International Journal of

Agricultural Research

ISSN 1816-4897

Academic
Journals Inc.

www.academicjournals.com

International Journal of Agricultural Research 2 (11): 937-944, 2007
ISSN 1816-4897

Growth and Yield of Onion (*Allium cepa* L.) as Influenced by Nitrogen and Phosphorus Levels

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Abstract: Field experiments were conducted in 2003/2004 and 2004/2005 dry seasons to study the effect of Nitrogen (N) and Phosphorus (P) on the growth and yield of irrigated onion in the Sudan Sananna of Nigeria. The treatments consisted of factorial combinations of four levels of nitrogen (0, 50, 100 and 150 kg N ha^{-1}) and three levels of phosphorus (0, 17.5 and 35 kg P ha^{-1}) laid out in split-plot design with three replications. Nitrogen was allocated to the main plots while phosphorus was assigned to the sub-plots. Results revealed that N and P as well as their interaction, significantly affected plant height, number of leaves per plant, percentage bolters, crop growth rate and individual bulb weight. However, interaction was not significant on bulb yield. Nitrogen at the rate of 150 kg N ha^{-1} gave the best results, though, statistically at par with 100 kg N ha^{-1}. 17.5 kg P ha^{-1} gave statistically similar results as 35 kg P ha^{-1}. The optimum combination from the results of this investigation was 100 kg N ha^{-1} and 17.5 kg P ha^{-1}.

Key words: Onion (*Allium cepa*), nitrogen, phosphorus, Sudan savanna, Nigeria

INTRODUCTION

Onion (*Allum cepa* L.) is a member of Alliaceae family and is of great benefit to man due to its dietic and medicinal values. Onion is one of the most important vegetable crops in Nigeria where it is an important condiment in the preparation of curry and spicy dishes. Onion cultivation in Nigeria is confined to the semi-arid northern Guinea and Sudan Savannah zones where it is normally transplanted in November and harvested in April in the dry season under irrigation. The soils in this area are mostly low in nutrients due to low organic matter content, which lowers the yield (Amans, 1989).

The average yield obtained by the farmers in Nigeria is about 15 t ha^{-1} much below the yield obtained in neighboring Niger Republic 36.986 t ha^{-1}, Egypt (30.567) and South Africa (26.488 t ha^{-1}) (FAOSTAT, 2005). Inadequate mineral nutrition has been reported as one of the major constraints to increased crop yield. Nitrogen is essential to growth and yield of onion but excessively high doses cause delay in bulb maturity and encourage bolting which is an undesirable characteristic. Shaikh *et al*. (1987) reported that application of 90 kg N ha^{-1} increased the yield of onion bulbs. Pandey *et al*. (1994) reported that application of nitrogen at the rate of 80 kg ha^{-1} gave higher yield than lower rates. Wiederfield (1994) found no additional yield increase from applying N rates higher than 84 kg ha^{-1}. Pandey and Ekpo (1991) at Maiduguri, Northern Nigeria reported maximum bulb yield with 120 kg N ha^{-1}. Al-Moshileh, (2001) in Saudi Arabia also reported significant yield increase due N application. But Halvorson *et al*. (2002) in Colorado reported that nitrogen resulted in only small increase in bulb yield.

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Researches from different parts of the world revealed that phosphorus nutrition greatly influenced growth and yield of onion. Pire *et al*. (2001) and Salo *et al*. (2002) reported significant effect of P on the growth and yield of onion. Greenwood *et al*. (2001) reported that P deficiency in onion resulted into reduced root and leaf growth, bulb size and yield and caused a delay in maturation. Woldetsadik (2003) in Ethiopia reported that phosphorus fertilization at the rate of 25 kg P ha^{-1} increased yield and bulb weight of onion even when soil analysis did not show deficiency.

Keeping in view these aspects, this research work was undertaken to determine the optimum doses of nitrogen and phosphorus fertilizers for profitable onion production under Sokoto semi-arid agro-ecological conditions.

MATERIALS AND METHODS

Field experiments were conducted at Usmanu Danfodiyo University, Fadama Teaching and Research Farm, Sokoto during 2003/2004 and 2004/2005 dry seasons. Sokoto (13° 01′N, 5° 15′E, 350 m above sea level) falls in the Sudan Savanna agro-ecological zone of Nigeria with erratic and scanty rainfall that lasts for about 4 months (mid June to September) and long dry period (October to May). The annual rainfall is highly variable over the years and averages around 700 mm. the temperature is also variable through out the year and the relative humidity is generally low for the greater part of the year which is about 20-35% in January and increases to 60-80% in August (Rao, 1983). The Solar radiation and the temperature pattern during the experiment are presented in Fig. 1.

