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Response of Onion (*Allium cepa* L.) to Bulb Size at Planting and NPK 15:15:15 Fertilizer Application Rate in the Guinea Savannah Agroecology of Ghana

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ABSTRACT
Studies were conducted during the 2013 and 2014 cropping seasons at the research field of the University for Development Studies, Nyankpala in the Northern Region of Ghana to determine the effects of bulb size at planting and NPK 15:15:15 application rate on growth and yield of onion. The NPK 15:15:15 was applied at the rate of 0 (control), 80, 165 and 250 kg ha^{-1}. Three different bulb sizes: small (2.5-3.5 cm), medium (4.5-5.5 cm) and large (6.5-8.5 cm) were used. The treatment combinations were laid out in a randomized complete block design with three replications. Leaf length, number of sprouts and leaf number were measured from 1-7 weeks after planting. Also individual bulb fresh weight, cluster bulb fresh weight and number of bulbs were measured at harvest. Results indicated that the plants produced from large bulbs produced the highest vegetative growth whilst those from small bulbs recorded the least growth. The application of 80 kg ha^{-1} of NPK 15:15:15 produced the highest number and fresh weight of bulbs at harvest whilst plants produced from small bulbs fertilized with 250 kg ha^{-1} recorded the least bulb yield at harvest.

Key words: Bulb size at planting, NPK 15:15:15, bulb fresh weight, number of sprouts, leaf growth

INTRODUCTION

Onion (*Allium cepa* L.) is a popular vegetable grown for its bulb and flavoured leaves. It is widely grown throughout the world (Pradeepkumar *et al*., 2008). Tweneboah (2000) reported that onion is a bulbous plant belonging to the family *Alliacea*. Onion has been cultivated for 5000 years or more, but was first grown in Central Asia (Langer and Hill, 1991). Approximately, 170 countries grow onion for its own domestic use and it is also involved in international trade. It is estimated that over 9.2 million acres of onion are harvested annually around the world (National Onion Association, 2011). The leading onion production countries in the world are China, India, United States, Turkey and Pakistan but Egypt, Algeria, Morocco, Nigeria, South Africa and Niger are the leading producers of the crop in Africa (FAOSTAT., 2008). Onion is grown commercially in the Northern and Upper Regions of Ghana, especially around Bawku, Bolgatanga and the Kusasi districts. Other production areas are Ashiama, Dawhenya, Akatsi, Nsawam, Prestsea, Koforidua, Kwahu, Mankessim and the Berekum districts (Obeng-Ofori *et al*., 2007). Norman (1992) stated that a 100 g edible portion of the crop contains energy, 31 g cal; protein, 1.5 g; Fat, 0.6 g; total sugar, 7.2 g; other carbohydrates, 0.3 g; thiamin, 0.04 mg; riboflavin, 0.02 mg; miacin, 0.1 mg; vitamin C, 7 mg; Ca, 30 mg; Fe, 0.5 mg; Mg, 16.5 mg; P, 35 mg; K, 150 mg; and Na 7 mg.

Gopalakrishnan (2007) reported that onion can be planted by raising seedlings for transplanting. Bulbs can also be planted directly in the field or by drilling seeds directly on seed beds. Abdissa *et al*. (2011) also reported that, the application of NPK 15:15:15, significantly increased plant growth in onions. According to Sinnadurai (1992), bulb size at harvest is influenced by the addition of nitrogen, phosphorus and potassium to the soil. But how much of fertilizer should be applied to the soils especially in Northern Ghana to enhance optimum growth and yield of the crop? The yield of onion produced in the country is low and one of the main factors identified to have contributed to the low yield of

the crop especially in Northern Ghana is farmers' inadequate knowledge on the use of right bulb size for optimum growth and bulb yield. Khokhar *et al*. (2001) stated that planting bulbs of suitable size increases the yield of the crop. There is the need to investigate into the effect of bulb size on growth and yield of onion in Northern Ghana. Also, since the most available compound fertilizer in the study area is NPK 15:15:15, there is the need to research into the effect of application rate on growth and yield of onion. It is against this background that the present studies were conducted to determine the appropriate bulb size for planting onion and the optimum rate of application of NPK 15:15:15 fertilizer for onion production in the Northern Region of Ghana.

