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RESPONSE OF SUNFLOWER (*Helianthus annuus* L.) TO NITROGEN APPLICATION IN A SAVANNA ALFISOL

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SUMMARY

Decline in crop yield has been a major problem in Northern Guinea savanna zones of Nigeria due to inherent low fertility status of the soils. Field experiments were conducted for two years (2003 and 2004) on an Alfisol of the Northern Guinea savanna of Nigeria to determine the effect of N fertilizer on growth and yield parameters of sunflower. Six rates of nitrogen (0, 30, 60, 90, 120 and 150 kg N ha^{-1}) were applied. Plant height and number of leaves were highly significant 10 weeks after planting (WAP). Highest plant heights of 120 and 138 cm were obtained in 2003 and 2004, respectively, at 120 kg N ha^{-1}. Application of N significantly increased seed and oil yields while excess N (150 kg N ha^{-1}) reduced the contents of the two parameters. Optimum N requirement of sunflower obtained from this study is between 90 and 100 kg N ha^{-1}.

Key words: **sunflower, nitrogen application, treatments vs. growing parameters, growing in savanna conditions**

INTRODUCTION

Of the nutrient elements required by plants, nitrogen (N) is most essential and is required in the largest amount from soil (Lewis, 1986). Nitrogen is essential for all life processes in plants (Lægreid, 1999). It is a vitally important plant nutrient and is the most frequently deficient of all nutrients (Tisdale *et al.*, 2003). Nitrogen is a mobile element and can easily be lost through leaching, erosion, denitrification, *etc.* Application of N to crops produces abundant vegetative growth, large leaves with deep green color and good yield.

The soils of savanna zones in Nigeria are inherently low in plant available nitrogen. This has made nitrogen an important constraint to crop production in the zone. Jones and Wild (1975) and Lombin (1987) identified N as the prime limiting nutrient to crop production in the savanna zones of Nigeria.

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Although savanna soils have high potential for crop production, the use of low external sources of nutrients results in poor growth development. Lægreid *et al.* (1999) has reported that the use of N fertilizer has been essential to increasing the productivity of agriculture, and that global food production has doubled in the past 50 years, which in part is due to the increased use of N fertilizers.

Sunflower is an important oilseed crop which ranks third after soybean and groundnut as a source of edible oil in the world. As in other crops, it requires NPK fertilization. Nitrogen deficiency is generally the most limiting nutritional disorder affecting sunflower production. Suzer (1998) had reported that appropriate fertilization is important for getting high yield per hectare, and N deficiency is the most limiting nutritional disorder to sunflower production. Similarly, Mortvedt *et al.* (2003) noted that adequate soil fertility is one of the requirements for profitable sunflower production and that N is the most yield limiting nutrient for its production. Significant responses to nitrogen fertilization have been obtained; Lauretti and Pieri (1999 and 2001) reported that 40-80 kg N ha^{-1} (depending on the available water) of fertilizer alone or associated with green manuring was sufficient. Mathers and Stewart (1981) reported that sufficient N for maximum sunflower yield was provided by 84 kg N ha^{-1}, while Monotti (1978) and Malligawad *et al.* (2004) had reported that 100 kg N ha^{-1} was suitable for nitrogen fertilization of sunflower. However, nitrogen fertilization is very variable and it depends on the amounts of the element already present in the soil and the potential yield of the environment (Laureti *et al.*, 2007).

Research information regarding the effect of nitrogen on oil contents and oil yield of sunflower in the savanna region of Nigeria are scarce. The study was initiated to determine the effects of different rates of nitrogen on growth, seed and oil yields of sunflower.

MATERIALS AND METHODS

Experimental site characteristics

Field trials were conducted in 2003 and 2004 rainy seasons at the Institute for Agricultural Research Experimental Field, Ahmadu Bello University, Samaru, Zaria, Nigeria Samaru (11^{o} 11' N, 7^{o} 38' E, 680 m above sea level) is located in the Northern Guinea savanna ecological zone. The mean annual rainfall of the site is about 1061 mm with a monomodal distribution pattern mostly concentrated between May and September. Rainfall distribution and temperature for Samaru for the years of the study are shown in Figure 1.

