**UNIVERSITY OF EDUCATION, WINNEBA**

# EFFECT OF BULB SIZE AND BULB CUTTING ON GROWTH AND YIELD OF ONION (*Allium cepa* L.) IN TWO ECOLOGICAL ZONES OF GHANA

**FREDRICK KWASI BARNOH**

**MASTER OF PHILOSOPHY**

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**JULY, 2021**

# DECLARATION

## STUDENT'S DECLARATION

I, Barnoh Fredrick Kwasi hereby declare that, except for references to other people's work, which have been duly acknowledged, this write-up, submitted to the School of Graduate Studies, UEW is the result of my own original research and that this thesis has not been presented for any degree elsewhere.

Signature ………………………………

Date..……………………………………

## SUPERVISORS' DECLARATION

We hereby declare that the preparation and presentation of this work was in accordance with the guidelines for supervision of thesis lay down by the University of Education, Winneba.

Prof. Kofi Agyarko (Principal Supervisor)

Signature ………………………………

Date.……………………………………

Rev. Hope Kwame Nkrumah (Co- Supervisor)

Signature ………………………………

Date.……………………………………

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The best of my thanks and appreciation goes to the good Lord for His grace, strength, protection and health to witness the end of this work. My heartfelt gratitude goes to my supervisors Prof. Kofi Agyarko, Rev. Hope Kwame Nkrumah and Prof. Margaret E. Essilfie (Mrs) for their technical advice, edition and guidance in making this work a success. God richly bless you.

# DEDICATION

I dedicate this work to my family, especially my wife Wiredu Hannah Nyantakyiwaa for their sacrifice towards my education and this work.

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| | |
|---|---|
| **LSD:** | Least Significance Difference |
| **DAP:** | Days After Planting |
| **NAN:** | National Agricultural Directory |
| **mm:** | Millimeter |
| **cc:** | Cubic centimeter |
| **cm:** | Centimeter |
| **mg** | Milligram |
| **kg** | Kilogram |
| **g:** | Gram |
| **t:** | Tonne |
| **ha:** | Hectare |
| **CV:** | Coefficient of Variation |

# ABSTRACT

Two field experiments were carried out at Asante-Mampong and Hohoe research fields to assess the effect of bulb sizes and bulb cutting on growth and yield of onion (*Allium cepa* L.) using Bawku Red Onion. The experimental design used was Randomized Complete Block Design (RCBD) with nine (9) treatments and three (3) replications. The treatments were: Control (Bawku onion seed), SB (small bulb, 20-40 mm), BB (large bulb, 40-60 mm), 1/5 SB (small bulb, cutting at 20 %), 1/4 SB (small bulb, cutting at 25 %), 1/2 SB (small bulb, cutting at 50 %), 1/5 BB (large bulb cutting at 20 %), 1/4 BB (large bulb, cutting at 25 %) and 1/2 BB (large bulb, cutting at 50 %). Data were analysed using Genstat (11$^{th}$ Edition). The results show that the highest percentage of crop establishment (100%) was recorded from BB and 1/4 BB and the lowest percent of crop establishment (55.37%) was recorded from 1/5 BB at Mampong while at Hohoe 1/5 BB (97.94 %) observed the highest crop establishment and 1/4 BB recorded the lowest at 52.60 %. No significant difference was observed between onion seed and 1/2 at Mampong. 1/2 SB recorded highest number of leaves (5.74) and 1/5 SB (3.54) as the lowest at Mampong while at Hohoe 1/5 SB and 1/5 BB recorded highest number of leaves (5.44) and 1/4 SB (3.54) recorded lowest. No significant difference was observed between onion seed, SB, 1/4 BB and 1/2 BB at Mampong and between onion seed, SB and 1/2 SB at Hohoe. At Mampong, BB obtained the highest leaf height at 37.49 cm and 1/5 SB at 15.69 cm as the lowest. At Hohoe, 1/5 SB recorded the highest leaf height of 31.92 cm and 1/4 SB giving the lowest leaf height of 12.99 cm. No significant difference was observed between onion seed and 1/2 SB at Mampong and between onion seed and BB at Hohoe. The biggest neck diameter was observed by 1/2SB and BB at 1.415 cm and 1.31 cm in both experiments at Mampong and Hohoe respectively at 60 DAP while the smallest neck diameters (0.85 cm) were observed in both 1/5 SB and 1/5 BB at

