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INFLUENCE OF PLANT DENSITY AND PHOSPHORUS LEVELS ON THE GROWTH AND YIELD OF ONION (*Allium cepa* L) IN HUMID ULTISOLS

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ABSTRACT

Field study was conducted at the Experimental Farm of the Faculty of Agriculture, University of Benin, Benin City, Nigeria in 2015 and 2016 to determine the effect of plant density and phosphorus application on the growth and yield of onion in the humid ultisols environment of Benin City. The experiment was laid out in a 3 x 3 split plot design with three replications. The main treatments were three plant densities 50 (10 x 20 cm), 66 (10 x 15 cm) and 100 (10 x 10 cm) plants m^{-2} and sub-treatments were three levels of phosphorus fertilizer (0, 30 (68.71 kg P_2O_5) and 60 (137.42 kg P_2O_5) kg P ha^{-1}). Data were collected on plant height and number of leaves per plant during the vegetative phase, while, at harvest, data were collected on number of roots, roots length, bulb length, bulb girth, bulb weight, bulb yield, relative yield (RY) and phosphorus use efficiency (PUE). Significant effect of plant density was observed on relative yield and PUE only. Phosphorus application significantly influenced all the parameters measured. The highest bulb yield (17 t ha^{-1}) was at 60 kg P ha^{-1} which was comparable to 15 t ha^{-1} observed at 30 kg P ha^{-1}. Onion bulb yield was significantly and positively correlated with plant height (r =0.813) and number of leaves per plant (r = 0.827). Based on the relative yield and PUE, a plant density of 50 plant m^{-2} and 30 kg P ha^{-1} are therefore recommended for onion cultivation in the humid ultisols environment of Benin City.

Keywords: Plant density; Phosphorous level; Ultisols

INTRODUCTION

Onion (*Allium cepa* L.) belongs to the family Alliaceae and originated from Middle Asia (Nanagouda and Rajasab, 2012). The crop is grown for consumption green and as mature bulbs. It ranks second to tomatoes among vegetables in Nigeria (Denton and Ejeifo, 1990). Onion cultivation in Nigeria is confined to the fadama areas of the northern part of the country (Nwokwu and Ekwu, 2015). Due to the high demand and consumption of this crop, there is a need to extend its production to the southern part of Nigeria. To achieve this, the development of suitable agronomic practices is needed.

According to Mondal *et al*. (1986) onion production is greatly influenced by environmental factors, cultivars and agronomic practices. Islam *et al*. (1999) reported that set size, spacing and nitrogen fertilization are among the agronomic practices that play important role in the crop. Naik and Hosamani (2003) pointed out that, apart from the varietal characteristics, plant population and soil fertility are important consideration for increasing the yield of onion. Farmers usually grown onions in complex mixed with other vegetable crops such as lettuce, tomato and pepper other crops (Mohammed *et al*., 2011). Plant densities under mixed cropping were estimated to be between 16 and 50 plants m^{-2}. A plant population lower than 60 plants m^{-2} or more than 100 plants m^{-2} yield decreased (Rumple and Felezynski, 2000). Brewster (2008) reported plant densities between 50 and 100 plants m^{-2} will produce bulbs that are between 5 – 7 cm in diameter, which are preferred in most markets (Rumple and Felezynski, 2000).

The yield of crop is directly influenced by the plant density and thus, the productivity of the crop can be enhanced by maintaining optimum plant density in the field. According to Weiner (1990) increasing the plant density may result in increased yield per unit area up to certain limit (100 pants m^{-2}). Coleo *et al* (1996) reported that highest marketable onion bulb was observed at the highest plant density but the highest proportion of large bulbs and average bulb weights were observed at the lowest plant density (50 plants m^{-2}). Rizk (1997) reported that the highest plant density (75 plants m^{-2}) produced higher yield of good quality bulbs than the lower rate. Dewar *et al* (2007) observed that lower plant density (50 plants m^{-2}) increased the number of leaves per plant and weight of large size bulbs. Crop yield per stand may however, decrease with increasing population due to inter- and- intra specific plant competition for growth resources (Law-Ogbomo and Osaigbovo, 2016). Hence appropriate plant density should be determined through conducting experiments.

