Preliminary studies on the response of onion (*Allium cepa* L.) to planting depth and NPK fertilizer application

I. K. ADDAI*, D. NIBORTOR & M.O. KWARTENG
(I.K.A. & D.N.: Department of Agronomy, University for Development Studies, Tamale, Ghana; M.O.K.: Department of Horticulture, University for Development Studies, Tamale, Ghana)
**Corresponding author's email: isaackwaheneaddai@yahoo.com*

ABSTRACT

Studies were conducted at the Department of Agronomy of the University for Development Studies in Nyankpala, Ghana, from July to October 2011 and repeated in the same period in 2012 to determine the response of onion to depth of planting and fertilizer application. Onion bulbs of average fresh weight of 24 g were planted 0, 2, 4 and 6 cm deep from soil surface, and NPK (15:15:15) fertilizer at the rate of 0, 85, 170 and 255 kg ha^{-1} was applied at the time of planting and 2 weeks after planting. The treatment combinations were replicated four times in randomized complete block (RCB) design. The results indicated that planting 4 cm deep, and applying NPK fertilizer at the rate of 85 kg ha^{-1} produced the highest bulb size and fresh weight at harvest. Bulbs planted 2 cm deep, which received no fertilizer application, produced the highest number of bulbs at harvest, whilst those planted at the depth of 6 cm and fertilized with 170 kg ha^{-1} of NPK gave the least number of bulbs. Leaf production was highest when bulbs were planted 2 cm deep, and no NPK fertilizer application. Tiller production was also highest when bulbs were planted 4 cm deep and no NPK fertilizer application. In onion production, therefore, whilst NPK fertilizer may not be required for vegetative growth, it is important to apply the fertilizer to enhance bulb production. Onion growers in the study area should plant onion bulbs on Nyankpala soil series 4 cm deep, and apply NPK fertilizer at the rate of 85 kg ha^{-1} to the soil for good bulb yield.

Original scientific paper. Received 03 Apr 14; revised 16 Sept 14.

Introduction

Onion (*Allium cepa* L.) was introduced into Ghana from Burkina Faso around 1930 and cultivated first at Bugri near Bawku (Sinnadurai, 1992). Onion planted from the bulb generally matures 3 - 4 weeks earlier and yield higher than seeded onion (Ware *et al*., 1992). Onion is used in soups and for seasoning other foods. Tindall (1983) indicated that onion leaves are used in salads, whilst some have been selected for their dry matter yield and suitability for dehydration in some tropical areas. Purseglove (1988) indicated that onion, among other fresh vegetables, has a relatively high food value, intermediate in protein content but rich in calcium and riboflavin. Harvested mature onion contains 86 per cent water, 1.4 per cent protein and 0.2 per cent fat, and carbohydrates are principally in the form of sugar. Yayock *et* *al*. (1988) reported that the crop has a place in traditional medicine. Onion is useful in treating fever, catarrh, dropsy and chronic bronchitis (Rai & Yadav, 2005). In Ghana, commercial onion production occurs in the Northern and Upper regions particularly around Bawku East, Bawku West and in Bolgatanga. Production on small scale also occurs around urban and peri-urban areas. Soil infertility in onion growing areas in Ghana has become a problem in Northern Ghana, and growers are seriously concerned about declining yield per unit area of production. Few farmers, in trying to improve upon the nutrient status of the soil, rely on chemical fertilizers. Yields of about 15-25 t ha^{-1} of the crop are obtained in the Upper regions of Ghana as compared to the yield level of about 60-80 t ha^{-1} (local cultivars) or 100 t ha^{-1} (exotic varieties) in Niger (Norman, 1992). Ghana imports onion from other neighbouring countries because of the existing low productivity of the crop in the country.