MATERIALS AND METHODS

Site description: The experiments were conducted during the 2013 and 2014 cropping seasons at the University for Development Studies, Nyankpala, in the Northern Region of Ghana. The experimental site is located on an altitude of 183 m and latitude 09°25' N and longitude 0°58'W. In general, rainfall in the study area is evenly distributed from May to October with a peak in August or September in each year. The total annual rainfall is about 1022 mm. The average minimum temperature is 25°C whilst the maximum average temperature is 35°C (Lawson *et al*., 2013). The area lies within the interior Guinea savannah of Ghana and is characterized with natural vegetation dominated by grasses with few shrubs. The soils of the area are moderately drained and are free from concretions; they are shallow with hardpan under the top few centimeters and were derived from Voltaian sandstone. The soils, according to FAO (1988), are classified as Nyankpala series or Plinthic Acrisol. The area has grassland vegetation and it is interspersed with short trees such as *Parkia biglobosa* and *Azadirachta indica* and weed species such as *Centrosema pubescens*, *Cyperus difformis* and *Striga hermontheca*. Soil physical and chemical properties and weather conditions during experimentation for the two years were not significantly different and the mean values for the two years are as shown in Table 1 and 2.

Table 1: Meteorological data for the experimental area during the study period

Time	Total monthly rainfall (mm)	Mean monthly max. Temp. (°C)	Mean monthly min. Temp. (°C)
2013			
Jul.	143.4	32.3	26.8
Aug.	252.6	34.5	25.3
Sep.	212.3	31.4	23.5
Oct.	104.5	33.2	25.7
2014			
Jul.	195.5	32.6	26.4
Aug.	79.3	34.5	25.5
Sep.	202.6	31.3	23.8
Oct.	148.1	35.6	24.7

Source: Council for Scientific and Industrial Research (CSIR)-SARI, Nyankpala

Table 2: Some physical and chemical properties of the soil at the experimental site

Soil property	Value
Sand (%)	52.20
Silt (%)	43.40
Clay (%)	4.40
pH	5.04
Organic carbon (%)	0.78
Available nitrogen (%)	0.14
Available phosphorus (mg kg^{-1})	2.81
Potassium (mg kg^{-1})	8.60
CEC (cmol kg^{-1})	2.78

Land preparation and experimental design: The field was prepared using cutlass and hoe after ploughing. The experimental area of 23.5×5 m was measured out using a tape measure, garden line and pegs. Decomposed plant parts were mixed into the soil to serve as organic matter. Beds were raised at 0.3 m high and 1.5×1 m. The bulbs used for the studies were obtained from Tamale Central Market and were categorized into three different bulb sizes: small (2.5-3.5 cm), medium (4.5-5.5 cm) and large (6.5-8.5 cm). The NPK 15:15:15 fertilizer bought from Wunpini Agro chemicals in Tamale, Ghana were applied at 0, 80, 165 and 250 kg ha^{-1} one week after planting. The treatment combinations were replicated three times in Randomised Complete Block Design (RCBD). The total land area for the study in each season was 117.5 m^2 with a block size of 23.5 m^2 and area per plot being 1.5 m^2. The spacing between the blocks was 1 m and that within the blocks was 0.5 m.

Planting and cultural practices: The bulbs were directly planted on the field. About one-third of the top of each bulb was cut off before planting. Six bulbs were planted on each bed at a depth of 4 cm. Weeding was done every two weeks to prevent weeds from competing with the crops for nutrients and water. Beds were occasionally loosened using hand fork to ensure easy penetration of bulbs. Occasional watering was also done when the soil became dry. To prevent the problems of bacterial diseases, thrips, onion maggot, cutworms and wireworms infestation, planting was not done in the same soil where other *Alliums* had been grown in recent years. Also clean, healthy bulbs were used for planting.