Most soils of the rainforest zone are inherently low in nutrients especially the primary nutrients (N, P and K), organic matter and exchangeable cations thus resulted in low crop yield (Nottidge *et al*., 2005). According to Kurtz *et al*. (2013) fertilizer application is one of the most important factors in onion production because it directly affects growth, development and yield. Phosphorus is the most limiting nutrient after nitrogen, its deficiency is one of the biggest constraints to the crop’s production in many tropical soils due to low natïve content and high phosphorus immobilization within the soil (Fairhust *et al*., 1999). Phosphorus plays an important role in enhancing drought tolerance in plants, stimulates root growth and photosynthesis (Singh and Sale, 2000). Results of long-term fertilizer trial on loamy sand soils in Germany have shown a strong response of onions to phosphorus fertilization in the range of 0 – 52 kg P ha-1 (Alt *et al*., 1999). Depending on yield levels, phosphorus uptake rates in onion are estimated to be about 15 – 30 kg P ha-1 in Malaysia (Salo *et al*., 2002). There is a dearth of information on the effects of phosphorus application and plant population on onion performance in the humid rainforest zone of Nigeria, an agro-environment where onion production holds high economic potentials. Thus, the present study was carried out to evaluate the effect of phosphorus and plant population on the growth and yield of onion in the humid ultisols environment.

MATERIALS AND METHODS

Study Area

The experiment was carried out during early cropping season of 2015 and 2016 at the Experimental Farm of Faculty of Agriculture, University of Benin, Benin City, Edo State. The experimental site lies within the geographic coordinates of longitude 05^0 40' and

06^0 43' E and latitude 05^0 44' N and 07^0 34' N (FOS, 1994), at elevation of 162 m above sea level. The study area was characterized by a humid tropical climate. It has a mean rainfall of 1762 mm and daily temperature of 26.4 ^{0}C. It lies within rainforest of agro-ecological zone of Edo State, Nigeia, now degraded to secondary forest due to shifting cultivation.

Experimental Design and Field Experimentation

The experiment was laid out as a split plot design replicated three times. The main plots consisted three plant densities; 100 (10 cm x10 cm), 66 (10 cm x15 cm) and 50 (10cm x20 cm) plants m^{-2} and subplots were three rates (0, 30 (68.71 kg P_2O_5) and 60 (137.42 kg P_2O_5) kg ha^{-1}) of phosphorus fertilizer.

The field was marked out after clearing and beds measuring 2 x 1 m spaced 0.50 m apart were prepared. Each replicate had 9 beds and a total of 27 beds made up the experimental unit. Composite soil sample was taken from the site and analyzed for physical and chemical properties using standard laboratory procedure. The soil routine analysis showed that it contained Sand (g kg^{-1}) 890.00; Clay (g kg^{-1}) 65.00; Silt (g kg^{-1}) 49.00; pH 5.5; Organic Carbon (g kg^{-1}) 24.50; total Nitrogen (g kg^{-1}) 0.89; available Phosphorus (mg kg^{-1}) 6.42; exchangeable (cmol kg^{-1}) Calcium 0.84; exchangeable (cmol kg^{-1}) Magnesium 0.34; exchangeable (cmol kg^{-1}) Potassium 0.24; exchangeable (cmol kg^{-1}) Sodium 0.21; exchangeable (cmol kg^{-1}) Acidity 0.15; C:N 27:53.1. Each bed received 20 t ha^{-1} of cured poultry manure as basal application four weeks prior to transplanting.

Onions seedlings (Red Creole) were transplanted to the field at 8 weeks after sowing (WAS) in the nursery. After transplanting, Plots were mulched with dry leaf litter to conserve soil moisture and suppress weeds. Phosphorus (P) fertilizer in the form of single super phosphate was applied at 0, 30 and 60 kg ha^{-1} to the respective treatment plots by band placement at transplanting. The field was weeded manually as at when due. Leaf eating Lepidoptera larvae (stem borers/ armyworm) were checked by spraying with Attacke (chlorophryphos) at the rate of 150 ml per 20 liters of water. Onion bulbs were harvested at maturity, after extensive drying up of the leaves. During harvesting, hand trowel was used to loosen the soil before the onion plant was pulled out carefully to prevent damage to the roots and bulb. The onion bulbs were cured by spreading them on the floor of a ventilated room and allowed to dry for 10 days before topping.

