Preliminary studies on the effects of bulb size at planting and NPK fertilizer application on growth and yield of shallot (*Allium cepa* var. *aggregatum* L.)

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ABSTRACT

Studies were carried out at the University for Development Studies, Nyankpala, Ghana from July to September 2012 to determine the effects of bulb size at planting, and NPK fertilizer application on growth and yield of shallot. Small, medium and big bulbs of diameter 0.8 – 1.2 cm, 1.3 – 1.5 cm and 1.6 – 2 cm, respectively, were planted on the field. Two weeks after planting, NPK (15-15-15) fertilizer was applied at 0, 85, 170 or 255 kg ha^{-1}. Treatment combinations were replicated three times in a randomized complete block design. Results of the study showed that planting large bulbs and applying no NPK fertilizer produced the highest leaf number, whilst the use of small bulb followed by an application of 85 or 170 kg ha^{-1} of NPK produced the least leaf number of leaves. The use of big bulbs at planting together with the application of 85 kg ha^{-1} of NPK gave the highest number of bulbs, whilst medium bulbs which received 255 kg ha^{-1} of NPK gave the least number of bulbs at harvest. Similarly, the application of 85 kg ha^{-1} of NPK to big bulbs gave the highest bulb fresh weight, whilst small bulbs which received no NPK application recorded the least bulb weight at harvest. In terms of bulb yield at harvest, the medium bulb also responded well to the application of 85 kg ha^{-1} of NPK fertilizer. In shallot production, especially in the study area, farmers should use big bulbs during planting and 85 kg ha^{-1} of NPK fertilizer should be applied for optimum bulb yield and vegetative growth.

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Introduction

Shallot, *Allium cepa* var. *aggregatum* L., is a seasonal crop of the family liliaceae and is related to onions, garlic and leeks (Tweneboah, 2000). Varieties of shallots differ in days of maturity, colour, bulb size, as well as many other agronomic traits. Shallot is an annual crop that produces several bulbs or bulbils around the base of a single plant. The plant produces clusters of bulbs from three to 20 bulbs per plant, and has an ideal marketable size of about 30 – 40 mm in diameter (Brewster & Butler, 1989, Krontal *et al*., 2000). The crop is cultivated in Ghana on commercial basis in areas such as Anloga, Berekum, Keta and Saltpond, employing about thousands of people in these areas (MoFA, 2003). Shallot bulbs are used as flavour and appetizers in the preparation of soups and stews at homes, and restaurants.

Most farmers who are involved in the cultivation of shallot are faced with the problem of selecting the right bulb size for planting in order to get optimum yield. Messiaen *et al.* (1994) reported that planting large bulbs produced many small bulbs, whilst planting small bulbs produced large bulbs but in small quantities. Earlier study on ornamental flower bulbs had reported that larger bulbs generally have greater amount of carbohydrate reserves stored in the bulb and, therefore, produced better yield than small bulbs (Addai & Scott, 2011). However, Mollah *et al.* (1997) observed that using medium bulb for planting resulted in better seed yield. Though shallot responds well to nutrient application (Sinnadurai, 1992), some of the farmers in the country do not use chemical fertilizers during the cultivation of the crop, because either these farmers cannot afford the cost of fertilizers or that they have limited knowledge about the rate of application of the fertilizers.

Under sub-optimal supply of nutrients, shallot can be severely stunted, with bulb size and marketable yields reduced, whilst too much of some nutrients, for instance nitrogen, can result in excessive vegetative growth, delayed maturity and increased susceptibility to diseases (Henriksen & Hansen, 2001; Sørensen & Grevsen, 2001). Similarly, if K is deficient in the soil, shallot is either stunted or become susceptible to diseases, and this may result in reduced yield (Develash & Sugha, 1997; Singh & Verma, 2001). Phosphorus application rates of up to 200 kg ha^{-1} were found to maximize yields and bulb weights (McPharlin & Robertson, 1999). Increased P levels are also known to improve bulb size and the number of marketable bulbs in shallots (Zahara *et al*., 1994; Nagaraju *et al*., 2000). The study was conducted to determine the impact of bulb size at planting and NPK fertilizer application on growth and yield of shallot in the Northern Region of Ghana.