Data collection: For the two years: 2013 and 2014, vegetative growth data were collected from 2-7 weeks after planting. Plant height was measured as the height from the level of the soil to the tip of the highest leaf. Leaf length was measured as the length of the leaf from the base to the tip of the leaf. Number of leaves per plant was taken by counting all leaves on each tagged plant. The number of sprouts per plant was taken by counting all the sprouts formed by the plant. At harvest, number of bulbs was recorded by counting all the bulbs formed by each plant. Each bulb in a cluster was also weighed using an electronic balance and recorded as fresh cluster bulb weight. Averages were computed for the two data sets for 2013 and 2014 and were subjected to the analysis of

variance using GenStat (Discovery Edition), where significant differences were observed among treatments, LSD (5%) was used to separate the treatment means.

RESULTS

Leaf length: The highest leaf length was recorded at 4 weeks after planting. Figure 1a shows the response in leaf growth of plants when no fertilizer was applied. Plants from the various bulb sizes increased in leaf length from week one to week four and then decreased from week four to week seven after planting. Plants produced from the large and medium bulbs recorded the highest leaf length while plants from the small bulb recorded the lowest leaf length (25.8 cm). When 80 kg ha^{-1} of NPK 15:15:15 was applied (Fig. 1b). Plants from the large bulb recorded the highest leaf length of 36.7 cm at 4 weeks after planting, followed by those from the medium bulb of 34.1 cm, while plants from the small bulb recorded the lowest leaf length of 28.8 cm.

Following the application of 165 kg ha^{-1}, plants from the large bulb recorded the highest leaf length of 32.9 cm at four weeks after planting, followed by those from the medium bulb of 30.1 cm, though the two bulb sizes (large and medium) did not significantly differ, while plants from the small bulb recorded the lowest leaf length of 25.1 cm. Plants from both large and medium bulb sizes recorded similar leaf length from week two to week seven after planting (Fig. 1c).

Following the application of NPK 15:15:15 at 250 kg ha^{-1}, plants from large and medium bulb sizes recorded the same leaf length of 31.9 cm at 4 weeks after planting while plants from the small bulb size recorded the lowest leaf length (27.9 cm). At 7 weeks after planting, however, plants produced from large bulb recorded the highest leaf length whilst those from the medium bulbs recorded the least length (Fig. 1d).

Number of leaves per plant: Plants produced from the large bulb recorded the highest number of leaves while those from the small bulb recorded the lowest number of leaves when no fertilizer was applied (Fig. 2a). But following the application of NPK 15:15:15 at 80 kg ha^{-1} (Fig. 2b) plants from the large bulb again recorded the highest leaf number of 44 at four weeks after planting, followed by those from the medium bulb (39 leaves), while plants from the small bulb recorded the lowest leaf number (19 leaves).

When 165 kg ha^{-1} of NPK 15:15:15 was applied, plants from the large bulb recorded the highest number of leaves of 59 at four weeks after planting, followed by those from the medium bulb (48 leaves) though the two bulb sizes did not differ significantly, while plants from the small bulb recorded the lowest number of leaves of 18 (Fig. 2c). At 25 kg ha^{-1} of NPK 15:15:15, plants produced from the large bulb had the highest number of leaves of 53 at four weeks after planting, followed by plants from the medium bulb (42 leaves), while those from the small bulb had the lowest number of leaves of 19 (Fig. 2d).

Number of sprouts: At four weeks after planting, unfertilized plants from the large bulb recorded the highest number of sprouts of 14, followed by those from the medium bulb (8 sprouts), while those from the small bulb recorded the lowest of 5 sprouts (Fig. 3a). Figure 3b shows the distribution of number of sprouts formed following the application of NPK 15:15:15 at 80 kg ha^{-1}. Plants from both the large and medium bulb sizes had similar sprout number while plants from the small bulb recorded the least and differed from the large and the medium bulbs throughout the growth period (Fig. 3b).

When 165 kg ha^{-1} of NPK 15:15:15 was applied (Fig. 3c) plants from the large bulb recorded the highest sprout number of 10 at four weeks after planting, followed by medium bulb (9 sprouts) and small bulb (5 sprouts). At 250 kg ha^{-1} of NPK 15:15:15 (Fig. 3d) plants from the large bulb had the highest sprout number of 11 at four weeks after planting, followed by those from the medium bulb (10 sprouts) whilst plants from the small bulb had the lowest sprout number throughout the season.