Data Collection and Analysis

Data were collected fortnightly on 10 plants randomly selected from the inner row of each plot for plant height and number of leaves. Plant height was measured in centimeters from the ground level to the top of the longest matured leaf. Number of leaves refers to the total count of leaves per plant.

After harvesting, data were collected on bulb length, bulb girth, bulb weight, bulb yield, number of roots/plant, root length, relative yield and phosphorus use efficiency (PUE) on 10 plants earlier sampled. Bulb length refers to bulb measurement using meter rule from the bottom to the top of the bulbs of the pre-tagged plants. Bulb girth refers to the average width at the widest point in the middle portion of all the mature bulb of pre-tagged plants measured with venier caliper. Bulb weight was estimated by weighting all bulbs of the pre-tagged plants together and calculating the average. Bulb yield was computed based on the weight of matured bulb per plot and converted into hectare and expressed in tonnes and thus:

$$\text{Bulb yield} = \left[\frac{Area\ of\ an\ hectare}{Area\ of\ plot}\ \text{x}\ weight\ of\ bulbs\ (kg/plot)\right] x\ \frac{1}{1000}\ \text{t ha}^{-1}$$

Number of roots is the total count of roots per plant of all the pre-tagged plants and average computed. Root length was obtained through measurement of all uprooted pre-tagged plants from the base of bulb to the tip of the root using meter rule and average computed. The relative yield (RY) was computed as:

$$\text{RY} = \frac{Weight\ of\ bulbs\ with\ phosphorus\ fertilizer\ application}{Weight\ of\ bulbs\ without\ phosphorus\ application}$$

PUE refers to the amount of yield that is produced per unit of P taken up. This was computed as:

$$\text{PUE} = \frac{Yield\ (P) - Yield\ (C)}{Yield\ (C)}$$ where P = phosphorus treated plants, C= untreated plants.

Data collected were subjected to combined analysis of variance and significant differences among treatment means were separated using the least significant differences (LSD) ($P<0.05$).

RESULTS

Growth of onion as influenced by plant density and level of phosphorus application over six weeks duration is presented in Table 1. Plant height was significantly different among plant densities at 2 WAT (weeks after transplanting). Plant density of 66 plants m^{-2} had significantly taller plants than others except onion planted at 50 plants m^{-2}. At 4 and 6 WAT, All plant density treatment effects were not significantly different $P>0.05$. Application of phosphorus influenced plant height positively. Phosphorus treated plants were significantly taller than untreated plants over the six weeks duration. At 2 WAT, plants treated with 60 kg P ha^{-1} had the tallest plants, followed by 30 kg P ha^{-1} and untreated control in that order. At four and six WAT, plants treated with 30 and 60 kg P per hectare had the taller plants than untreated plants. There was no significant ($P>0.05$) interaction of plant density and fertilizer application on plant height across the assessment periods.

The number of leaves was not significantly ($P>0.05$) different among plant densities over the assessment periods. However, there was significant difference among the rates of phosphorus application all through the durations. Plants treated with 30 and 60 kg P ha^{-1} had similar number of leaves but were significantly ($P<0.05$) higher than the untreated plants. The interaction of plant density and phosphorus fertilizer on number of leaves was not significant ($P>0.05$).