The soil of the experimental site was a Typic Haplustalf in the USDA system or Orthic Acrisol in the FAO system (Valette and Ibanga, 1984), with sandy loam surface soil texture. Samaru soil was also classified according to the USDA soil classification system as Alfisol (IAR, 1987).

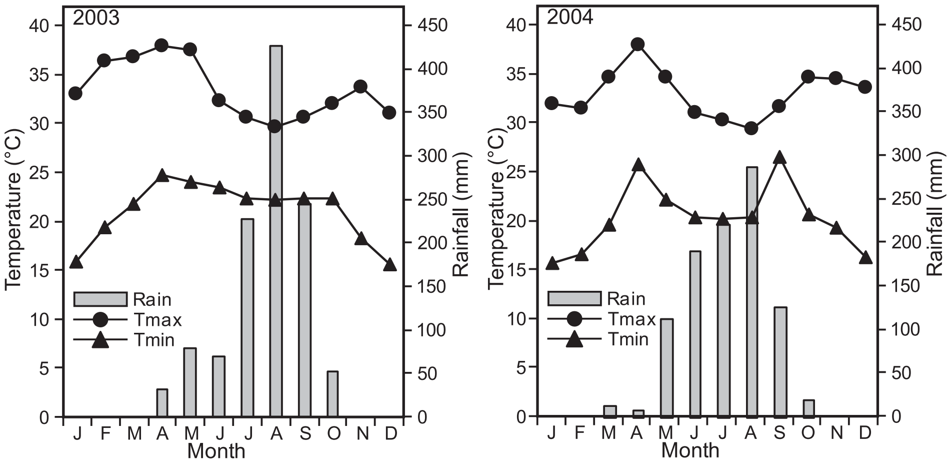

Figure 1: Mean monthly weather conditions in 2003 and 2004.

Soil sampling and analysis

The soils of the experimental sites were sampled (0-30 cm), bulked, air-dried, sieved and analyzed for physicochemical properties. Values of pH in water and $CaCl_2$ were determined using the glass electrode pH meter. Particle size analysis was done by the hydrometer method and total N by the Kjeldahl method. Available P was determined by the Bray1 method, while organic matter was determined by Walkley and Black methods. Exchangeable cations were extracted with 2 M ammonium acetate, Na and K concentrations in the extract were determined with a flame photometer, Ca and Mg with an atomic absorption spectrometer (AAS). For micronutrients determination, the soils were digested with a mixture of perchloric, hydrochloric and sulphuric acids; the elements were read in the digests with AAS. The method of Juo (1979) was adopted for the various soil analyses. Details of the physical and chemical properties of the experimental sites are shown in Table 1.

Experimental design and treatments

The experiment was laid out in a RCBD with four replications. There were six treatments, 0, 30, 60, 90, 120 and 150 kg N ha^{-1}. Sunflower variety Record was planted on 29th July, 2003 and 14th July 2004 at 2 seeds per hill at interplant spacing of 25 cm and 75 cm row spacing. The seedlings were thinned to one plant per hill two weeks after planting (WAP). The N fertilizer was split applied, half at 2 WAP, while the remaining portion was applied at 6 WAP. Phosphorus and potassium fertilizers (50 kg P_2O_5 and 50 kg K_2O ha^{-1}) were applied to all the plots. Weeding was done at 3 and 6 WAP. Plots were remolded manually with a hoe at 8 WAP in place of last weeding as commonly practiced in the locality. This was done to control weeds and prevent lodging.

Table 1: Physical and chemical properties of the soil at the experimental sites

Soil properties	2003	2004
pH (H_2O) 1:2.5	5.3	5.6
pH ($CaCl_2$) 1:2.5	5.0	5.2
Organic carbon (g kg^{-1})	6.6	7.6
Total nitrogen (g kg^{-1})	0.50	0.56
Available P (mg kg^{-1})	6.8	5.9
Exchangeable bases (c mol ± kg^{-1})		
Ca	2.58	1.84
Mg	0.98	0.60
Na	0.30	0.18
K	0.19	0.14
CEC	5.6	5.20
Micronutrients (mg kg^{-1})		
Available Zn	2.4	3.2
Available B	0.18	0.12
Available Cu	2.8	3.9
Available Mn	6.5	7.8
Available Fe	11.0	14.0
Mechanical analysis (g kg^{-1})		
Sand	50	30
Silt	37	45
Clay	13	25
Textural class	Sandy loam	Loam