Soil samples were randomly collected at 0-30 cm soil depth for physico-chemical analysis before the commencement of the experiment in 2003/2004 and 2004/2005 cropping seasons. The physico-chemical analysis of the soil of the study area showed that the soil was predominantly sandy loam (Table 1). The soil reaction was moderately acidic with pH values of 5.76 to 5.85 in 2003/2004 and 5.72 to 5.80 in 2004/2005. The organic carbon and total N content was high and P content was very low (Table 1).

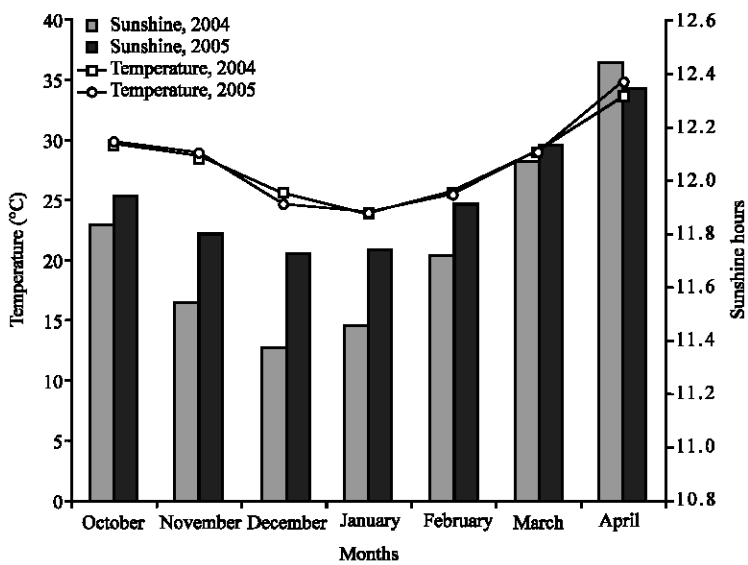

Fig. 1: Meteorological data of the experimental site showing mean temperature and sunshine hours during 2004 and 2005 cropping season

Table 1: Physico-chemical properties of soils at the experimental site during 2004 and 2005 dry seasons at Sokoto

	2004		2005	
	0-15	15-30	0-15	15-30
Properties	(cm)			
Chemical properties				
pH (water (1:1))	5.76	5.85	5.72	5.80
pH ($CaCl_2$)	5.27	5.46	5.22	5.43
Organic carbon (%)	7.66	8.50	7.63	8.51
Total nitrogen (%)	0.73	0.46	0.75	0.66
Available P (mg kg^{-1})	0.50	0.52	0.51	0.53
Exch. cations (cmol kg^{-1})				
Ca	1.25	0.96	1.23	0.98
Mg	1.29	1.26	1.27	1.26
K	2.54	1.06	2.53	1.03
Na	1.73	1.62	1.71	1.52
CEC	33.30	20.57	33.45	21.20
Physical properties (%)				
Sand	53.30	63.10	53.00	63.50
Silt	31.20	21.40	31.50	21.00
Clay	15.50	15.50	15.50	15.50
Textural class	Sandy loam	Sandy loam	Sandy loam	Sandy loam

The treatments consisted of factorial combinations of four levels of nitrogen (0, 50, 100 and 150 kg N ha^{-1}) and three levels of phosphorus (0, 17.5 and 35 kg P ha^{-1}) laid out in split-plot design with three replications. Nitrogen was allocated to the main plots while phosphorus was assigned to the sub-plots.

The prescribed treatments of N fertilizer were applied in two split doses while P was applied as a single dose at transplanting. All recommended cultural practices were adopted uniformly according to onion requirements. Data was collected on plant height, number of leaves per plant, crop growth rate, percentage bolting, bulb diameter, bulb weight and bulb yield.

The data obtained was subjected to analysis variance procedure using (SAS)® (2003). Duncan's Multiple Range Test was adopted for the means comparison among treatments showing significant difference. Effect of N and P fertilizer was partitioned into linear and quadratic components and regressions were calculated for effects significant at 0.05 level of probability.