Table1: Growth of onion plant as influenced by plant density and levels of phosphorus application

Treatment	Plant height (cm)			Number of leaves		
	Weeks after transplanting			Weeks after transplanting		
	2	4	6	2	4	6
Plant density (plants m^{-2})						
50	19.96^{ab}	22.91	22.60	2.05	2.85	2.78
66	25.22^{a}	27.91	35.00	3.46	3.94	5.67
100	18.39^{b}	19.22	24.00	2.50	2.72	2.78
$LSD_{(0.05)}$	5.964	6.945	14.955	1.873	1.844	2.96
Phosphorus (kg ha^{-1})						
0	16.38^{c}	18.46^{b}	20.90^{b}	1.98^{b}	2.20^{b}	2.65^{b}
30	23.00^{b}	23.45^{a}	30.60^{a}	3.16^{a}	3.18^{a}	4.00^{a}
60	25.89^{a}	26.21^{a}	30.00^{a}	3.33^{a}	3.66^{a}	4.57^{a}
$LSD_{(0.05)}$	2.672	3.288	5.66	0.874	0.769	0.579
Interaction	ns	ns	ns	ns	ns	ns

ns - not significant ($P>0.05$)

Yield Components

Plant density had no significant effect on number of roots, root length, bulb length, bulb girth, bulb weight and bulb yield except relative yield (Table 2) plant density of 50 plants m^{-2} had the higher relative yield than 66 and 100 plant m^{-2} plant densities. Phosphorus application had significant effect on bulb yield and its components. Number of roots was significantly higher with plants treated with 30 and 60 kg P ha^{-1} than untreated plants. This distribution pattern was repeated for bulb length, bulb girth, bulb weight, bulb yield and relative yield (Table 2).

However, root length and bulb girth was longer and thicker in plants treated with 60 kg P ha^{-1} followed by 30 P kg^{-1} and untreated plants in that order. There was no significant interaction of plant density and phosphorus fertilizer on bulb yield and its components. Plant density and rates of phosphorus application had no significant effects on the relative yield (Table 3).

The result of the effect of plant density and phosphorus application on phosphorus use efficiency is presented in Table 3. Among the plant densities, onion planted at 50 plants m^{-2} had significantly ($P>0.05$) higher PUE. Values of PUE for 30 and 60 kg P ha^{-1} were comparable and significantly ($P>0.05$) higher than untreated control.

Table 2: Yield and yield components of onion as influenced by plant population and level of phosphorus application

Treatment	No. of root	Root length(cm)	Bulb length(cm)	Bulb girth(cm)	Bulb weight(g)	Bulb yield (t ha^{-1})	Relative yield
Plant population (plants m^{-2})							
50	24.70	8.28	6.00	8.74	10.70	9.70	3.81^{a}
66	36.00	11.57	6.74	10.39	10.80	18.90	1.28^{b}
100	15.80	7.07	5.37	8.04	8.00	12.20	1.47^{b}
$LSD_{(0.05)}$	20.800	4.873	1.783	2.891	12.170	9.732	1.787
Phosphorus (kg ha^{-1})							
0	16.60^{b}	6.74^{b}	5.18^{b}	7.37^{b}	5.10^{b}	8.70^{b}	1.00^{b}
30	28.00^{a}	9.09^{a}	6.50^{a}	9.52^{a}	11.80^{a}	15.00^{a}	2.24^{a}
60	31.90^{a}	11.09^{a}	6.43^{a}	10.26^{a}	12.70^{a}	17.00^{a}	3.31^{a}
$LSD_{(0.05)}$	6.400	1.867	0.696	1.236	6.070	5.610	1.787
Interaction	ns	ns	ns	ns	ns	ns	ns

ns - not significant at 0.05 level of probability

Table 3: Phosphorus use efficiency (PUE) of onion as influenced by plant population and level of phosphorus application

Treatment	PUE
Plant population (plants per hectare)	
500,000	0.41^{a}
666,666	0.21^{b}
1,000,000	0.26^{b}
$LSD_{(0.05)}$	0.141
Phosphorus (kg ha^{-1})	
0	0.00^{b}
30	0.38^{a}
60	0.50^{a}
$LSD_{(0.05)}$	0.205
Interaction	ns

ns - not significant at 0.05 level of probability

Growth and Yield Correlation

The correlation coefficient of bulb yield components and growth variables is presented in Table 4. The correlation of the number of leaves with bulb length (0.828), plant height (0.859), bulb girth (0.821), bulb weight (0.541), bulb yield (0.827) and number of bulbs (0.504) was significantly ($P>0.05$) positive. Bulb weight was positively correlated with root length ($r = 0.531$), bulb length ($r = 0.837$), plant height ($r = 0.565$), number of roots ($r = 0.672$), number of leaves ($r = 0.541$) and bulb yield ($r = 0.703$). Bulb yield was significant and positively correlated with bulb length ($r =0.871$), plant height ($r = 0.813$), number of roots ($r = 0.740$), number of leaves ($r = 0.827$) and number of bulbs ($r = 0.394$).