Plant height and number of leaves were taken weekly, starting from 5 WAP to 10 WAP. Number of days to 50% flowering was determined by careful observation on daily basis when half the number of plants in a plot had flowered. Harvesting was done manually. Capitulum diameter was determined. Threshing was made by hand and seed weight was recorded after drying in open air condition for three to four days. Percentage oil content and oil yield were also determined by calculation.

Statistical analysis

All data collected were subjected to analysis of variance (ANOVA) and differences between means were evaluated. Correlation analysis was used to compare growth and yield components. Regression analysis was done to determine the relationships between N rates and seed and oil yields.

RESULTS

Soil analysis

Some physical and chemical properties of the soils used in the study before application of treatments are given in Table 1. The soil texture was sandy loam in the 2003 site and loam in the 2004 site. The soils were slightly acidic and low in organic carbon. Available P contents were low (6.8 and 5.9 mg kg^{-1}) and N contents were very low (0.5 and 0.62 g kg^{-1}), below the 1.0 g kg^{-1} considered critical soil N for crops in northern Nigeria savanna (Enwezor, 1990). The poor fertility status of the soil is due to the parent material from which the soil was formed and over-exploitation without commensurate fertilization and other required management. It is imperative that judicious use of adequate amounts of fertilizer is recommended for improved and sustained productivity of the soils.

Effect of treatments on growth parameters

Effect of nitrogen level on the height of sunflower plants and number of leaves produced per plant are shown in Figures 2 and 3. Nitrogen application increased the plant height of sunflower in both years, although the increment was not significant at 5 and 6 WAP in 2003 and from 5 to 8 WAP in 2004. Tallest plants (120 and 136 cm) were obtained from plants treated with 120 kg N ha^{-1} in both years, while least plant heights were recorded for the control (Figure 2).

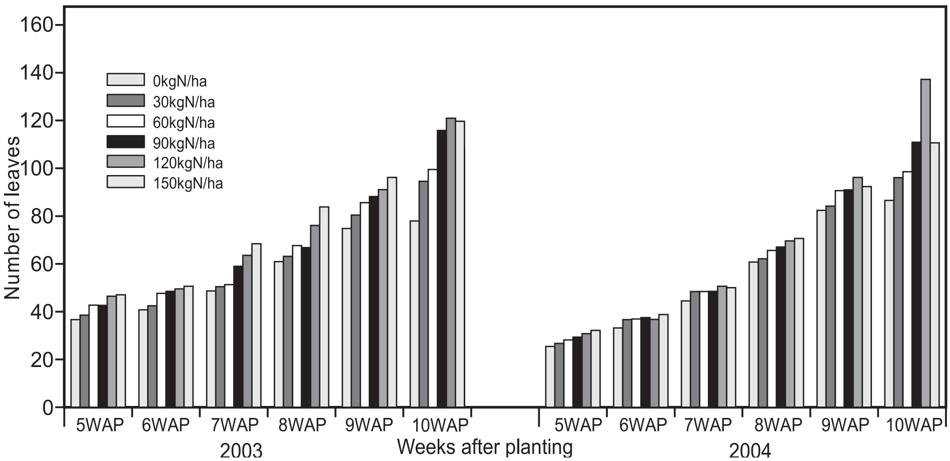

Figure 2: The effect of nitrogen fertilizer on plant height of sunflower.

Nitrogen application significantly affected the number of leaves at 7 and 10 WAP in both years (Figure 3). Plants treated with 90 kg N ha^{-1} produced the highest number of leaves (33 and 36) in 2003 and 2004. During the time of the trials, plants treated with 120 and 150 kg N ha^{-1} were always greener, taller and with larger leaves. Response of sunflower growth to nitrogen application could be attributed to the fact that nitrogen enhances growth vigor in plants. The trend in plant growth with respect to the years could be explained by the differences in the amount of moisture available for plant growth.