RESULTS AND DISCUSSION

Effect of Nitrogen

Significant effect was found among the nitrogen levels tested for all the parameters studied (Table 2). Nitrogen had significant effect on plant height of onion with the highest value (55.85 cm) obtained from application of 150 kg N ha^{-1} which was at par with 55.67 cm obtained from the application of 100 kg N ha^{-1}. This showed that the N available in the soil was not adequate for onion production and additional N was required for the growth of the plant. The soils at the experimental site showed that the N content was high (Table 1). Similar results have been reported by Kumar *et al.* (1998), Amans *et al.* (1996), Arboleya and Garcia (1993) and Khan *et al.* (2002).

Nitrogen levels significantly affected the number of leaves per plant of onion with the highest value (12.63) obtained from 150 kg N ha^{-1} but not statistically different from 12.52 obtained from 100 kg N ha^{-1}. This also shows that, nitrogen plays important role in leaf production via its role in vegetative growth. Effect of nitrogen in increasing number of leaves in onion was reported by Kumar *et al.* (1998) and Khan *et al.* (2002) who reported that number of leaves per plant was increased with increasing nitrogen level up to 150 kg ha^{-1}.

Table 2: Effect of nitrogen rate on plant height, leaf number and crop growth rate of irrigated onion

Nitrogen rate (kg ha^{-1})	Plant height (cm)	No. of leaves $plants^{-1}$	Crop growth rate (g m^{-2} day^{-1})
0	41.85c	8.25d	0.57d
50	47.66b	10.19c	0.71c
100	55.67a	12.52a	0.92b
150	55.85a	12.63a	1.03a
CD	2.44	0.29	0.123
SED	1.152	0.131	0.041

Means in a column followed by the same letter(s) are not significantly different at 5% level using DMRT

Table 3: Effect of nitrogen rate on mean bulb weight, bulb diameter and cured bulb yield of irrigated onion

Nitrogen rate (kg ha^{-1})	Mean bulb weight (g)	Bulb diameter (cm)	Cured bulb yield (t ha^{-1})
0	89.61c	3.75c	10.29c
50	151.38b	7.10b	25.17b
100	228.30a	8.76a	40.59a
150	230.32a	8.74a	40.81a
CD	19.91	0.52	1.44
SED	9.08	0.24	0.665

Means in a column followed by the same letter(s) are not significantly different at 5% level using DMRT

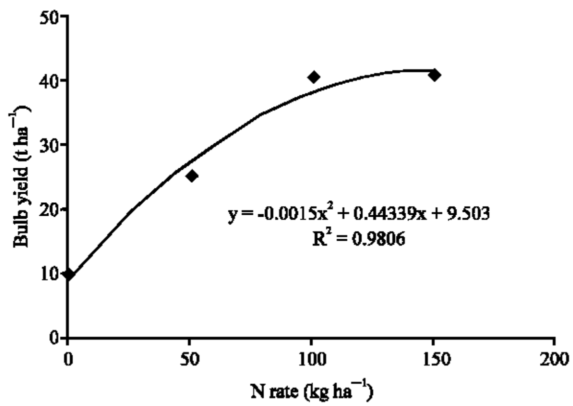

Fig. 2: A quadratic model of the relation between bulb yield of onion and nitrogen rate

Crop growth rate was significantly influenced by the nitrogen application up to 150 kg ha^{-1} (Table 2). It was observed that N triggered the growth rate of onion with the highest value (1.03 g m^{-2} day^{-1}) obtained from 150 kg N ha^{-1}. This was followed by (0.92 g m^{-2} day^{-1}) obtained from 100 kg N ha^{-1}. Control plots recorded the lowest crop growth rate of 0.5 g m^{-2} day^{-1}.

Bulb yield of onion was significantly affected by application of nitrogen (Table 3). Increase in N rate up to 100 kg ha^{-1} resulted in the increased yield of onion bulbs (40.59 t ha^{-}). But further increase did not significantly increase the yield. Bulb yield increased quadratically as N fertilizer levels increased, with yield peaking at 100 kg N ha^{-1} (Fig. 2). The lowest bulb yield of (10.29 t ha^{-1}) was recorded from the control plots, where no N was applied. Similar results were reported by Shaikh *et al*. (1987), Patel and Patel (1990) and Khan *et al*. (2002).

Nitrogen significantly affected the bulb diameter of onion with highest (8.7 cm) recorded from application of 100 kg N ha^{-1} (Table 3). The minimum value for bulb diameter (3.75 cm) was recorded from the control plots where no nitrogen was applied. Kumar *et al*. (1998) and Khan *et al*. (2002) also reported that bulb diameter was significantly affected by the application of nitrogen.