It has been established that onion responds well to the application of organic and inorganic fertilizers (Tweneboah, 2000). Nitrogen deficiency causes a reduction not only in bulb sizes but also in marketable yield. Phosphorus deficiency may also result in stunted growth, and plants tend to have small root systems. Such plants are less efficient in accessing soil for uptake of nutrients. It has been established that onion takes up potassium in quantities nearly equivalent to nitrogen (Pire *et al*. 2001). According to Brewster (1994), potassium requirement of onion increases with yield and its functions are linked to photosynthesis. In onion, potassium deficiency results in stunted growth, susceptibility to diseases and reduced yield. Onions produce good yield when 60-120 kg ha^{-1} of nitrogen, 60-70 kg ha^{-1} of phosphoric acid and 110-135 kg ha^{-1} of potash are applied to the soil.

In plant production, depth of planting is another important factor to be considered in order to obtain good yield. Poor establishment occurs when the planting depth is too deep (Markley, 1950). Chapman & Cartar (1976) stated that emergence decreases markedly if plants are sown deeper than 5 cm. According to Upfold & Olechowski (1994), deep planting exposes plants to greater risk of damage by soil-borne pathogens than shallow planting. However, in geophytic crops, plants must be planted 8 -10 cm deep (Rattan, 1995). The need to determine the optimum fertilizer requirement and the depth of planting onion bulb has been felt over the years, because available literature in this area of study indicates that not much work has been done in the study area. Planting onion bulbs at the right depth and applying fertilizer at optimum rate will result in increases in yield of the crop. The study was, therefore, conducted to investigate the response of onion to planting depth, and the rate of NPK fertilizer application in the Guinea savanna zone of Ghana.

Materials and methods

Site description

The study was conducted at the research farm of the Agronomy Department of the University for Development Studies in Nyankpala, Ghana from July to October 2011, and repeated on a different field but within the same community and geographical location from July to October 2012. The area lies within the interior Guinea savanna of Ghana which falls on latitude 9˚ 25`

141``, longitude 0˚ 58` 142`` and at an altitude of 183 m above sea level (Lawson *et al*., 2008). The relative humidity of the area greatly increases during the rainy season to a maximum monthly value of 87 per cent in September and minimum monthly value of 44 per cent in January. The climatic conditions which prevailed within the period of study are shown in Table 1. The area is characterised with natural vegetation dominated by grasses with few shrubs. The area has an average minimum temperate of 25 ˚C and maximum average temperature of 35 ˚C with total annual rainfall of about 1022 mm (Lawson *et al*., 2013). The soil was derived from Voltaian sandstone and classified as Nyankpala series (Plinthic Acrisol; FAO, 1988). Soil physical and chemical properties of the experimental sites for the 2 years were not significantly different, and the mean values for the 2 years are summed up in Table 2.

Table 1

Meteorological Data for the Experimental Area During the Study Period.

Yr	*Total monthly rainfall (mm)*	*Rainy days*	*Mean monthly max. temp. (°C)*	*Mean monthly min. temp. (°C)*
2011				
Jul	145.7	8	34.4	25.6
Aug	254.8	14	33.6	26.4
Sep	210.1	14	32.5	24.3
Oct	102.4	8	34.2	25.5
2012				
Jul	198.8	13	33.8	25.2
Aug	77.0	6	35.3	26.7
Sep	209.1	13	32.2	24.6
Oct	151.3	13	34.4	25.4

Source: CSIR – SARI, Nyankpala Station.

Table 2

Some Physical and Chemical Properties of the Soil at the Experimental Site

Soil property	*Value*
Sand (%)	51.10
Silt (%)	43.60
Clay (%)	5.30
*p*H	5.06
Organic carbon (%)	0.81
Available nitrogen (%)	0.13
Available phosphorus (mg kg^{-1})	2.91
Potassium (mg kg^{-1})	8.90
CEC (cmol kg^{-1})	2.88