Effect of treatments on number of days to 50% flowering was significant in 2003, but not in 2004 (Table 2). The least number of days to flowering 57 and 62 were obtained in 2003 and 2004, respectively, from plants treated with 60 kg N ha-

1, though there were no significant differences between the results obtained from 30 to 120 kg Nha^{-1}.

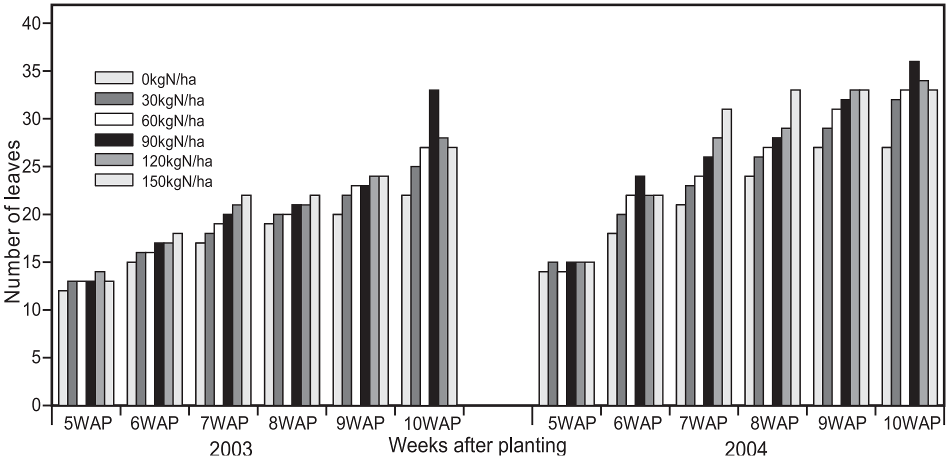

Figure 3: The effect of nitrogen on number of leaves of sunflower.

Table 2: Effect of N fertilizer on days to 50% flowering and capitulum diameter of sunflower in 2003 and 2004

Treatment (kg N ha^{-1})	2003		2004	
	Days to50% flowering	Capitulum diameter (cm)	Days to 50% flowering	Capitulum diameter (c)
0	64a	8c	66	9c
30	59bc	9.3c	63	10.5bc
60	57c	10.5abc	62	11.5abc
90	58bc	13a	63	14.0a
120	60bc	13a	63	12.5ab
150	61b	11.4ab	64	11.5abc
SE± (0.05)	1.2**	0.99**	NS	0.89**

Effect of treatment on yield and yield parameters

There was a highly significant effect (P≤0.01) of nitrogen rates on capitulum diameter in both years of trial (Table 2). Capitulum diameter (CD) increased as the rates of N increases up to 120 kg N ha^{-1}, after which there was a decrease in CD. In 2003, plants treated with 90 and 120 kg N ha^{-1} produced the same number of CD (13 cm), whereas, 90 kg Nha^{-1} gave the highest CD of 14 cm in 2004. However, there were no significant differences in the results obtained for CD from 60 to 90 kg Nha^{-1} in either year. Control plots gave the least CD of 8 and 9 cm in 2003 and 2004, respectively.

The seed yield of sunflower was significantly increased in 2003 and 2004 (Table 3). The highest seed yield of 1222 kg ha^{-1} was obtained at 90 kg N ha^{-1} in 2003, which gave a yield increase of 47% above control, whereas, in 2004, seed yield of 1311 kg ha^{-1} was obtained at 120 kg N ha^{-1} with a yield increase of 72% above the control. The relationship between seed yield and nitrogen rates is shown in Figure 4.

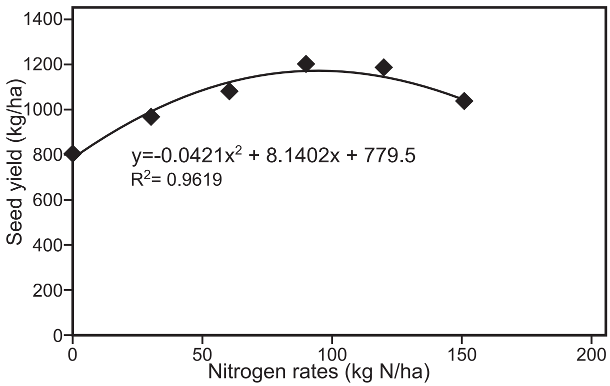

Figure 4: The response of sunflower seed yield to nitrogen rates.