Table 4: Correlation coefficients of onion bulb yield components and growth variables

Variable	Bulb girth	Bulb weight	Bulb yield	No. of bulbs	No. of leaves	No. of roots	Plant height	Bulb length	Root length
Bulb girth	1.000	0.694*	0.940*	0.367	0.821*	0.764*	0.804*	0.909*	0.643*
Bulb weight	0.694*	1.000	0.763*	-0.135	0.541*	0.672*	0.565*	0.837*	0.531*
Bulb yield	0.940*	0.763*	1.000	0.394*	0.827*	0.740*	0.813*	0.871*	0.599*
No. of bulbs	0.367	-0.135	0.394*	1.000	0.504*	0.318	0.384*	0.297	0.321
No. of leaves	0.821*	0.541*	0.827*	0.504*	1.000	0.870*	0.854*	0.828*	0.808*
No. of roots	0.764*	0.672*	0.740*	0.318	0.870*	1.000	0.695*	0.853*	0.900*
Plant height	0.804*	0.565*	0.813*	0.384*	0.854*	0.695*	1.000	0.771*	0.617*
Bulb length	0.909*	0.837*	0.871*	0.297	0.828*	0.853*	0.771*	1.000	0.736*
Root length	0.643*	0.531*	0.599*	0.321	0.808*	0.900*	0.617*	0.736*	1.000

* Significant at 0.05 level of probability

DISCUSSION

This study demonstrated that phosphorus enhanced the growth and yield of onion in the Ultisols environment of Benin City. The soil of the experimental site was of a low native fertility due to low nutrient content, immobilization within the soil (Fairhust *et al*., 1999) and organic matter deficiency. The low nutrient status of the experimental site might have resulted in the lower heights and numbers of leaves exhibited by plants without phosphorus treatment. This finding agrees with Brewster (1994) who reported that P is an important nutrient influencing the performance of onion. The pre-cropping soil test result justified the application of additional phosphorus to enhance plant growth and productivity. The enhancement of growth of onion could probably be due to increase in P availability to plant through conversion of water insoluble P to soluble form (Akande *et al.*, 2003). P enhanced plant growth as it played a key role in energy metabolism, cell division, synthesis of nucleic acids and membranes, photosynthesis, respiration and enzymes regulations (Raghottama, 1999).

Plant density had no significant effect on plant height and number of leaves. This observation negated the finding of Dewar *et al* (2007) who reported that lower plant density increased the number of leaves per plant and weight of large size bulb. However, the plant population of 666,666 per hectare was about 26% and 37% taller than 500,000 and 1,000,000 pph, respectively.

Number of roots, longer root and bulb length, thicker girth, heavier bulbs and higher bulb yield were not significantly influenced by plant density. This finding is contrary to the observation of Akoun (2004) who reported marked increase in the girth of bulbs as plant density consistently decreased. However, the bulb yield of 666,666 pph was about 95 % and 55 % higher than 500,000 and 1,000,000 pph respectively.

The relative yield and PUE at 500,000 pph was highest due to fewer numbers of plants per unit area. This implies that increase in plant density brought about increased limitation and decrease of growth resources (physical space, light, nutrients and moisture) due to interspatial competition. The higher relative yield associated with higher plant density agrees with Brewster (2008) who reported that as plant density increase, onion relative yield also increase, owing to leafy canopy intercepting higher percentage of light. However, the bulb yield of 59 t ha^{-1} reported by Rumple and Felezynski (2000) was far higher than 12.20 t ha^{-1} obtained at 100 plants m^{-2} in this study. Thicker bulbs (8.04-10.39 cm in diameter) were obtained in this study compared to those produced by Bosch – Serra and Kanton-Currah (2002) (50 – 70 mm in diameter). Since the bulbs were greater than 7.00 cm in diameter, it implied that they are suitable for the processing industry (Shock *et al.,* 2005).