Mampong and in Hohoe 1/4 SB (0.78 cm) recorded the lowest. No significant difference was observed between onion seed, SB, 1/4 BB and 1/2 BB at Mampong and between Onion seed, SB, 1/5 SB, 1/4 SB, 1/2 SB and 1/4 BB at Hohoe. highest plant height was recorded by BB (41.38 cm) while 1/5 SB (17.95 cm) recorded the lowest at Mampong. At Hohoe, 1/5 SB recorded the highest height (34.45 cm) and 1/4 SB the lowest (16.92 cm). Onion seed and BB observed no significant difference. The highest fresh bulb weight (72.95 g) was recorded by BB and the least (34.32 g) by 1/5 BB at Mampong. At Hohoe, the highest fresh bulb weight (65.20 g) was produced by 1/5 SB and the least fresh bulb weight (25.54 g) was produced by 1/4 BB. No significant difference was observed between Onion seed and 1/4 BB at Mampong. At Mampong experiment, SB had the highest bulb diameter (5.42 cm) and the least (3.12 cm) bulb diameter was from 1/5 BB. At Hohoe, 1/5 SB had highest bulb diameter (5.16 cm) and the least bulb diameter (2.16 cm) was from 1/4 BB. No significant difference was observed between Onion seed and BB and between 1/5 SB, 1/2 SB and 1/4 BB at Mampong. At Mampong, the highest bulb yield of 3.65 t/ha was recorded from BB and the least bulb yield of 1.72 t/ha was from 1/5 BB while in Hohoe 1/5 SB (3.28 t/ha) recorded the highest bulb yield and least was from 1/4 (1.27). Based on the study it is therefore recommend that farmers use BB (40 – 60 mm) as planting materials, to obtain high bulb yield.

# CHARTER ONE

## 1.0 INTRODUCTION

### 1.1 Background to the study

Onion (*Allium cepa* L.), is a herbaceous biennial plant. It belongs to the Liliaceae family. This includes other plants such as chives, leek, garlic and shallot. It has been valued as a food and a medicinal plant since ancient times. It is a short duration horticultural crop grown at low latitudes (Brewster, 2008). It is commonly known as "Queen of the kitchen," due to its highly valued flavour, aroma, and unique taste, and the medicinal properties of its flavour compounds (Griffiths *et al*., 2002). It is one of the most important vegetable crops commercially grown in the world. It probably originated from Central Asia between Turkmenistan and Afghanistan where some of its relatives still grow in the wild. Onion from Central Asia, the supposed onion ancestor had probably migrated to the Near East (Bagali *et al*., 2012).

It produces roots, stem, and leaves during the first season of production. During the second season, the plant produces flowers, fruits, and seeds, and then complete it life cycle. Onion is classified into three spieces, *Allium cepa*, *Allium aggregattum and Allium prolilum,* which are all diploids (2n = 2x = 16). Onion is ranked as the world's 4th most enjoyed vegetable apart from tomato, cabbage and watermelon. Globally, dry onion bulbs production is about 54 million tonnes, grown per year (Boukary *et al*., 2012). The crop is grown in over 134 different countries across the world. This represents a doubling in world production over the last ten years (GhanaVeg, 2019). In 2011, the National Onion Association estimated the production of onion at about 640 billion cedis (105 billion pounds) per year (NOA, 2011). According to the UN Food and Agriculture Organisation (FAO, 2017) records, Ghana ranks 58th in world onion production chart of which Egypt is the first African producer with 2,208,080 tons and the fourth world producer after China (20,507,759 tons), India (13,372,100 tons), and USA (3,320,870 tons) (Kuete, 2017). Several reports show its benefits as for nourishment, mummification, medicine and art (Lawande, 2012). Onion has been used to treat skin diseases, ear pain, heart attack and stroke (Ado, 2001). Onions are the most important horticultural crops rich in vitamin C. It also contains high quantity of fiber, with 45 calories per medium onion bulb. It adds abundant flavour to most daily food consumed by human. Generally, onion bulbs contain most nutritional elements excluding sodium, fat, and cholesterol. In addition, onions provide a number of other key nutrients such as sugar, protein, minerals and water (Roberford, 2007; Jilani *et al.,* 2010).

The most crucial vegetable crop grown in the country is onion, because it generates high revenue to farmers. In Ghana, the cultivation of the crop has been concentrated in the Sudan savannah, Guinea savannah and the coastal savannah agro-ecological zones. The Upper East region produces 85% of the total onion production in Ghana. Northern Ghana has a competitive advantage in onion production; more than 20,000 households in northern Ghana grow onion in the dry season for cash. Onion farming in Northern and Volta regions of Ghana is a source of revenue not only for farmers, but also for input dealers, middlemen, transporters, and farm labourers (Ghana-Made, 2017). The consumption of onions is increasing in Ghana; the market is growing at an estimated 11% per annum, indicating that onion production is sustainable in the future (Ghana-Made, 2017). Increasing demand for the crop also brings with it high employment creation opportunities.