Materials and methods

The study was conducted at the University for Development Studies, in the gardens of the Department of Agronomy located in Nyankpala from July to September 2012.

Planting of bulbs and experimental design

Bulbs were obtained from the CSIR - Crops Research Institute in Kumasi and put into the following arbitrary groups of bulb sizes: Small (0.8 – 1.2 cm in diameter), medium (1.3 – 1.5 cm in diameter) and big (1.6 – 2 cm in diameter). The bulbs were pre-sprouted for 5 days in saw dust, and later planted on the field at a depth of 3 cm from soil surface. Watering was done immediately after planting to ensure proper establishment of the roots. The NPK (15-15-15) fertilizer was applied at 0, 85, 170 or 255 kg ha^{-1} using the banding method of fertilizer application 2 weeks after planting. Levels of the two factors were combined factorially and replicated three times in randomized complete block design.

Data collection and statistical analysis

The following data were collected: Plant height, leaf length and number of leaves. At harvest, number of bulbs per plant and bulb fresh weight were also recorded. Data collected were subjected to the analysis of variance (ANOVA) using Genstat (Discovery Edition) and LSD was used to separate the treatment means.

Results

Number of leaves

Number of leaves (Table 1) significantly varied among bulb sizes. Variations with respect to number of leaves among the levels of applied NPK were also significant. Leaf numbers increased with increases in bulb size at planting. Leaf number, however, decreased with increasing rate of the fertilizer from 0 to 170 kg ha^{-1}. Leaf number also increased from 170 to 255 kg ha^{-1} of NPK (Tables 1ab). In general, the highest number of leaves were obtained by planting big bulb size without fertilizer application, whilst planting small bulb size and applying 85 kg ha^{-1} of NPK (Tables 1a) produced the least number of leaves.

Leaf length

Leaf length varied (Table 2) significantly among bulb sizes and NPK fertilizer application. Variation in leaf length with respect to the interaction among the two factors was also significant. The general trend was that as the size of the planted bulbs increased, leaf length also increased. Leaf length decreased with increasing rate of applied fertilizer from 0 to 170 kg ha^{-1} (Tables 2ab). The highest leaf length was recorded when 255 kg ha^{-1} of NPK was applied to big bulbs, whilst the application of 170 kg ha^{-1} to the small bulb produced the least leaf length.

TABLE 1

Effects of Bulb Size at Planting and NPK Fertilizer Application on Leaf Number of Shallot

(a) at 6 weeks after planting

Bulb size at planting	*NPK fertilizer application (kg ha^{-1})*				*Mean*
	0	*85*	*170*	*255*	
Small	17.33	9.67	12.33	13.00	13.08
Medium	20.67	13.00	14.33	11.67	14.92
Big	23.00	16.00	14.67	19.67	18.33
Mean	20.33	12.89	13.78	14.78	

Cv = 8.00; LSD = 0.05: Bulb size = 1.04; NPK = 1.20; Bulb size × NPK = 2.08

(b) at 8 weeks after planting

Bulb size at planting	*NPK fertilizer application (kg ha^{-1})*				*Mean*
	0	*85*	*170*	*255*	
Small	21.00	14.33	16.00	16. 00	16.83
Medium	23.67	16.00	18.00	15.33	18.25
Big	25.67	19.67	18.00	24.00	21 .83
Mean	23.44	16.67	17.33	18.44	

Cv = 4.80; LSD = 0.05: Bulb size = 0.78; NPK = 0.89; Bulb size × NPK = 1.55

TABLE 2

Effects of Bulb Size at Planting and NPK Fertilizer Application on Leaf Length (cm) of Shallot

(a) at 6 weeks after planting

Bulb size at planting	*NPK fertilizer application (kg ha^{-1})*				*Mean*
	0	*85*	*170*	*255*	
Small	13.13	11.20	9.60	12.17	11.53
Medium	11.93	13.70	12.57	10.20	12.10
Big	16.07	14.73	11.67	16.83	14.83
Mean	13.71	13.21	11.28	13.07	