In comparison to P treated plants, onion plants without P treatment had reduced number of roots, shorter roots, thinner bulbs, smaller bulbs and lower bulb yield. This could probably be attributed to inherent low P in the control plots. This observation confirms the report of Nottidge *et al*. (2005) who reported that inherently low P in nutrient soils had resulted in low yield of maize. The increase in bulb yield and its component associated with P treated plants was probably due to enhancement of P availability leading to increase in plant height and number of leaves which might increase the assimilate production and allocation to the bulbs. The positive correlation observed between number of leaves and bulb weight, bulk girth and bulb yield is an indication that an increased photosynthetic area in response to phosphorus application had enhanced onion productivity which might be through the production of more assimilate (Abdissa *et al*., 2011). The significant positive correlation of bulb weight with bulb girth and length signified that phosphorus application increased bulb weight by improving both variables. This process could lead to increased bulb yield and enhancement of its components. The higher number of roots and longer roots of the P treated plants probably led to greater bulb yield through enhancement of absorption of water and nutrients the plant.

CONCLUSION

This study demonstrated that growth and yield response of onions was significantly influenced by phosphorus fertilizer application rather than plant density. Plant density of 50 plants m^{-2} had the highest relative yield and PUE among other plant densities used in this trial. P treated plants had higher growth and yield parameters than untreated plants. Phosphorus application rate of 30 kg ha^{-1} had higher PUE than 60 kg P ha^{-1}. Base on the results of this study, growing onion at a plant density of 50 plants m^{-2} (10 x 15 cm) and 30 kg P ha^{-1} could be appropriate for the study area.

REFERENCES

Abdissa, Y., Telkalign, T. and Pant, L. M. (2011). Growth, bulb yield and quality of onion (*Allium* L.) as influenced by nitrogen and phosphorus fertilization on vertisol. *African Journal of Agricultural Research*, 6(14): 3252 – 3258.

Akande, M.O., Oluwatoyinbo, F.I., Adediran, J. A., Buari, K.W and Yusuf, I. O. (2003). Soil amendments affect the release of P from rock phosphate and the development and yield of okra. *Journal of Vegetable Crop Production*, 2: 3-9.

Akoun, J. (2004). Effect of plant density and manure on yield and yield components of common onion (*Allium cepa* L.) var. Nsukka Red. *Nigerian Journal of Horticultural Science*, 9: 43 – 48.

Alt, D., Ladebusch, H. and Melzer, O. (1999). Long-term trial with increasing amount of phosphorus, potassium and magnesium applied to vegetable crops. *Acta Horticulture*, 506: 29 – 36.

Banger, K. C., Yadev, K. S. and Mishra, N. M. (1985). Transformation of rock phosphate during composting and the effect of humic acid. *Plant and Soil*, 85: 259-266.

Bosch-Serra, A. D. and Kanton-Currah, L. (2002). Agronomy of onions. In: Rabinowitch, H. D. and Kanton-Currah, L. (eds), *Allium Crop Science*: *Recent Advances*. CAB International, Wallingford. 187-232.

Brewster J. L (1994). *Onions and other Vegetable Alliums,* 1st edn. CAB International, Wallingford. pp. 63-83.

Brewster, J. L. (2008). *Onion and other Vegetable Alliums*. 2nd Edition, Development, Pretoria, South Africa. 257 pages.

Coleo, R. F., Souza, A. B. and Conceicao, M. A. (1996). Performance of onion crops under three irrigation regimes and five spacing. *Pesquisa Agropecuaria Brasilcira*, 31(8): 585 – 591.

Dawar, N. M., Wazir, F. K., Dawar, M. and Dawar, S. H. (2007). Effect of planting density on growth and yield of onion varieties under climatic conditions of Peshawar, Sarhad. *Journal of Agriculture*, 23(4): 911 – 918.