There were increases in percent oil content and oil yield with the application of N. In 2003, 90 kg N ha^{-1} treatment gave the highest oil content and oil yield, whereas 90 and 120 kg N ha^{-1} gave the highest percent oil content and oil yield, respectively, in 2004 (Table 3). Least oil contents (50.6 and 52%) and oil yields (420 and 402.4%) were obtained from the control plots in 2003 and 2004, respectively.

Table 3: Effect of N fertilizer on seed yield and oil contents of sunflower in 2003 and 2004

Treatment (kg N ha^{-1})	2003			2004		
	Seed yield	Oil content (%)	Oil yield (%)	Seed yield	Oil content (%)	Oil yield (%)
0	833c	50.6b	420c	764b	52b	402.4b
30	911bc	54.0a	492bc	1021ab	54ab	554.3ab
60	1089ab	56.0a	611ab	1077ab	57a	613a
90	1222a	57.5a	703.3a	1167a	58a	676a
120	1056ab	56.4a	588ab	1311a	57.3a	748a
150	1000bc	54.8a	548b	1058ab	55.3ab	585ab
SE± (0.05)	77.2*	1.3**	45.2**	116*	1.5*	69.1*

DISCUSSION

Application of nitrogen (N) increased plant height and number of leaves (growth parameters) up to the highest rate of N, in both years. The supply of N is related to carbohydrate utilization, when N supplies are adequate and conditions are favorable for growth, proteins are formed from the manufactured carbohydrates, less carbohydrate is thus deposited in the vegetative portion, more protoplasm is formed and because the protoplasm is highly hydrated, a more succulent plant results. But when N supplies are insufficient, carbohydrates are deposited in vegetative cells causing them to thicken (Marschner, 1995; Tisdale *et al.*, 2003). Therefore, increase in crop growth is in line with increase in N application.

Vigorous vegetative growth was observed in the N-treated plants, because the N applied was sufficient to correct the initial N deficiency in the soil. This is due to the fact that adequate supply of N is associated with high photosynthetic activity, vigorous growth and dark green color of leaves (Tisdale *et al.*, 2003).

Flower formation is affected by nutrition. Application of 60 kg N ha^{-1} resulted in earliest flowering by plants in both years. Below and above this amount, flowering was delayed. Applications of high rates of N are known to delay flowering as a result of consumption of metabolites by vegetative tissues. The high rates of N in this study appeared to have stimulated enough vegetative growth to delay flowering.

The increase in seed yield with increase in N levels obtained from this study is in line with the report of Monotti (1978), Crnobarac *et al.* (2004) and De Giorgio *et al.* (2007). The significant effect that N rates had on oil contents and yield is due to seed yield increase by applying increasing N rates.

It has been reported that N fertilizer affects seed and oil yields of sunflower (De Giorgio *et al.*, 2007), while others associated N requirement with available water (Bonari *et al.*, 1992; Petcu and Petcu, 2006; Lauretti *et al.*, 2007; De Giorgio *et al.*, 2007). However, the mean monthly rainfalls at the experimental sites during the time of the trials were normal, except that it was slightly excessive in August 2003 (Figure 1). Nitrogen and phosphorus fertilization affect seed and oil yield (Blamey, 1987; Pasricha, 1997), the later also reported that N application in the absence of P decreased oil content. In this study, 50 kg P_2O_5/ha was applied to all the plots, due to the important role of P in carbohydrate metabolism, in the conversion of carbohydrate into oil and its low content in the savanna soils. Decreased oil content and yield obtained at the highest N rate in this study is in line with the report of Pasricha, (1997) and Lauretti *et al.* (2007).

The relationship between N rates and seed yield of sunflower (Figure 4) can be expressed by the following regression equation: $y=779.5+8.14\times-0.042\times^2$, $R^2=0.961$.

Optimum N rate calculated from this equation is 97 g N ha^{-1}, whereas for other regression equations that relate N rates, oil yield and oil contents, optimum N rate is between 90 and 110 kg ha^{-1}.