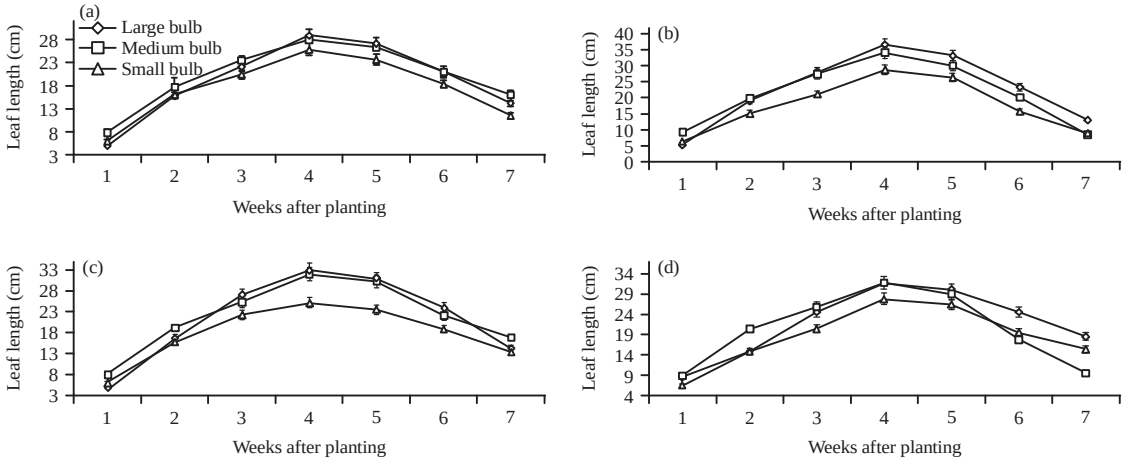

Fig. 1(a-d): Effect of bulb size at planting on leaf length for the control treatment, (a) 0, (b) 80, (c) 165 and (d) 250 kg ha^{-1} of NPK). Bars represent Mean±SE of 3 replicates

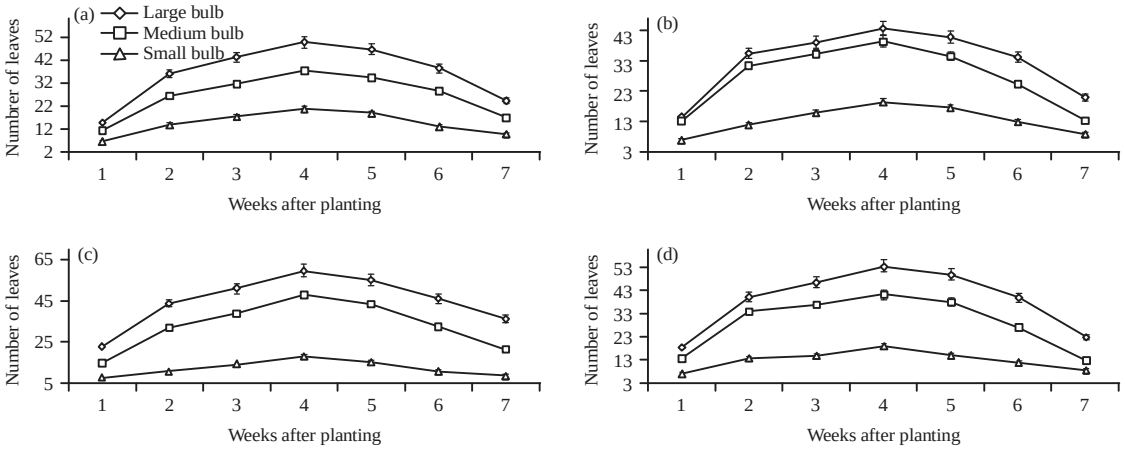

Fig. 2(a-d): Effect of bulb size at planting on number of leaves for the control, (a) 0, (b) 80, (c) 165 and (d) 250 kg ha^{-1} of NPK. Bars represent Mean±SE of 3 replicates