Increased nitrogen application up to 100 kg ha^{-1} resulted in an increase in the bulb weight of onion. But further increase to 150 kg ha^{-1} did not result in the weight increase (Table 3). 150 kg N ha^{-1} produced the heaviest bulbs (230.32 g) which was not statistically different from the (228.30 g) obtained from the application of 100 kg N ha^{-1}. Therefore 100 kg N ha^{-1} is technically the optimum dose for onion bulb production. Control plots produced the lowest values for bulb weight (89.61 g) due to the absence of the nitrogen, which is an important element needed for proper growth and development of every plant including onion. Kashi and Frodi (1998) Greenwood *et al*. (2001) and Khan *et al*. (2002) reported significant increase in the bulb weight of onion due to increased nitrogen application.

Effect of Phosphorus

Significant effect of phosphorus was observed for all the parameters investigated (Table 4, 5). Phosphorus had significant effect on the number of leaves per plant with the highest value (11.33) recorded when 35 kg P ha^{-1} was used which was statistically similar to 11.01 recorded with 17.5 kg P ha^{-1}. The lowest number (9.24) was recorded when no P was applied. The positive response of onion to P fertilization was mainly due to the fact that the plants have too weak root system to effectively explore and utilize soil P. Amans *et al*. (1996) reported significant effect of phosphorus on the number of leaves of onion.

Phosphorus application significantly affected the plant height of onion with the highest value (51.18 cm) recorded with 35 kg P ha^{-1} which was similar to 51.08 cm obtained with 17.5 kg P ha^{-1} application. Similarly, P application significantly influenced the crop growth rate (CGR) of onion with the highest value (0.69 g m^{-2} day^{-1}) recorded for 17.5 kg P ha^{-1} which was at par with 0.68 g m^{-2} day^{-1} obtained with 35 kg P ha^{-1} application (Table 4).

Phosphorus had significant effect on the percentage bolting in onion. P was found to reduce bolting in onion with the highest value (17.09%) obtained when P was not applied and lowest bolting (12.64%) was recorded when 35 kg P ha^{-1} was applied (Table 5). This investigation revealed that P application suppressed bolting onion. Amans (1982) and Umar (2000) have reported similar findings.

Individual bulb weight of onion was significantly influenced by P application with 35 kg P ha^{-1} recording the highest value (185.28 g) which was statistically at par with 185.58 g obtained with 17.5 kg P ha^{-1} application (Table 5). The findings in this research concur with the reports of Marschner (1995) and Greenwood *et al*. (2001). Also, P significantly affected the bulb diameter of onion with the highest value (7.63 cm) recorded when 35 kg P ha^{-1} was applied. This value was at par with the 7.55 cm obtained when 17.5 kg ha^{-1} was used. The effect of P on the bulb diameter of onion was through its influence on the bulb development. This finding was similar to that reported by El-Rehim (2000).

Table 4: Effect of phosphorus rate on plant height, leaf number and crop growth rate of irrigated onion

Phosphorus rate (kg ha^{-1})	Plant height (cm)	No. of leaves plants^{-1}	Crop growth rate (g m^{-2} day^{-1})
0.0	48.47b	10.11b	0.56b
17.5	51.08a	11.10a	0.69a
35.0	51.18a	11.33a	0.68a
CD	0.93	0.13	0.02
SED	0.473	0.067	0.015

Means in a column followed by the same letter(s) are not significantly different at 5% level using DMRT

Table 5: Effect of phosphorus rate on percent bolters, mean bulb weight, bulb diameter and cured bulb yield of irrigated onion

Phosphorus rate (kg ha^{-1})	Percentage bolters (%)	Mean bulb weight (g)	Bulb diameter (cm)	Cured bulb yield (t ha^{-1})
0.0	17.09a	149.96c	5.82b	20.93b
17.5	13.57b	186.36a	7.55a	30.86a
35.0	12.64c	187.53a	7.63a	31.92a
CD	0.12	4.79	0.13	0.93
SED	0.395	2.425	0.064	0.378

Means in a column followed by the same letter(s) are not significantly different at 5% level using DMRT

Table 6: Effect of interaction between nitrogen and phosphorus on growth and yield of onion

Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Plant height (cm)	No. of leaves $plant^{-1}$	CGR (g m^{-2} day^{-1})	Bulb diameter (cm)	Mean bulb weight (g)
0	00.0	39.15ij	7.50h	0.26h	4.15g	52.83h
0	17.5	42.51h	8.35g	0.37g	4.91f	82.40g
0	35.0	43.88gh	8.92f	0.33g	5.15f	84.75g
50	00.0	45.99f	9.46e	0.40f	6.57e	134.51f
50	17.5	48.48d	10.44d	0.51e	7.28d	142.46e
50	35.0	48.37d	10.66d	0.51e	7.47d	143.62e
100	00.0	53.88c	11.38c	0.63d	8.15c	149.57d
100	17.5	56.56a	1.69a	0.87c	9.09c	168.80bc
100	35.0	56.58c	12.90a	0.92c	9.06a	164.90cd
150	00.0	54.87bc	12.11b	0.93b	8.42b	170.70b
150	17.5	56.79a	12.91a	1.05a	8.90a	175.47a
150	35.0	55.88ab	12.86a	0.95b	8.80a	175.06a
SED		0.933	0.127	0.030	0.127	3.79

Means in a column followed by the same letter(s) are not significantly different at 5% level using DMRT

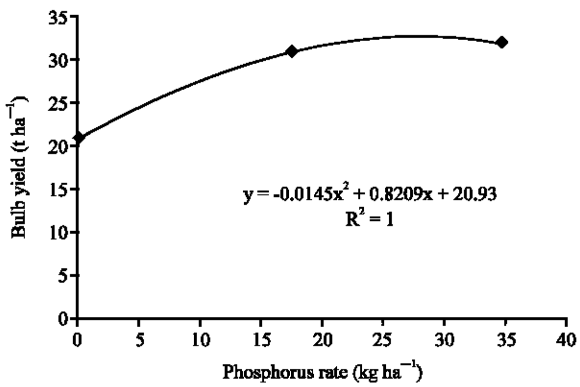

Fig. 3: A quadratic model of the relation between bulb yield of onion and phosphorus rate

Total cured bulb yield of onion was significantly influenced by the P application with the highest yield (31.92 t ha^{-1}) obtained with 35 kg P ha^{-1} application (Table 5). This was however at par with 30.86 t ha^{-1} recorded with 17.5 kg P ha^{-1} application. Control plots where no P was applied recorded 20.93 t ha^{-1}. This response was due to low P content of the soil at the experimental site as evident from the physico-chemical characteristics of the soil at the experimental site (Table 1). Bulb yield increased quadratically as P fertilizer levels increased, with yield peaking at 28 kg P ha^{-1} (Fig. 3). Many researchers such as Halder *et al.* (1998), Greenwood *et al.* (2001) and Woldetsadik (2003) have recorded significant effect of P fertilizer on the bulb yield of onion.

Effect of Nitrogen and Phosphorus Interaction

Influence of interaction between N and P on the parameters under study is presented in Table 6. Significantly higher values (12.91) for number of leaves was obtained when 150 kg N ha^{-1} was combined with 17.5 kg P ha^{-1}. This was statistically similar with (12.69) leaves obtained when 100 kg N ha^{-1} was combined with 17.5 kg P ha^{-1}. Similar trend was maintained for the plant height. Interaction of nitrogen and phosphorus on the crop growth rate of onion was also significant with the highest value (1.05 g m^{-2} day^{-1}) obtained at a combination of 150 kg N ha^{-1} and 17.5 kg P ha^{-1}. Interaction of nitrogen and phosphorus on the total yield of onion was not significant. But nitrogen and phosphorus interaction significantly influenced the bulb diameter of onion with the highest value (9.09 cm) obtained when 100 kg N ha^{-1} was used in combination with 17.5 kg N ha^{-1}. This was at par with the value obtained from 150 kg N ha^{-1} was combined with 35 kg P ha^{-1}. Similarly interaction of N and P was significant on the bulb weight of onion with the highest value (175.47 g) recorded when 150 kg N ha^{-1} was combined with 17.5 kg P ha^{-1} which was at par with (175.06 g) obtained when same level of nitrogen was combined with 35 kg P ha^{-1}. The lowest bulb weight (52.8 g) was obtained when neither nitrogen nor phosphorus was applied. Researchers such as Rahim *et al.* (1992) and Almoshileh (2001) have also reported a significant interaction of nitrogen and phosphorus on growth and yield of onion.

CONCLUSIONS

From the results of this investigation, it can be concluded that, nitrogen application at the rate of 100 kg N ha^{-1} combined with phosphorus at the rate of 17.5 kg P ha^{-1} is the optimum combination for the growth and yield of onion under semi-arid agro-ecological zone.

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