Land preparation, pre-planting treatment and planting of bulbs

Stumps and old pegs as well as fresh grasses were removed using hand fork. Decomposed plant parts were mixed into the soil to serve as organic matter before raising the beds. About one-third of the top of each bulb was cut before placing them in well decomposed sawdust. This was kept for 3 days to allow pre-sprouting of the bulbs to occur before planting. The experimental area of 10.2 m × 3.9 m was measured out after ploughing and harrowing. The beds were raised at 0.30 m high and 0.3 m × 0.75 m using hoe, tape measure, pegs and garden line. In all, four replications were considered, and each had a dimension of 8.19 m^2. The area per plot was 0.225 m^2 and the spacing between blocks and plots were 0.6 m and 0.3 m, respectively. NPK fertilizer (15:15:15) at the rates of 85, 170 and 255 kg ha^{-1} were applied at planting using the banding method of fertilizer application. Plots that received no fertilizer application (0 kg ha^{-1}) were considered as control. The fertilizer application was repeated 2 weeks after planting. The onion bulbs (average fresh weight of 24 g) were planted 2, 4 and 6 cm deep from the soil surface but some were also placed on soil surface (0 cm) to serve as control. The levels of the two factors were combined and replicated in randomized complete block design.

Data collection and statistical analysis

Data were collected on the following parameters: plant height (measured from the base of the plant to the tip of the tallest leaf), leaf length (measured from the base to the tip of the tagged leaves) and number of leaves. At harvest, number of tillers (sprouts) per plant, number of bulbs per plant, bulb size (bulb diameter for the widest point from one side to the other) and bulb fresh weight were also recorded. Data collected were subjected to analysis of variance (ANOVA) using Genstat (Discovery Edition) statistical software and LSD at five per cent was used to separate the treatment means.

Results

The interactions between seasons (2 years) and any of the factors considered in the study for the various parameters measured were not significant.

Leaf number

Table 3 shows the number of leaves recorded. Leaf number significantly differed among levels of NPK fertilizer application and planting depth. Significant interactions between the two factors were also observed. Leaf number generally decreased with increases in rates of fertilizer application. Leaf number also increased from a planting depth of 0 to 2 cm, but decreased later from the planting depth of 2 to 6 cm. Bulbs planted 2 cm deep, which received no NPK fertilizer application produced the highest number of leaves (Tables 3ab), whilst those planted 4 cm deep but fertilized with 255 kg ha^{-1} of NPK recorded the least number of leaves (Tables 3ab).

Plant height

Plant height (Tables 4ab) did not vary significantly among the levels of planting depth and fertilizer application, and no significant interactions were also observed.

Leaf length

Like plant height, leaf length did not significantly differ among the levels of the two factors considered (Tables 5ab).

Tiller (sprout) and bulb numbers

Tiller and bulb number varied significantly among planting depths and levels of NPK fertilizer application. Significant NPK × planting depth interactions were also observed. In general, as the rate of application of NPK fertilizer increased, tiller and bulb numbers significantly decreased (Tables 6ab). Plants planted 2 cm deep recorded significantly higher values of tiller and bulb numbers than those placed on the soil surface (0cm). Bulbs planted 4 cm deep which were not fertilized with NPK produced the highest number of tillers, whilst bulbs placed on the soil surface but fertilized with 255 kg ha^{-1} recorded the least tiller number (Table 6a). Similarly, bulbs which were planted 2 cm deep but received no fertilizer application produced the highest number of bulbs whilst those planted 6 cm deep and fertilized with 170 kg ha^{-1} of NPK produced the least number of bulbs at harvest (Table 6b).

