	3.39b	3.13b
30:60:30kgN	45.07b	43.33b	3.14b	2.95b
S.E (±)	1.29**	1.26**	0.119**	0.112**
Varieties x Rate				
S.E (±)	NS	NS	0.266**	0.250**

WAS = weeks after sowing, ***, **** = Significant at 0.05 and 0.01 level of probability, respectively, Mean followed by the same letter(s) within the same column and treatments are not significantly different

Table 4 Effect of split N Application rate on grain moisture, grain yield and 1000 grain weight of Maize

	Grain moisture (%)		Grain yield/ha (t ha^{-1})		1000 grain weight (g)	
Treatments	**Mokwa**	**Ibadan**	**Mokwa**	**Ibadan**	**Mokwa**	**Ibadan**
Varieties (V)						
2013 TZEE WDT STR	13.76	15.56	2.57a	2.38a	358.21	341.2
2013 TZEE YDT STR	12.69	14.44	2.31b	2.08b	338.85	321.7

Table continue

	Grain moisture (%)		Grain yield/ha (t ha^{-1})		1000 grain weight (g)	
Treatments	**Mokwa**	**Ibadan**	**Mokwa**	**Ibadan**	**Mokwa**	**Ibadan**
TZEE W POP C5	13.92	15.72	2.27bc	2.12b	350.77	333.5
TZEE Y POP C4	13.99	15.94	2.07c	1.93b	351.44	334.3
99 TZEE Y STR QPR	13.75	15.75	1.83d	1.73c	354.98	337.8
S.E (±)	NS	NS	0.73**	0.67**	NS	NS
Urea rate(R)						
0kgN	12.21	13.61b	0.47d	0.55d	274.11e	257.1e
30kgN	13.36	14.78ab	2.01c	1.84c	325.34d	307.7d
30:30 kgN	12.25	14.56ab	2.60b	2.35b	369.11c	351.3c
60kgN	14.14	16.58a	2.04c	1.91c	395.63b	378.0b
60:30kgN	14.7	16.29a	2.99a	2.80a	432.16a	414.9a
30:30:30kgN	14.35	15.41ab	2.53b	2.37b	372.29c	355.7c
60:60kgN	13.84	16.05a	2.62b	2.36b	322.52d	306.1d
30:60:30kgN	14.15	16.6a	2.42b	2.21b	315.64d	298.9d
S.E (±)	NS	0.72*	0.92**	0.85**	6.39**	6.51**
Varieties x rate						
S.E (±)	NS	NS	0.206*	0.191**	NS	NS

WAS = Weeks After Sowing, * = Significant at 5% level of probability, Mean followed by the same letter(s) within the same column and treatments are not significantly different at 5

Table 5 Effect of split N application rate on Nitrogen Use Efficiency of extra early maize

	Nitrogen use efficiency (%)	
Treatments	**Mokwa**	**Ibadan**
Varieties (V)		
2013 TZEE WDT STR	33.01a	28.95a
2013 TZEE YDT STR	29.52ab	24.07bc
TZEE W POP C5	29.32ab	25.23ab
TZEE Y POP C4	27.07bc	23.00bc
99 TZEE Y STR QPR	22.74c	19.86c
S.E (±)	1.67**	1.52**
Urea rate(R)		
30kgN	51.3a	42.96a
30:30 kgN	35.63b	29.96b
60kgN	26.19c	22.58c
60:30kgN	28.08c	24.98bc
30:30:30kgN	22.95cd	20.21c
60:60kgN	17.94de	15.06d
30:60:30kgN	16.24e	13.79d
S.E (±)	1.97**	1.79**
Varieties x rate		
S.E (±)	4.42*	4.02*

WAS = weeks after sowing. *, **= Significant at 0.05 and 0.01 level of probability, Mean followed by the same letter (s) within the same column and treatments are not significantly different at 5% level of probability

The Nitrogen use efficiency was greatly affected by varietal differences and split N application rates. Variety 2013 TZEE-W DT STR gave the highest nitrogen use efficiency in both Mokwa and Ibadan (33.01 and 28.95 %) respectively. The 99 TZEE-Y STR QPR recorded the least nitrogen used efficiency at both Mokwa and Ibadan (22.74 and 19.86 %). The observed NUE difference among the five extra early maize varieties is an indication that genetic characteristics of the materials played a major role in Nitrogen use efficiency as it agreed with the reports of Ahrens et al,[30] and Hatfield and Prueger,[31] who reported that agronomic practices and genotypes variability can affect Nitrogen Use Efficiency. Rate 30 kg N/ha single applied at 2 weeks after sowing had better nitrogen use efficiency in both Mokwa and Ibadan with (51.3 and 42.96 %) respectively, followed by the 60 kg N split (30:30) applied at 2 and 4 weeks after sowing in both Mokwa and Ibadan (35.63 and 29.96 %) respectively.

The lowest N application rate for Nitrogen use efficiency was found in application rate 120 kg N split (30:60:30) applied at 2, 4 and 6 weeks after sowing in both Mokwa and Ibadan (16.24 and 13.79 %) respectively. The result indicated that NUE decreases with increasing N application rate, also the split application rates significantly enhanced nitrogen use efficiency of the extra early maize when compared with single application of the same N rate. These results agree with the findings of Ali and Raouf,[12] Raun and Johnson,[32] Pierce and Rice,[33] who earlier reported that high rates of nitrogen application decrease NUE in cereal. Halverson and Wienhold[34] also established that Nitrogen use efficiency may be affected by crop species, soil type, and application rate of N fertilizer.[35–39]

Conclusion and recommendations

The maize variety 2013 TZEE-WDT STR in both locations had higher number of leaves, plant height, cob dry yield, and grain yield and nitrogen use efficiency at Mokwa and Ibadan respectively. Though, split application of 90kgN/ha at 2 and 4 WAS produce significantly higher 1000 grain weight, cob yield and grain yield at Mokwa and Ibadan respectively, it was 30kgN that efficiently utilized the N applied.

The control produced significantly reduced cob yield and grain yield in both locations compared to the rest treatments, therefore growing extra early maize without adding supplement of N fertilizer should be discouraged. The 2013 TZEE-WDT STR is the best variety in terms of growth and yield of maize at the two locations. The N application rate of 30kgN/ha had the best nitrogen use efficiency across the varieties used in both locations, therefore blanket application of 30kgN/ha is recommended as basic requirement for extra early maize cultivation in both ecological zones for effective grain production though 60/30 N kg/ha gave optimum biological yield. Mokwa (9°18'N, 5°4'E) representing Southern Guinea Savanna showed to be a favourable environment to produce higher yield of maize using extra early maize varieties.

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Conflicts of interest

The authors declare that there was no conflict of interest.

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