**1.2 Statement of the problem and justification**

Onions are one of the well-known commodities, which have been intensively cultivated by farmers for a long time. It has been also a source of income and employment opportunities that contribute significantly to the economic development of Ghana. Onions have a high value economically, which encourages farmers in almost all the two upper regions and southern Volta to cultivate the crop. Unfortunately, Ghana's onion consumption needs far exceed its onion production, a large quantity of onions are imported into the country from Niger and Burkina Faso on a constant basis, thus about $107 million of dry onion bulb is imported into the country per annum, even though there is a huge potential to grow good quality onions in the country (Ghanabusiness, 2019).

According to Ministry of Food and Agriculture of the Republic of Ghana (MoFA, 2018), 145,156 Mt of onion is produced from 5,000 ha of land in the onion producing areas of the country. However, the average yields of the crop are low as compared to those of other countries within Africa. Commonly, the economically important onion group is mostly grown from seeds (Brewster, 1994). However, seed supply from domestic production in Ghana and some other African countries is inadequate and therefore, vegetable growers mainly depend on imported seeds that have mostly poor germination percentage, uniformity and susceptibility to diseases (Lemma, 1998 as cited by Ashenafi *et al*., 2017). Every year the area under onion cultivation in Ghana is increasing but the farmers are facing shortage of high quality seeds, which is partly responsible for such low yield in the country (Assibey-Yeboah, 2018)

Several procedures in the field to overcome seeds unavailability include, accelerating seed that has not reached shelf life or to break dormancy by cutting the seed bulb into half (Firmansyah *et al*., 2017). In recent times, one of the several techniques that has been adopted is the use of whole bulb and bulb cutting as planting materials in Ghana. However, most farmers do not have adequate information on the right bulb size as well as the right cutting size that needs to be planted for optimum bulb yield. To minimize the cultivation and production problems, emphasis must be given to improve cultivation methods of onion, such as proper planting geometry, planting time, optimum mother bulb size and bulb cutting size for planting. This study therefore was aimed at evaluating the effect of bulb sizes and percentage cutting of bulb to the growth and yield of local 'Bawku red' onion.

## 1.3 Main Objective

The main objective of the study was to evaluate the effect of bulb sizes and percentage cutting to the growth and yield of local 'Bawku red' onion in two ecological of Ghana.

### *1.3.1 Specific Objectives*

The specific objectives of this study were to evaluate the effect of:

(i) bulb size on growth and yield of onion

(ii) bulb cutting on growth and yield of onion

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Description of Onion Crop

Onion (*Allium cepa* L.) belongs to the family *Alliaceae* or Amaryllidaceae, which is one of the most important monocotyledonous crops. It belongs to the genus *Allium* and recent estimations accept about 750 species in the genus *Allium*, among which onion, Japanese bunching onion, leeks, and garlic are the most important edible *Allium* crops. In addition, about 60 taxonomic groups at sub-generic, sectional and sub-sectional rank (Rabinowitch & Currah, 2002). Onion from central Asia, the supposed onion ancestor had probably migrated to the Near East. Then it was introduced to India and South-East Asia; and into the Mediterranean area and from there to all the Roman Empire (Grubben & Denton, 2004).

Onion is mentioned in the Bible, when the Israelites complained of their hardships while being led by Moses from Egypt to the land of Canaan about 1500 BC remembering the onions that they ate in Egypt. Onion is frequently referred to in the literature from Hippocrates, 430 BC down to the present time. It is on record that the Jews loved onions so much that they named a city after it Onion. This city was built in 173 BC near the Gulf of Suez (Anon, 2011). Now, onions are grown in regions ranging from the subtropics to the subarctic, but are best adapted to subtropical and temperate regions (Brewster, 2008). The onion commonly found in the markets of Ghana comes from the Upper East or the Upper West Region. The variety is called 'Bawku red'. A study conducted by Adomako (1959), reveals that, onion was first introduced in Ghana around 1930 and this was cultivated at Bugri, near Bawku in the Kusasi District of the Bawku in the Upper East Region. Later, it was spread to other parts of the Northern and Upper

West regions. Currently, onion is now popular in the big urban towns in Ghana where the crop is grown more as green onion than for bulbs. Despite this, Kusasi District remains the most important District where onion cultivation is prevalent. Onion is one of the oldest known vegetable and a cool season crop. It is an indispensable and important vegetable crop, which is used in every kitchen therefore; its constant demand always remains throughout the year. Besides its high food value, it is also a good source of income for vegetable growers. The onion has its own unique flavour and used in soups, dishes, salad and sandwiches and is cooked alone as a vegetable. It can be eaten as green leaves, bulbs that are mature and immature which can be eaten as fresh. The pungency of the onion bulbs is due to the presence of a volatile oil that is allylpropyl disulfide (Baloch, 1994).