TABLE 3

Effects of Planting Depth and NPK Fertilizer Application on Leaf Number of Onion:

(a) at 6 weeks after planting

	Depth of planting (cm)				
Levels of NPK (kg ha^{-1})	*0*	*2*	*4*	*6*	*Mean*
0	22.60	23.05	19.60	17.10	20.59
85	19.40	18.15	16.05	15.10	17.18
170	14.15	17.10	14.80	15.45	15.38
255	12.70	15.80	11.75	16.98	14.31
Mean	17.21	18.53	15.55	16.16	

CV (%) = 18.7; LSD (0.05): NPK = 1.42; planting depth = 1.25; NPK × planting depth = 1.48

(b) at 8 weeks after planting

	Depth of planting (cm)				
Levels of NPK (kg ha^{-1})	*0*	*2*	*4*	*6*	*Mean*
0	20.00	20.15	16.80	14.90	17.96
85	16.80	15.50	13.90	12.55	14.69
170	11.35	13.65	11.70	13.25	12.49
255	9.55	12.15	8.40	14.55	11.16
Mean	14.43	15.36	12.70	13.81	

CV(%) = 21.5; LSD = 0.05; NPK = 1.12; Planting depth = 0.87; NPK × Planting depth = 1.31.

Bulb size, cluster weight and fresh weight at harvest

Table 7 shows values for bulb size, cluster weight and fresh weight at harvest which differed significantly among planting depths and fertilizer applications. Significant interactions were also observed (Tables 7ab). Bulb size was significantly higher following the application of 85 kg ha^{-1} of NPK as compared to the control (0 kg ha^{-1}). Fertilizer application beyond the 85 kg ha^{-1} of NPK resulted in a decrease in bulb size. Similarly, increasing planting depth from 0 to 2 cm significantly increased bulb sizes. In general, beyond 2 cm, the deeper the depth of planting, the smaller the bulb size at harvest. The highest bulb size was recorded by plants planted 2 cm deep which received 85 kg ha^{-1} of NPK; but bulbs planted 4 cm deep that received 255 kg ha^{-1} of NPK gave the lowest bulb size at harvest (Table 7a).

Cluster weight of bulbs, that is, the total weight of the bulbs from one stand before separation into individual bulbs, increased significantly from 0 to 85 kg ha^{-1} of NPK application in all planting depths. From 85 to 255 kg ha^{-1} of NPK application, cluster weight of bulbs decreased (Table 7b). Clus-

Table 4

Effects of Planting Depth and NPK Fertilizer Application on Plant Height (cm) of Onion

(a) at 6 weeks after planting

	Depth of planting (cm)				
Levels of NPK (kg ha^{-1})	*0*	*2*	*4*	*6*	*Mean*
0	36.78	36.81	37.23	37.13	36.99
85	36.98	36.99	37.09	37.06	37.0
170	36.83	36.88	37.02	37.01	36.93
255	37.01	36.83	36.87	36.85	36.89
Mean	36.90	36.88	37.05	37.01	

CV (%) = 0.40; LSD = 0.05; NPK = 0.21; Planting depth = 0.20; NPK × Planting depth = 1.23

(b) at 8 weeks after planting

	Depth of planting (cm)				
Levels of NPK (kg ha^{-1})	*0*	*2*	*4*	*6*	*Mean*
0	38.34	38.40	38.73	38.98	38.61
85	38.49	38.52	38.61	38.61	38.56
170	38.51	38.38	38.52	38.73	38.53
255	38.55	38.39	38.46	38.42	38.45
Mean	38.47	38.42	38.58	38.68	

CV (%) = 21.5; LSD (0.05): NPK = 0.20; planting depth = 0.21; NPK × planting depth = 1.21

ter weight of bulbs increased from 0 to 2 or 4 cm deep, but decreased significantly as the planting depth increased to 6 cm. Plants planted 4 cm deep and fertilized with 85 kg of NPK per hectare produced the highest cluster weight, whilst those from the same planting depth which received 255 kg ha^{-1} recorded the lowest cluster weight at harvest.

Like bulb cluster weight, the highest value of bulb fresh weight at harvest was recorded by plants planted 4 cm deep that were fertilized with 85 kg ha^{-1} of NPK, whilst the lowest bulb fresh weight was recorded when plants were planted 6 cm deep and fertilized with 255 kg ha^{-1} (Table 7c).