Cv = 5.90; LSD = 0.05: Bulb size = 0.64; NPK = 0.74; Bulb size × NPK = 1.29

(b) at 8 weeks after planting

Bulb size at planting	*NPK fertilizer application (kg ha^{-1})*				*Mean*
	0	*85*	*170*	*255*	
Small	13.93	12.37	10.83	13.17	12.57
Medium	12.83	14.90	13.67	10.93	13.08
Big	17.20	15.87	13.30	17.57	15.98
Mean	14.66	14.38	12.60	13.89	

Cv = 6.80; LSD = 0.05: Bulb size = 0.566; NPK = 0.654; Bulb size × NPK = 1.13

Plant height

Plant height also differed significantly (Table 3ab) among bulb sizes and NPK fertilizer application. The response of plant height to fertilizer application was similar to that of leaf number and leaf length.

Bulb yield at harvest

There was a highly significant difference among bulb sizes in terms of number of bulbs (Table 4). The application of 85 kg ha^{-1} of NPK to the big bulbs produced the highest number of bulbs, whilst the medium bulbs which received 255 kg ha^{-1} of NPK had the least number of bulbs at harvest.

Table 5 shows the mean (from three bulbs) fresh weight of bulbs at harvest when the three bulb sizes were used for planting and treated with the four levels of NPK fertilizer application. The results showed a highly significant difference among the various bulb sizes. The application of 85 kg ha^{-1} of NPK to the big bulbs produced the highest bulb weight, whilst the small bulbs which received no NPK application recorded the least bulb weight.

Discussion

In the study, vsgetative growth was measured in terms of leaf numbers, plant height and leaf length. In general, plants obtained from the big bulbs had better vegetative growth than those from the medium and small bulbs. Results from a previous study

TABLE 3

Effects of Bulb Size at Planting and NPK Fertilizer Application on Plant Height (cm) of Shallot

(a) at 6 weeks after planting

Bulb size at planting	*NPK fertilizer application (kg ha^{-1})*				*Mean*
	0	*85*	*170*	*255*	
Small	14.60	12.90	11.30	13.87	13.17
Medium	14.17	15.30	13.90	11.50	13.72
Big	17.37	16.07	13.37	17.90	16.17
Mean	15.38	14.76	12.86	14.42	

Cv = 6.1; LSD = 0.05, Bulb size = 0.73; NPK = 0.85; Bulb size × NPK = 1.47;

(b) at 8 weeks after planting

Bulb size at planting	*NPK fertilizer application (kg ha^{-1})*				*Mean*
	0	*85*	*170*	*255*	
Small	15.40	13.63	12.63	15.13	14.20
Medium	14.83	16.33	14.90	13.07	14.78
Big	18.27	17.23	14.87	18.93	17.33
Mean	16.17	15.73	14.13	15.71	

Cv = 4.0; LSD = 0.05, Bulb size = 0.51; NPK = 0.59; Bulb size × NPK = 1.03

on ornamental geophytes (Addai & Scott, 2011) confirm the findings of the study. In that study, plants obtained from the small bulbs also had reduced vegetative growth as compared to those from large bulbs. The observed decrease in vegetative parameters of the small bulbs relative to the medium and big bulbs as observed in the study might have been due to variation in the amount of stored carbohydrate reserves found in the bulbs at the time of planting (Addai & Scott, 2011). Watada *et al*. (1999) had also reported that the bigger the bulb size at planting, the higher the amounts of reserved carbohydrates stored in the bulb.