Onion is a cross-pollinated, shallow rooted, biennial crop that is grown as annual. The leaves are long, hollow with widening, overlapping bases. The tubular leaf blades are flattened on the upper surface, and the stem of the plant is flattened. Bulbs consist of a growing point (stem or shoot tip) surrounded by layers of modified fleshy leaves designed to store food reserves. Both the growing point and the leaves are attached to a compact stem located at the base of the bulb called a basal plate. Thus, bulbs contain both stem and leaf tissue. Roots arise from the bottom of the growing bulb. Leaf initiation stops when the plant begins to bulb. The base of each leaf becomes one of the "scales" of the onion bulb, so the final bulb size depends in part on the number of leaves present at bulb initiation. The leaf base begins to function as a storage organ at bulb initiation, so the size of the leafy part of the plant also influences bulb size. Thus, the more leaves present and the larger the size of the plant at the onset of bulb initiation, the larger will be the bulbs and the greater will be the crop yield (Hamasaki *et al*., 1999).

The onion develops distinct bulbs depending on the varieties. These bulbs are varying in size (small, medium and large). Bulb weight may be one kg in some Southern European cultivars, and the shape covers a wide range from globose to bottle like and to flattened disk-form. The colour of the membranous skins may be white, silvery, buff, yellowish, bronze, rose red, purple or violet. The colour of the fleshy scales can vary from white to bluish-red. There is also much variation in flavor and keeping or storage ability of the bulbs ( Fritsch, 2005; All About Onion, 2018).

### 2.1 Onion Nutrition

Onions are chief food plants in which the food is stored in a bulb (Craig, 2010). Onion is grown not only because of the bulbs but also because of its green leaves. Green leaves can be harvested and commercialized. They are usually used in salads, while bulbs are eaten raw or cooked (Craig, 2010). Onions are super-healthy vegetable. Onion bulbs are a source of fiber, folic acid and vitamins C and B helping in the production of strong and new cells (Jarzabkowski, 2017). According to Jilani *et al.* (2010), mature bulbs contain some starch, appreciable quantities of sugar and some protein. A medium sized onion bulb contains about 45 calories. Additionally, onions provide flavour to various food and contain no sodium, fat, and cholesterol (Jarzabkowski, 2017; FDA, 2018). They are also rich source of sulphuric compounds, dietary flavonoids, and contain three diverse and highly valuable phytochemicals (Craig, 2010; Jessie, 2017; Sunil *et al.,* 2017). Phytochemicals are natural compounds (flavonoids, fructans and organosulfur) found in onions which have the potential to promote health benefits in humans and offer protection from variety of diseases; they have antimicrobial, antiallergenic, anti-inflammatory, and antithrombotic activity. Additionally, flavonoids in onions, such as quercetin and kaempferol, also possess different crucial biological roles for health maintenance, like antiviral, anticancer activity along, with protection of the heart and brain (Alexander, 2006; Harwood *et al*., 2007; Utesch *et al*., 2008; Ansari *et al*., 2009). Robertford (2007) conducted a study using 60 vegetables. The result of the study indicate that, onions have the highest quantity of fructans. This suggests that, onions have the potential to decrease the population of bacteria. Similar study conducted by Obeng-Ofori *et al*. (2007) using 100 g of onion contains 31 cal of energy; 1.5g of protein; 0.6g of fat; total sugar, 7.2g; carbohydrates, 0.3g; vitamin A, nil; thiamin, 0.04 mg; riboflavin, 0.02 mg; niacin, 0.1 mg; vitamin C, 7 mg; Ca, 30 mg; Fe, 0.5 mg; Mg, 16.5 mg; K, 150 mg; and Na, 7 mg.

**2.3 Health risks**

Regardless of several medicinal uses of onion, it has its own side effect. According to National Digestive Diseases Information Clearing house report (DDICH), consuming onions can cause bloating of some individual, as well as accumulation of gases in the stomach of the individual because of the carbohydrate content it contains. The consumption of raw onions has been known to cause heartburn in people who chronically suffer from gastric reflux disease or heartburn. High consumption of green onions is likely to interfere with drugs that cause blood thinning and can potentiate the action of anticoagulants (Winston, 2011). According to Jarzabkowski (2017), when onions are sliced or chopped, it is spoilt faster than the whole bulb. A study shows that yellow onions not refrigerated facilitated the growth of *Escolar* and salmonella and those that were refrigerated showed no such growth (Jessie, 2017).