Discussion

Leaf production decreased with increases in planting depth. This observation is in accordance with the earlier finding of Galil (1961) that bulbs, like many other geophytes, struggle in their natural habitat to maintain their required depth in the soil, and by so doing, a number of their characteristics are affected. An earlier study on ornamental geophytes (Addai *et al*., 2011) revealed that when bulbs are planted in the

TABLE 5

Effects of Planting Depth and NPK Fertilizer Application on Leaf Length (cm) of Onion:

(a) at 6 weeks after planting

	Depth of planting (cm)				
Levels of NPK (kg ha^{-1})	*0*	*2*	*4*	*6*	*Mean*
0	30.12	30.24	30.13	30.30	30.20
85	30.13	30.21	30.17	30.19	30.17
170	30.13	30.21	29.99	30.24	30.14
255	30.16	30.19	30.14	30.07	30.14
Mean	30.13	30.21	30.10	30.20	

CV (%) = 18.7; LSD = 0.05; NPK = 0.11; Planting depth = 0.09; NPK × Planting depth = 0.20

(b) at 8 weeks after planting

	Depth of planting (cm)				
Levels of NPK (kg ha^{-1})	*0*	*2*	*4*	*6*	*Mean*
0	30.70	30.98	30.82	30.99	30.87
85	30.77	30.98	30.96	30.94	30.91
170	30.87	30.82	30.87	30.94	30.87
255	30.88	30.86	30.88	30.90	30.88
Mean	30.80	30.91	30.88	30.94	

CV (%) = 21.5; LSD = 0.05; NPK = 0.12; Planting depth = 0.10; NPK × Planting depth = 0.21

soil, they generally expend most of their reserved carbohydrates to pushing their shoots upwards so as to emerge from the soil. Bulbs depend on their reserved carbohydrates for growth and development during the initial stages of their growth (Miller, 1992; Theron & Jacobs, 1996). Also, deep planted bulbs expend more of the reserves stored in their bulbs scales than shallow planted bulbs during sprouting (Addai & Scott, 2011).

It is expected that in the study, the number of leaves produced decreased with increases in depth of planting. The study, however, revealed that from 6 to 8 weeks after planting, the number of leaves decreased. The decline in number of leaves during this period of growth may be attributed to the onset of bulbing which normally occurs between 7 and 11 weeks after planting (Ibrahim, 2010). The time of bulbing is the most critical stage in the life of onion, and during this time, the crop attains maximum leaf production and plant height. Rey *et al*. (1974) reported that at the start of bulbing, some onion leaves desiccate and the production of new leaves almost ceases. Results of the study indicated that, bulbs planted 2 cm deep which received no NPK fertilizer application produced the

TABLE 6

Effects of Planting Depth and NPK Fertilizer Application on Average Tiller and Bulb Number of Onion

(a) Tiller number

Levels of NPK (kg ha^{-1})	Depth of planting (cm) 0	2	4	6	Mean
0	5.03	5.80	6.45	5.55	5.71
85	5.04	5.95	5.30	4.75	5.26
170	4.30	5.55	4.70	5.00	4.88
255	3.70	4.70	4.05	5.55	4.50
Mean	4.52	5.50	5.12	5.21	

LSD = 0.05; NPK = 0.60; Planting depth = 0.41; NPK × Planting depth = 1.50

(a) Bulb number

Levels of NPK (kg ha^{-1})	Depth of planting (cm) 0	2	4	6	Mean
0	5.70	6.30	5.05	4.10	5.28
85	4.85	5.00	4.65	4.15	4.66
170	3.83	3.90	3.60	2.90	3.55
255	3.65	4.68	3.15	4.00	3.87
Mean	4.51	4.97	4.11	3.78	

LSD = 0.05; NPK = 0.44; Planting depth = 0.36; NPK × Planting depth = 1.41

highest number of leaves, followed by those from the same planting regime that were fertilized with 85 kg ha^{-1} of NPK. However, the application of 255 kg ha^{-1} of NPK seemed to have enhanced leaf production when bulbs were planted 6 cm deep. The observation made here probably suggests that, good vegetative growth in onion is enhanced when little or no fertilizer application is made, and also when bulbs are planted shallow (2 cm).