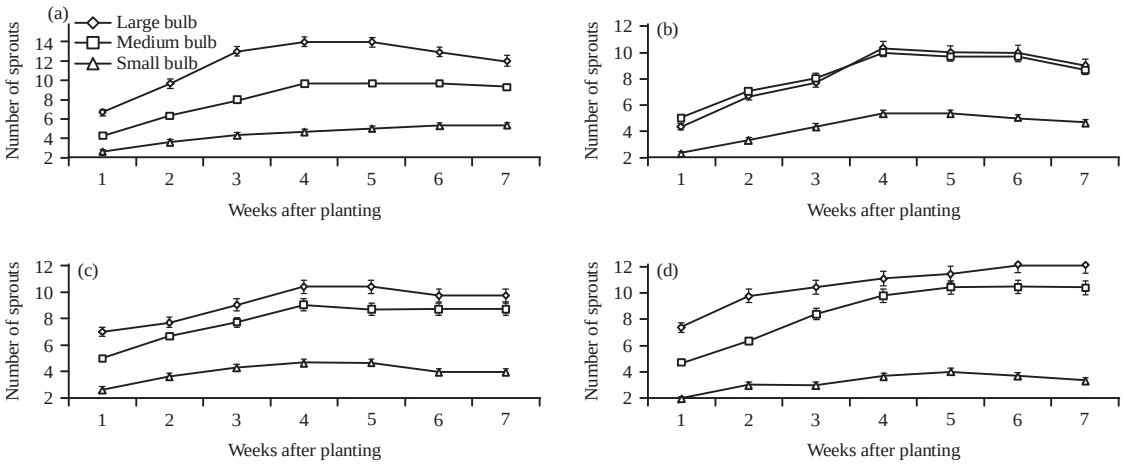

Fig. 3(a-d): Effect of bulb size at planting on number of sprouts for the control, (a) 0, (b) 80, (c) 165 and (d) 250 kg ha^{-1} of NPK. Bars represent Mean±SE of 3 replicates

Table 3: Effect of bulb size at planting and NPK 15:15:15 application on cluster bulb weight (g)

NPK levels (kg ha^{-1})	Bulb sizes (cm) Small	Medium	Large	Mean
0	30.00	61.80	87.20	59.67
80	38.10	76.50	130.40	81.67
165	25.10	87.80	58.00	56.97
250	21.50	75.30	83.40	60.07
Mean	28.68	75.35	89.75	

LSD (0.05): NPK 15:15:15 = 30.97, Bulb size = 26.82, NPK 15:15:15× Bulb = 53.64

Table 4: Effect of bulb size at planting and NPK 15:15:15 application on individual bulb weight (g)

NPK levels (kg ha^{-1})	Bulb sizes (cm) Small	Medium	Large	Mean
0	8.20	6.80	6.77	7.26
80	6.53	8.23	10.60	8.45
165	4.43	10.03	6.87	7.11
250	4.30	4.87	4.60	4.59
Mean	5.87	7.48	7.21	

LSD (0.05): NPK 15:15:15 = 2.41, Bulb size = 2.09, NPK 15:15:15×Bulb size = 4.18

Cluster bulb weight: Table 3 shows that the main effect of bulb size significantly ($p<0.05$) affected cluster bulb weight but the single effects of NPK 15:15:15 application rate did not significantly ($p>0.05$) affect this parameter. Plants treated with 80 kg ha^{-1} of NPK 15:15:15 from large bulbs recorded the highest cluster bulb weight whiles those from 250 kg ha^{-1} of small bulbs recorded the lowest cluster bulb weight.