A correlation coefficient matrix between growth and yield parameters (Table 4) shows that there were significant positive correlations between seed yield and plant height, number of leaves, capitulum diameter, oil contents and oil yield (r=0.488**, r=0.433**, r=0.309*, r=0.456** and r=0.980**, respectively). Days to 50% flowering which correlated negatively with all the parameters determined were only significant with capitulum diameter. The significant relationship between these parameters indicates that they are important parameters that influence growth and yield parameters of sunflower. Similar relationship had been reported by De Giorgio *et al*. (2007).

Table 4: Correlation coefficient between growth and yield components based on mean values from 2003 and 2004

	Parameter	1	2	3	4	5	6	7
1	Plant height	-						
2	Number of leaves	0.377**	-					
3	DTF	-0.156	-0.054	-				
4	CP	0.621**	0.501**	-0.299*	-			
5	Seed yield	0.488**	0.433**	-0.164	0.309*	-		
6	Oil content	0.498**	0.479**	-0.245	0.423**	0.456**	-	
7	Oil yield	0.526**	0.484**	-0.178	0.352*	0.980**	616**	-

* Significant at 0.05 and ** significant at 0.01 probability levels. DTF=days to 50% flowering
CP - capitulum diameter

CONCLUSION

The results of this research indicate that nitrogen has a significant effect on sunflower growth and yield parameters. However, excess N reduced seed yield and oil contents as well as delayed flowering of sunflower in the savanna Alfisols.

The optimum N requirement of sunflower obtained from this study from quadratic equations is between 90-100 kg N ha^{-1}.

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RESPUESTA DEL GIRASOL (*Helianthus annuus* L.) A LA APLICACIÓN NITROGENADA EN UN ALFISOL DE LA SABANA

La disminución del rendimiento ha sido un gran problema en las áreas de sabana de Guinea del Norte de Nigeria debido a la baja fertilidad de los suelos. Durante dos años (2003 y 2004), se realizaron a campo experimentos en un alfisol de la Sabana de Guinea del Norte de Nigeria para determinar los efectos del N sobre el crecimiento y los parámetros de crecimiento del girasol. Se aplicaron seis dosis de nitrógeno (0, 30, 60, 90, 120 y 150 kg Nha^{-1}). La altura de la planta y el número de hojas fueron altamente significativos a las 10 semanas después de la siembra (WAP). Las tallas más altas, 120 y 138 cm, se obtuvieron en 2003 y 2004, respectivamente, con una dosis de 120 kg Nha^{-1}. La aplicación de N aumentó significativamente el rendimiento de granos y aceite, mientras que un exceso de N (150 kg Nha^{-1}) redujo los parámetros determinados. En girasol el requerimiento óptimo de N, obtenido de este estudio, es entre 90 y 100 kg Nha^{-1}.

RÉPONSE DU TOURNESOL (*Helianthus annuus* L.) À L'APPLICATION D'AZOTE DANS UN ALFISOL DE SAVANE

RÉSUMÉ

Le déclin dans le rendement des cultures est un problème majeur dans les zones nordiques de la savane de Guinée du Nigéria, en raison de la faible fertilité inhérente des sols.

Des expériences en champ ont été menées durant deux ans (2003 et 2004) sur un Alfisol au nord de la savane de Guinée du Nigéria afin de déter-

miner l'effet de la fertilisation azotée sur la croissance et les facteurs de rendement du tournesol.

Six taux d'azote (0, 30, 60, 90, 120 et 150 kg N ha^{-1}) ont été appliqués. La hauteur de plante et le nombre de feuilles étaient fortement significatifs 10 semaines après le semis.

Les plantes les plus hautes, de 120 et de 138 cm, ont été obtenues respectivement en 2003 et 2004 pour 120 kg N ha^{-1}.

L'apport d'azote a permis une hausse significative du rendement en grains et en huile alors qu'un excès (150 kg N ha^{-1}) diminuait la valeur des paramètres déterminés.

L'optimum d'azote pour le tournesol dans le cadre de cette étude se situe entre 90 et 100 kilogrammes N ha^{-1}.