In the study, tiller numbers decreased with increasing planting depth above 2 cm. Since each tiller is capable of producing one or more bulbs, the number of bulbs observed had a similar pattern as the number of tillers produced. Bulb size, fresh weight and cluster weight at harvest increased from 0 to 85 kg ha^{-1} of NPK application. This implies that adding NPK fertilizer to the soil resulted in higher bulb yield at harvest. In bulbs, the developing plants cannot photosynthesize because they lack mature and true photosynthetic leaves. During sprouting and the time of initial growth stages of bulbs, reserved carbohydrates stored in the scales decreased, because the developing plant make use of these nutrients as a source of energy to sprout and grow (Theron

TABLE 7

Effects of Planting Depth and NPK Fertilizer Application on Bulb Size (cm), bulb Cluster Weight (g) and Bulb Fresh Weight (g) of Onion at Harvest

(a) Bulb size (cm)

Levels of NPK (kg ha^{-1})	*Depth of planting (cm)* 0	2	4	6	*Mean*
0	2.52	2.73	2.49	2.63	2.59
85	2.61	3.88	3.67	3.47	3.40
170	1.91	2.12	1.97	1.92	1.98
255	1.85	1.68	1.52	1.56	1.65
Mean	2.22	2.60	2.41	2.39	

LSD = 0.05; NPK = 0.18; Planting depth = 0.23; NPK × Planting depth = 0.36

(b) Bulb cluster weight (g)

Levels of NPK (kg ha^{-1})	*Depth of planting (cm)* 0	2	4	6	*Mean*
0	35.29	41.89	39.78	34.85	38.35
85	42.78	44.30	58.05	36.72	45.46
170	18.58	15.96	14.27	14.55	15.84
255	14.31	14.23	9.91	10.65	12.27
Mean	27.74	29.09	30.50	24.19	

LSD = 0.05; NPK = 5.22; Planting depth = 2.31; NPK × Planting depth = 5.62

(c) Bulb average fresh weight (g)

Levels of NPK (kg ha^{-1})	*Depth of planting (cm)* 0	2	4	6	*Mean*
0	5.55	7.70	7.63	7.96	7.21
85	9.30	10.2	13.97	10.23	10.92
170	4.71	3.38	3.87	4.44	4.10
255	2.68	3.93	2.90	2.48	2.99
Mean	5.56	6.30	7.09	6.27	

LSD = 0.05; NPK = 0.58; Planting depth = 0.69; NPK × Planting depth = 1.98

& Jacobs, 1996). Soils at the experimental sites were predominantly sandy with little organic matter content and available nutrients (Table 2). Adding NPK to the soil replenished soil with plant nutrients, and this resulted in better bulb yield as compared to the unfertilized soil (0 kg ha^{-1}). Nasreen *et al* (2007) found that the application of 120 kg ha^{-1} of nitrogen significantly increased the yield of bulbs in their study.

Nagaraju *et al*. (2000) also reported that the application of P and K improved both the number and size of bulbs at harvest. Nitrogen is utilized in enzyme formation which play a major role in many metabolic processes of plants. Phosphorus helps in root development and its deficiency in soil results in reduction in plant growth (McPharlin & Robertson, 1999), whilst K is known to influence yield and photosynthetic processes of plants (Marschner, 1995).