At harvest, the number and fresh weight of bulbs increased with increasing bulb size at planting. The big bulbs recorded the highest bulb number and fresh weight, whilst the small bulbs had the lowest of these parameters. In shallot, like many other bulbous plants, the initial growth of plant mainly depends on the remobilization of the reserved metabolites stored in the bulb, particularly in the bulb scales. In vegetatively propagated plants, Hidekazu *et al*. (1998) reported that large planting materials generally experience a higher rate of reduction in weight during emergence as compared to small planting materials. The higher the reduction in weight during sprouting, the higher the growth rate and vegetative biomass produced. The observed increase in vegetative growth and bulb yield at har-

TABLE 4

Mean Bulb Numbers at Harvest in Response to Varying Bulb Sizes at Planting with Different NPK Fertilizer Rates

Bulb size at planting	*NPK fertilizer application (kg ha^{-1})*				*Mean*
	0	*85*	*170*	*255*	
Small	4.67	7.51	8.00	4.00	6.04
Medium	8.00	11.67	6.00	2.67	7.08
Big	8.67	12.65	5.00	4.00	7.58
Mean	7.11	10.61	6.33	3.56	

Cv = 6.8; LSD = 0.05; Bulb size = 1.04; NPK = 1.23; Bulb size × NPK = 2.08

TABLE 5

Mean Bulb Fresh Weight at Harvest (g) in Response to Three Different Bulb Sizes at Planting and Four Levels of NPK Fertilizer Application

NPK fertilizer application (kg ha^{-1})

Bulb size at planting	*0*	*85*	*170*	*255*	*Mean*
Small	1.63	1.93	2.03	2.40	1.90
Medium	2.83	3.50	3.60	3.30	3.30
Big	3.10	4.13	3.93	3.26	3.61
Mean	2.52	3.19	3.12	2.98	

Cv = 5.9; LSD = 0.05; Bulb size = 0.19; NPK = 0.22; Bulb size × NPK = 0.39

vest with increases in bulb size at planting, therefore, demonstrates the importance of reserved carbohydrates to growth and development of bulbous crops. Plants from the big bulbs might have been characterised by higher photosynthetic ability than those from smaller bulbs (Addai & Scott, 2011), and this might have resulted in high assimilate production of the former, resulting in their having high bulb numbers and fresh weight as compared to plants produced from small bulbs.

The application of NPK fertilizer also tremendously influenced bulb yield at harvest. Plants, especially those from big bulbs from plots where 85 kg ha^{-1} of NPK was applied, recorded significantly higher bulb numbers and fresh weight than those that did not receive any NPK fertilizer applications. It has been established that the amount of reserved carbohydrates stored in the bulb decreased following sprouting and growth of the bulb (Du Toit *et al*., 2004). The developing plants cannot carry out the essential process of photosynthesis during the initial stages of growth because they lack mature and true photosynthetic leaves. Plants fertilized with NPK produced higher number of bulbs and bulb fresh weight at harvest than their control counterparts that received no fertilizer application, because nutrients lost during sprouting as a result of degradation of the reserved metabolites were replaced through the application of NPK. The NPK fertilizer contains nitrogen which plays a very crucial role in plants. Nitrogen deficiency is detrimental to the growth and development of plants (Scott, 2008). Nitrogen enhances the formation of chlorophyll, cell wall formation and nucleotide synthesis (Brewster & Butler, 1989; Havlin *et al*., 1999). Phosphorus deficiency in the soil reduces plant growth (McPharlin & Robertson, 1999), whilst potassium influences yield and photosynthetic processes of plants (Marchner, 1995). These nutrient elements in the applied NPK might have all played good roles in terms of bulbs yield at harvest. The low performance of plants fertilized with 170 or 255 kg ha^{-1} relative to those that received 85 kg ha^{-1} might have been due to the high levels of the fertilizer used in the former, which was probably in excess of the amount required for growth and development.

Conclusion

The results of the study clearly revealed that shallot needs supplementary NPK fertilizer for optimum yield in the study area. The crop does not, however, require the application of fertilizer in excess of 85 kg ha^{-1}. Big bulbs produced plants with higher vegetative growth and bulb yield than small bulbs. Shallot growers in the study area, who cultivate the bulbs on Nyankpala soil series, should use big bulbs for planting, and apply NPK fertilizer, but the rate of application of the fertilizer should not exceed 85 kg ha^{-1}.

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