Bulb fresh weight and number at harvest: Bulb size did not show any significant ($p>0.05$) difference for this parameter but there was significant difference among the levels of NPK 15:15:15 (Table 4). Plants produced from large bulbs fertilized with 80 kg ha^{-1} of the fertilizer recorded the highest individual bulb weight while those produced from small bulbs and fertilized with 250 kg ha^{-1} of NPK 15:15:15 recorded the

Table 5: Effect of bulb size at planting and NPK 15:15:15 fertilizer application on bulb number

NPK levels (kg ha^{-1})	Bulb sizes (cm)			
	Small	Medium	Large	Mean
0	4.67	9.33	13.00	9.00
80	5.67	9.33	12.67	9.22
165	6.00	11.00	12.33	9.78
250	4.00	15.67	17.33	12.33
Mean	5.08	11.33	13.83	

LSD (0.05): NPK 15:15:15 = 5.65, Bulb size = 4.89, NPK 15:15:15×Bulb size = 9.79

lowest individual bulb weight. But the application of 250 kg ha^{-1} of the fertilizer did not show any significant ($p>0.05$) difference among the means for the single effects of NPK 15:15:15. However, there was significant difference among the bulb sizes. The application of 250 kg ha^{-1} of NPK 15:15:15 to the large bulbs recorded the highest bulb number while unfertilized plants from the small bulbs recorded the lowest bulb number (Table 5).

DISCUSSION

The large bulb generally produced the highest vegetative growth followed by the medium and small bulb sizes, respectively. Large bulbs contain more carbohydrates and other food reserves than medium and small bulbs (Addai and Scott, 2011). The data agrees with the findings made by Tsitsia (2012). According to him, large bulbs produced higher plant height and leaf length than medium and small bulbs, but Fuseini (2012) reported that medium bulb produced the highest vegetative growth than large and small bulbs. In the present study, plants generally treated with 80 kg ha^{-1} of NPK 15:15:15 especially from large bulbs produced higher leaf growth and leaf numbers and these resulted in higher bulb yield than those fertilized with 165 and 250 kg ha^{-1}. The increase in bulb yield generally in the form of number of bulbs and bulb fresh weight at harvest might be as a result of increases in the photosynthetic apparatus which might have enhanced high assimilate production with the concomitant effect of food reserve accumulation in the bulbs. Fuseini (2012) observed that 170 kg ha^{-1} of NPK 15:15:15 produced higher leaf growth than 80 kg ha^{-1}. The reduced leaf growth of plants treated with 250 kg ha^{-1} relative to those fertilized with 80 kg ha^{-1} in this study might be as a result of excessive use of the amount of the macronutrients required for growth. In general over application of NPK hinders growth and development of bulb (Rahn *et al*., 1996). It has also been reported that, application of N beyond 84 kg ha^{-1} will not increase crop yield (Wiedenfeld, 1994). The increased in number of leaves was directly related with the number of sprouts, thus confirming what Tsitsia (2012) reported. In the present study the application of NPK increased leaf number and this confirmed the statement made by Abdissa *et al*. (2011) that NPK application increased the number of leaves per plant of crops.

Bulb size influenced cluster bulb weight, individual bulb weight and number of bulbs per plant at harvest. Plants from the large bulb produce the highest number of bulbs and this might be due to their increased number of leaves. The higher the sprout number, the higher the number of leaves and bulb number. According to Iannotti (2008) the higher the number of leaves, the higher the number of bulbs produced at harvest and this result also confirms the observation made by Perez *et al*. (1996). Fuseini (2012), however, indicated that medium bulbs produced more bulbs. The application of 250 kg ha^{-1} to plants produced the highest bulb number relative to the other levels of the fertilizer application and this is probably due to the high level of phosphorus made available in the soil. Nagaraju *et al*. (2000) reported that the higher the soil p level, the higher the bulb number produced at harvest.

CONCLUSION

Results from the study revealed that large bulb size (6.5-8.5 cm) produced the highest vegetative growth and bulb yield at harvest whilst small bulbs size (2.5-3.5 cm) generally produced the least of these quantities. The NPK 15:15:15 at 80 kg ha^{-1} generally produced higher bulb yield and any application rate of the fertilizer beyond this rate resulted in reduced bulb yield in the present study. The study recommends the use bulbs of size ranging from 6.5-8.5 cm for cultivation by onion growers in the study area and 80 kg ha^{-1} of NPK 15:15:15 should be applied for optimum growth and bulb yield.

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