The observed increases in bulb yield of the treated plants (85 kg ha^{-1}) in the study as compared to the untreated plants (0 kg ha^{-1}) were due to the roles played by the nutrient elements (NPK), and possibly the relatively good weather conditions (Table 1) that prevailed during the experimental period. Drost *et al*. (2002) confirmed that the application of nutrients influenced the yield of bulbs. In the study, there were no increases in bulb yield beyond the 85 kg ha^{-1} of NPK, and as the application of NPK exceeded 85 kg ha^{-1}, bulb cluster weight, fresh weight and sizes decreased. Also, the deeper the depth of planting, the lower the bulb cluster weight, fresh weight and sizes of bulbs at harvest. These observations confirm the earlier finding of Galil (1961), that deep planted bulbs use more of their reserved metabolites during sprouting and a number of their characteristics are affected. The results obtained from the study suggested that, in the study area, onion does not require fertilizer application at a rate more than 85 kg ha^{-1} of NPK. This agrees with the observation made by Rahn *et al* (1996) that too much of NPK in soil reduces the growth and yield of bulbs. Batal *et al* (1994) also observed that excessive application of NPK causes bulb decay leading to reductions in yield and quality of marketable bulbs.

Conclusion

The application of 85 kg ha^{-1} of NPK to bulbs planted 4 cm deep produced the highest bulb size or fresh weight at harvest. However, planting 2 cm deep and applying no fertilizer gave the highest bulb yield. Leaf production was highest when bulbs were planted 2 cm deep and no NPK fertilizer application. Tiller production was also highest when bulbs were planted 4 cm deep and no NPK fertilizer application. Whilst NPK fertilizer may not be required for vegetative growth, the application of the fertilizer, especially at 85 kg ha^{-1}, enhances bulb production. Planting onion 4 cm deep and applying NPK fertilizer at the rate of 85 kg ha^{-1} to the soil is recommended for good bulb yield in the study area.

Acknowledgement

The authors are most grateful to the Faculty of Agriculture of the University for Development Studies for providing funds for land preparation prior to planting of the bulbs. Sincere thanks also go to all technicians in the Department of Agronomy of the University for assisting in data collection, weeding and other cultural practices.

REFERENCES

Addai, I. K. & **Scott, P.** (2011) Influence of bulb sizes at planting on growth and development of the common hyacinth and the lily. *Agricultural and biological journal of North America* **2**(2), 298 – 314.

Addai, I. K., Scott, P. & **Takyi, H.** (2011) Influence of planting depth on growth, flower production and bulb yield of the common hyacinth and the lily. *International Research Journal of Applied and Basic Sciences* **2** (7), 272 – 287.

Batal, K. M., Bondari, K., Granberry, D. M., & **Mullinix, B. G.** (1994) Effects of source, rate and frequency of N application on yield, marketable grades and rot incidence of sweet onion (*Allium cepa* L. cv. Granex-33). *Journal of Horticultural Science* **69**, 1043 – 1051.

Brewster, J. L. (1994) *Onion and other vegetable Alliums.* CAB International, UK.

Chapman, S. R. & **Carter, L. P.** (1976) *Soybean in crop production principles and practices.* Freeman, San Francisco. pp. 345 – 357.

Drost, D., Koenig, R. & **Tindall, T.** (2002) Nitrogen use efficiency and onion yield increased with a polymer-coated nitrogen source. *HortScience*, **37**, 338 – 342.

FAO (1988) *Soil Map of the World, Revised Legend, Reprinted with corrections. World Soil Resources Report 60*. FAO, Rome.

Galil, J. (1961) *Kinetics of geophytes (bulbs and corms*). Hakkibutz Hameuchad Ltd, Israel .224 pp.

Ibrahim, N. D. (2010) Growth and yield of Onion (*Allium cepa* L.) in Sokoto, Nigeria. *Agric. Biol. J. N. Am.* **1**(4), 556 – 564

Lawson, I. Y. D., Mensah, E. A. & **Yeboah, E. N**. (2008) Improving the establishment and yield of soyabean through planting depth and land preparation. *WAJAE* **14**, 47 – 55.

Lawson, I. Y. D., Issahaku, A., Acheampong, S. K., Adams, B. & **Tuffour, V.** (2013) Time of planting and weed suppression abilities of some legumes intercropped with maize in the Guinea savanna zone of Ghana. *Agric. Biol. J. N. Am.,* **4**(4), 358 – 363.