**2.4 Environmental Requirements of Onion**

Onion can be grown in a varied range of climatic environments, but it thrives best at mild climate without excessive rainfall or extremes of heat and cold. Onion is a cool season crop that has some frost tolerance but is best adapted to a temperature range between 13 and 24 $^{0}$C. Optimum temperatures for early seedling growth are between 23 and 27 $^{0}$C; growth is slowed at temperatures above 30 $^{0}$C. Acclimatized plants are able to tolerate some freezing temperature. Photoperiod and temperature influence the process of bulbing. Both factors must be at optimum for the initiation of the bulbs. Cool conditions with long days are normally important for production, although there are cultivars that tolerate warm conditions and short day-lengths. Cool conditions are usually required during the first part of the season, when the plants start to form bulbs. Warm and dry weather is needed for harvesting and curing. Each cultivar differs in its sensitivity to day-length (Jelani *et al.,* 2010; Savva & Frenken, 2002).

Khokar *et al*. (2002) conducted a study on effect of planting dates on onion bulb yield. The results indicated that, when temperature is above 30 ºC and more than 80% relative humidity, it causes reduction in onion yield. However, temperature ranged between 18 - 22°C can facilitate vegetative growth, but will slow bulbing rate. In order for proper and faster bulbing to occur, right from bulb initiation to harvesting, temperature range from 25 - 28°C is required (SAKATA, 2014). According to USAID (2009) the required temperatures during bulb formation range between 15 – 30ºC. High temperatures have a strong impact on bulb formation (Brice *et al.,* 1997). The performance and development of the onion plant at every phase of growth is primarily controlled by temperature (Ansari, 2007; Abu-Rayyan & Abu-Irmaileh, 2004; Coolong & Randle, 2003).

Onions are grouped into short-days and long-days depending on the day length requirements. The bulbs that require day length of 11.5 hours are categorized into short-day group and those that take 14 hours or more for bulb formation fell into long-day group. A relatively high temperature and long photoperiod are required for bulb formation, and for seed production, temperature is of immense importance than day length. Onion bulbs have specific temperature requirement for seed and bulb production (Baloch, 1994). Light intensity, light quality, and other factors interact with temperature and day length to influence the bulbing response of onion cultivars. With warm weather and bright days, onions bulb at shorter day lengths than when the days are cool and over cast (Hamasaki *et al*., 1999).

Though onions can be produced on a wide range of soil types, varying in texture from coarse-grained sands to clays, avoid heavy soils as these may lead to problems such as bad aeration, crusting and a blemished product of lower quality. Lighter soils are easy to manage. Soils should be 45-60 cm deep and well drained. Soils with high water holding capacity are better able to provide moisture to the shallow rooting system but must also drain well to be suitable. Growth is retarded when available soil moisture is low, but onions are also sensitive to a high-water table or water logging. Uniform moisture availability about 400-800 mm per crop is conducive to large bulb size and high yields. Favourable soil pH is about 6.5–8.0 in mineral soils (Savva & Frenken, 2002). Lower pH levels can result in problems with regard micronutrient uptake.

### *2.5 Crop Propagation*

Onion dry bulb are established either by direct sowing to the field, by transplanting seedling or from dry sets depending on the growing conditions of the specific regions.

Sowing seeds directly into the soil where the crop is to be grown is potentially the most economical method of raising an onion crop, particularly where the availability of labour for transplanting is limited and its cost is high or where the availability of facilities for raising transplants is limited. Setts and transplants are used in areas where the season is not long enough for proper bulb development. Transplants have the advantage on economic use of seed, selecting superior (healthy and vigorous) seedlings. It saves weeding and watering effort during the early weeks of onion growth and it enables the farmers attend to the seedlings in a compact area (Lemma & Shimeles, 2003).

## 2.6 Vegetative, Yield and Yield components parameters as influenced by Bulb size and Bulb cutting size

### *2.6.1 Percentage Crops Establishment*

According to Ali *et al.* (2015), bulb size has a significant effect on the crop percentage establishment and in their study the highest percent of crop establishment (95%) was recorded from large size bulbs and the lowest percent of establishment (90.50%) was recorded from small size bulbs. The same trend was found in the work of Muktadir *et al.* (2001). They stated that increase in percentage establishment might be due to high food reserves present in the large bulb, which, in turn, might supply nutrient to the plant.

Production is always influenced directly by the population of bulb that is planted. If many plants die, plant population is decreased resulting in low production. According to Firmansya *et al*. (2017), percentage of cuts bulb significantly affected plants establishment. According to the authors, treatment of cuts at 25% slightly caused plants to die, that is 3.5% and 16.3% at the age of 35 DAP and 45 DAP respectively. While for cutting bulb 50% increase mortality percentage 1.7% and 34.3% respectively at the age of 35 DAP and 45 DAP and therefore, high percentage of deaths of bulb cut by 50% is most likely due to the high contamination of disease caused by the extent of cut at bulb. Cutting bulb can quicken the emergence of shoots compared with no cutting (Arifin *et al.,* 1999). The authors added that cutting of bulb into 2 parts could produce shoot earlier than cutting into 3 parts. This is in agreement with another research conducted by Boswell that the cutting of tuber into 2 parts results in faster growth of shoots (Boswell, 1924, as stated in Firmansyah*, et al*., 2017).