Denton, L. and Ojeifo, I. M. (1990). Onion production practices and their improvement in Nigeria. *Onion Newsletter for the Tropics*, 2: 10-113.

Fairhust, T., Lefroy, R., Mutert, E. and Batijes, N. (1999). The importance, distribution and causes of phosphorus deficiency as a constraint to crop production in the tropics. *Agroforestry Forum*, 9: 2-8.

FOS (1994). Federal Office of Statistics Nigeria.

Islam, M. K., Awal, M. A., Ahmed, S. U. and Baten, M. A. (1999). Effect of different set sizes, spacing and nitrogen levels on the growth and bulb yield of onion. *Pakistan Journal of Biological Science*, 2 (4): 1143-1146.

Kurtz, C., Ernani, P. R., Pauletti, V., Menezes, J. F. and Vieira, N. J. (2013). Produtividade e conservacao de cebola afetada pela adubacao nitrogenada no sistema de plantio direto. *Hortic Bras*, 31: 559 – 567.

Law-Ogbomo, K. E. and Osaigbovo, A. U. (2016). Growth and yield of *Corchorus olitorius* as influenced by plant population and fertilizer type in the humid ultisols of southwestern Nigeria. *Nigerian Journal of agriculture, food and Environment*, 12(1): 56-61.

Mondal, M. F., Brester, J. L., Morris, G. E. L. and Butler, H. A. (1986). Bulb development in onion (*Allium cepa* L.). 1. Effects of plant density and sowing date in field condition. *Annal of Botany,* 58: 187-195.

Muhammed, A., Gambo, B. A. and Ibrahim, N. D. (2011). Response of onion (*Allium cepa* L.) to irrigation intervals and plant density in Zuru, Northern Guinea Savanna of Nigeria. *Nigerian Journal of Basic and Applied Science*, 19(2): 241 – 247.

Nanagouda, P. and Rajasab, A. H. (2012). Constraint experienced by onion growers from Gulbarga District of Karnataka, India. *International Journal of Extension Education*, 8: 45 – 50.

Naik, B. H. and Hosamani, R. M. (2003). Effect of spacing and nitrogen levels on growth and yield of Kharif onion. *Karnataka Journal of Agricultural Science*, 16(1): 98 – 102.

Nottidge, D.O., Ojeniyi, S. O. and Asawalen, D. O. (2005). Comparative effects of plant residues and NPK fertilizer on nutrient status and yield of maize in a humid ultisol. *Nigerian Journal of Soil Science*, 18: 1-8.

Nwokwu, G. N. and Ekwu, L. G. (2015). Influence of planting techniques and potting media on the growth and yield of onion (*Allium cepa* L.). *International Journal of Agricultural Science,* 4(7): 140 – 147.

Raghottama, K. G. (1999). Phosphate acquisition. *Annals of Review of Plant Physiology and Plant Molecular Biology,* 50: 665-693.

Rizk, F. A. (1997). Productivity of onion plant (*allium cepa* L.) as affected by method of planting and NPK application. *Egyptian Journal of Horticulture,* 24(2): 219 – 238.

Rumple, J. and Felezynski, K. (2000). Effect of plant density on yield and bulb size of direct sown onions. *Acta Horticulture,* 533: 179-185.

Salo, T., Suajala, T. and Kallela, M. (2002). The effect of fertilization on yield and nutrient uptake of cabbage, carrot and onions. *Acta Horticulture*, 571: 235 – 241.

Shock, C. C., Feibert, E. B. G. and Saunders, L. D. (2005). Single centered and supper colossal bulbs from yellow onion cultivars. *Horticulture Technique,* 15; 399-408.

Singh, R. B. and Sale, A. S. (2000). Studies on drought tolerance in plants. *Agricultural Water Management*, 82: 114 – 115.

Weiner, J. (1990). Plant population ecology in agriculture. In: Carroll, C. R., Vandermeer, J. H. and Rosset, P. M. (eds), *Agroecology*. Mcgraw Hill, New York. 235-262.