Markley, J. C. (1950) *Depth of planting small seeds. Soybean production and utilization.* pp. 20 – 36.

Marschner, H. (1995) *Mineral nutrition of higher plants.* 2nd edn. Academic Press, London.

McPharlin, I. R. & **Robertson, W. J.** (1999) Response of onions (*Allium cepa* L.) to phosphate fertilizer placement and residual phosphorus on a Karrakatta sand. *Australian Journal of Experimental Agriculture* **39**, 351 – 359.

Miller, W. B. (1992) A review of carbohydrate metabolism in geophytes. *Acta Hortic* **325**, 239 – 246.

Nagaraju, R., Haripriva, K., Rajalingam, G. V., Sriamachandrasekarn, V. & **Mohideen, M. K.** (2000) Effect of VAM on growth and yield of aggregatum onion (*Allium cepa* L. var. *aggregatum* Don) *South Indian Horticulture* **48**, 40 – 45.

Nasreen, S., Haque, M. M., Hossain, M. A. & **Farid, A. T. M.** (2007) Nutrient uptake and yield of onion as influenced by nitrogen and sulphur fertilization. *Bangladesh J. agric Res.* **32**(3), 413 – 420.

Norman, J. C. (1992) *Tropical vegetable crops.* A. H. Stocwell Ltd, Devon. pp 138 – 148.

Pire, R., Ramirez, H., Riere, J. & **Gomez, de T. N.** (2001) Removal of NPK and Ca by an onion crop (*Allium cepa* L.) in a silty-clay soil in a semi-arid region of Venezuela.*Acts Horticultural.* **555**, 103 – 109.

Purseglove, J. W. (1988) *Tropical crops (monocotyledons*). Longman Group Ltd, Singapore. pp. 39 – 57.

Rahn, C. R., Shepherd, M.A. & **Hiron, R. W. P.** (1996) The effect of water supply on the response of onions and calabres to starter solutions. *Acta Horticulturae* **428**, 141 – 150.

Rai, N. & **Yadav, D. S.** (2005) *Advances in vegetable production***.** Researchco Book Center, New Delhi, India.

Rattan, L. A. (1995) *Seed technology*. Raju-Primlani, Oxford and IBH publishing co. pvt.

Ltd 66 Janpath, New Delhi. pp. 279 – 282.

Rey, C., Stahl, J., Antonin, P. & **Newry, G.** (1974) Stades reperes de l oignon de semis. *Revue Suiss de Viticulture, arboriculture et Horticulture* **6**, 101 – 104.

Sinnadurai, S. (1992) *Vegetable cultivation*. Asempa Publishers. Accra, Ghana. pp. 83 – 90.

Theron, K. I. & **Jacobs, G.** (1996) Changes in carbohydrate composition of the different bulb components of Nerine bowdenii W. Watson (Amaryllidaceae). *J. Am. Soc. Hortic. Sci.* **121**, 343 – 346.

Tindall, H. D. (1983) *Vegetables in the tropics.* Macmillan press Ltd, London. pp. 20 – 23.

Tweneboah, C. K. (2000) *Vegetables and spices in West Africa.* Co-Wood Publishers, Accra, Ghana. pp.148 – 152.

Upfold, R. A. & **Olechowski, H. T.** (1994)*Soybean production.* Ontario, Ministry of Agriculture and Food Publication 173. Queen's printer for Ontario, Toronto. 23 pp.

Ware, G.W., Swaider, J. M. & **McCollum, J. P.** (1992) *Producing vegetable crops*. Intestate publishers, Inc. DevilleIllinois. pp. 318 – 398.

Yayock, J. Y., Lombin, G. & **Owanubi Onazi, O. C.** (1988) *Crop science and production in warm climates*. Macmillan publishers, Hong Kong. pp. 212 – 114.