### *2.6.2 Plant height and leaf height*

Mosleh (2008) observed that different sizes of onion bulb showed significant effect on plant height and leaf height. According to the author the maximum plant height and leaf height was produced by large mother bulb, which was significantly higher than the medium and small sized bulb. Addai *et al.* (2014), also confirm same result in their study. In the case of Ali *et al.* (2015), the highest plant height and leaf height was produced by small bulb size whereas, large size bulbs produced the lowest plant height and leaf heights at 60 DAP. Probably it happened due to internal hormonal effect. Setiawan *et al.* (2014) also showed that, cutting bulb by one third could significantly improve growth and production for plant parameter such as plant height and leaf height compared to cutting bulb by half.

### *2.6.3 Number of leaves*

Mother bulb size also has effect on number of leaves. A study conducted by Addai *et al.* (2014), indicated that, leaf numbers were positively influenced by the large sized mother bulb, which was significantly higher than the medium and small sized bulb. The finding is similar to the results obtained by [Hussain *et al*. (2001). Mosleh ud-Deen (2008).

Ashrafuzzaman *et al.* (2009)] and Hamasaki *et al*. (1999) who reported that large sized bulbs produced greater number of leaves per plant. Research conducted by Setiawan *et al.* (2014) also showed that, cutting bulb by one third could significantly improve growth and production for plant parameter such as number of leaves and number of tillers compared to cutting bulb by half.

***2.6.4 Yield and Yield Components***

In a study conducted by Mosleh (2008), showed that bulb diameter, bulb weight per plant and bulb yield were increased with the increase of mother bulb size. The maximum bulb diameter (5.38 cm), bulb weight per plant (47.96 g) and bulb yield (14.68 t/ha) were obtained from large mother bulb, which was significantly higher than medium and small sized bulb, whereas the minimum (4.33 cm, 44.33 g and 7.47 t/ha, respectively) were found from small mother bulb. Similar trend was found in number of flowers per umbel, fruit set percentage, weight of seeds per plant, 1000-seed weight and seed yield. The greatest 1000-seed weight (2.87 g) and seed yield (392.3 kg/ha) were obtained from large mother bulb, which were significantly different from other two sizes of mother bulb (Hamasaki *et al*., 1999). MoIlah *et al.* (1997) and Karim *et al.* (1999) also reported similar result that, large mother bulb showed better performance in bulb and seed production of onion compared to that of medium and small mother bulb.

According to Jumini *et al.* (2010), cutting of onion bulb treatment significantly affects number of bulbs, the diameter of bulb, fresh bulb weight and dry bulb weight. They observed that, cutting bulb into four parts tend to be better than cutting into two or three parts in terms of the parameters mentioned above. Deviana *et al*. (2014) also observed in their research that, cutting of bulb into two or four parts produce lower weight of dry bulb 62% and 36% respectively of the bulb without cutting.

## 2.7 Vegetative parameters as influenced by agronomic factors

### *2.7.1 Percentage crop establishment*

A good land preparation together with careful application of both organic and inorganic fertilizers and quality seed and whole bulb usage will result in a higher percentage crop establishment (Tweneboah, 2000). According to the author increase in the rate of nitrogen fertilizer application from nil to 82 kg N ha-1, percentage crop establishment increased significantly. Ghaffoor *et al*. (2003) observed that survival percentage of onion bulbs increased when 150 kg N ha-1 was applied. Jilani *et al*. (2004) also found that, minimum numbers of bulbs were recorded for the control level of nitrogen.

### *2.7.2 Number of leaves per plant*

According to Akuamoah-Boateng (2016), the number of leaves of onion plant depend on the amount of fertilizer especially nitrogen applied. Ibrahim (2010) was of opinion that, the application of fertilizer to soil can increase leaf number from 6 to 11 with an average of a leaf per week. The improvement in leaf number per plant was achieved because both organic and inorganic fertilizers supply the soil with more nutrients, especially nitrogen which significantly support vegetative growth (Blay *et al.,* 2002). For leaf canopy development a minimum temperature of 6°C is required and leaf growth will terminate if temperatures fall below 6°C. There is linear increase in the relative rate of growth of onion leaf when temperature increases from $6^0$C to 20°C. A further increase in temperature of the onion will cause rate of growth to start declining and then will stop when temperatures go above 26°C (Bosekeng, 2012).

The number of sprouts (Addai & Anning, 2015; Tsitsia, 2012) can also influence increase in number of leaves. Furthermore, Addai and Anning (2015) and Iannotti (2008), indicated that when the leaf number and bulb number was high, the sprout number will also be high and consequently bulb number at harvest will be high.

### *2.7.3 Plant height*

Onion height is normally appreciated by 10 percentage when a quantity of 69kg per hectare of nitrogen fertilizer is added to it as compared to the control. In addition, onion plant growth is significantly appreciated by the addition of NPK 15-15-15 (Abdissa *et al.* 2011). Aside that, K fertilizer is a significant booster to the growth of plant height (Sinaga *et al* 2016). Despite late planting or sowing, plant height is still higher as evidenced in Ahmed *et al.* (2013). They observed a growth using a period of 45 days and Bhatt *et al.* (2007) period of 60 days. According to Bosekeng (2012), when growth period is lengthened, larger plants are obtained and this can occur when early sowing is done. The variations that exist between cultivars are as a result of the genetic make-up varieties (Ahmed *et al.,* 2013). For Mohanty and Prusti (2001), environmental factors particularly temperature and photoperiod also influenced the variations in height of onion plant and not mainly attributed to the genetic make – up or potential only.

A study by Tsitsia (2012) also reveal that the size of bulb influenced plant height with larger bulbs recording higher plant height and length of leaf as compared to other bulb sizes. According to Khan *et al*. (2005) and Addai and Anning (2015), vegetative growth and yield were high in large bulb size and were reduced in smaller bulbs size, also the leaf number can define the critical size of the plant, and thus the size of an onion plant is sensitive when it develops 7 to 10 leaves. Another study also shows that, vegetative growth was rather high in medium bulb size relative to large and small bulbs size (Fuseini, 2012).

### *2.7.4 Stem diameter*

For optimum plant growth and yield, each plant need to be fertilized with the appropriate amount or dose of fertilizer so that there is a balance of nutrients in the soil which enables plants to grow and develop well. This is in accordance with the findings of Bybordi and Malakouti (2003). They indicated that application of sufficient potassium (K) fertilizer in soil boosted the growth of onions. Again, they reported that, addition of K with high dosage displayed good results due to its role to aid the plants in photosynthesis. It helped the formation of new organic compounds that are transported to bulbs. According to Cramer (2003), date of sowing has an effect on the size of onion plants formed. Mosleh (2008) observed that early planting was always essential to get big onion plants.

## 2.8 Reproductive parameters

### *2.8.1 Bulb initiation*

Onion bulb initiation starts as soon as the day length period is more than the minimum required by a specific cultivar (Quadir & Boulton, 2005). Each cultivar differs in its sensitivity to day-length (Jelani *et al.,* 2010; Savva & Frenken, 2002). Several cultivars during bulb initiation require long days. When this is not met, onion will not form bulbs. According to Bok *et al.* (2003) 'Australian Brown' intermediate day length cultivar performed well in South Africa. However, the same cultivar grown in Botswana could not do well. As soon as onions crop meet the day length required, bulbs formation is initiated.

Temperature is one of the factors that influence bulb formation. Early bulb initiation and maturation is enhanced, when temperatures are high, between 25 and 28°C. At short photoperiod during drought season onions will start with bulb formation. This depends on the interaction between day length and temperature. According to Ansari (2007) and Ahmed *et al.* (2013), the best time for onion to produce bulbs was late February.

### *2.8.2 Bulb growth*

The number of leaves, which are produced before bulbing, has influenced on bulb growth. The leaf area is very essential for photosynthesis and bulb growth. The time taken for leaves to develop and mature influences the leaf area and hence efficient photosynthetic capacity and potential for bulb growth. Photosynthesis is the production of sucrose that will be transported and stored in the structural and storage tissue of the plant. This sucrose is converted to glucose and fructose by the specific enzyme namely 'invertase' during the development of onion bulbs (Brewster, 2008). Therefore, if an onion cultivar is sown on a date which allows for long duration of vegetative growth, the better the growth of bulbs will be and eventually better yield will be attained (Bosekeng, 2012).

### *2.8.3 Bulb length*

Bulb height and length of onion is influenced by N fertilization (Yadav *et al.,* 2003; Yohannes *et al.,* 2013). Yohannes *et al.* (2013) added that among the different levels of N assessed, the maximum rate of N at 150 kg/ha gave the highest mean length of bulb, which was 12% more than the control. Sultana *et al.* (2014) observed that a combined addition of N from organic and inorganic sources to the soil resulted in increased length of the bulb. The highest length of bulb length at 2.8 cm was obtained when 80 kg N/ha obtained from urea and 40 kg N/ha substituted by cow dung was applied to the soil. But, on contrary, no significant effect on bulb length when N fertilizer was used (Abdissa *et al.,* 2011).

### *2.8.4 Bulb and neck diameter*

The bulb sizes of onion vary from a medium of 40-69 mm to an extra small size of 10-34 mm, a small size of 35-39 mm, a large size of 70-89 mm and extra-large of >90 mm. Consumers like medium size onions that will attain higher prices on the market than the extra small (Bosch Serra & Currah, 2002). Bulb neck diameter is also an important element among others to consider in bulb quality and storage. Yemane *et al.* (2013) indicated that with increasing intra-row spacing from 5 to 10 cm, statistically bulb diameter and bulb neck diameter of onion increased from 4.66 to 5.63 cm and 1.48 to 1.74 cm respectively. Jilani *et al.* (2009) and Dawar *et al.* (2005) indicated that bulb neck diameter decreased as population density increased. Gautam *et al*. (2006) reported that bulbs with thinner necks tend to store longer than bulbs with thicker necks. The reason is that, bulb with big necks require enough time to dry.

Onion growers prefer to produce and sell onion in a specific market. They grow medium size bulbs for fresh market and good revenue (Bosch Serra & Currah, 2002) and thinner necks for good storage (Mohanty & Prusti, 2001). There is also market for thick bulb sizes with low price. Onion bulb is the widely consumed part of the plant that is why its characteristics interest several works, which insisted on the existence of genetic difference between the varieties of onion in diameter of neck (Gautam *et al*., 2006).

### *2.8.5 Average healthy and rotten bulb weight*

According to Abdelkade *et al.* (2014), data of bulb weight indicated that 'BHP' cv. produced the biggest bulb of 155.02 g followed by MA (139.25 g) and KR (110.43 g), whereas 'Z6' cv. had the minimum weight of bulb (63.13 g). Similar result was observed in others varieties of onion (Trivedi & Dhumal, 2010; Dwivedi *et al.*, 2012). Bosekeng (2012) also confirmed that when onion plants are sown early, they tend to have a longer growth period, which then results in the formation of larger bulbs.

## 2.9 Bulb quality parameters

### *2.9.1 Bulb shape*

Onion bulbs shape is based on the type of cultivar and is a very relevant marketing characteristic. Consumers' prefer circular bulb both in South Africa and for export market (Bosch Serra & Currah, 2002). The type of variety influenced onion form and all onion variety has a specific bulb shape (Jilani & Ghaffoor, 2003; Bosekeng, 2012). According to Hasegawa *et al.* (2001), onion bulb present different form such as flat, globe and sphere. Plant population and date of sowing affect onion bulb shape (Grant & Carter, 1994). According to them, the bulb shape index changed from 1.02 to 1.06, when the population of plants increased dramatically. Shape of bulb can be identified visually or by using the bulb shape index (Bosekeng, 2012).

### *2.9.2 Bulb colour*

According to Grauert (2014), nitrogen reduction results in improved bulb quality (skins, firmness etc.). A study conducted by Advisory Committee on vegetable crops of Atlantic Canada (2017), noted that when onions are cured at temperature ranges between 24 to 32°C and an 80% relative humidity it develops the best skin colour.

### *2.9.3 Bulb firmness*

Bulb firmness in addition contributes to consumers' preference of bulb quality. It also influences the storability of onions (Mallor *et al*., 2011). Bulb firmness is largely affected by the composition of the cell walls such as physical and chemical composition. Dry matter content and total soluble solids (TSS) play an important role in bulb firmness during harvest (Coolong *et al*., 2008). They reported that the differences in dry matter content could lead to an increase in cell water content and cell turgor which results in firmer plant tissue. Bulb firmness varies during storage. This is affected by the activities of pectinase, an enzyme which controls the composition of pectic polysaccharides and binds to free calcium ions, increasing bulb firmness.

Lancaster *et al*. (2001a), El-Tantawy and El-Beik (2009) respectively reported that sulphur or copper affected onion bulbs firmness. This was supported by Nasreen *et al*. (2003) who indicated that sulphur or copper fertilizers play a role of onion dry matter accumulation, strengthen bulb cells and increase onion bulb shelf life so that they can be stored long. In addition, low application of sulphur initiates softer bulbs (Lancaster *et al*., 2001b). Similar finding was reported by Grauert (2014), that nitrogen reduction does not lead to less yield but improved quality (skins, firmness etc.). Agronomic practices such as irrigation has influence on onion bulb firmness (Larsen *et al*., 2009). They added that small bulbs are extremely firm compared to big size onion. Bettson (1961) reported that most foreign cultivars are not very firm when mature. According to Starke Ayres (2014), the curing process allows for development of scale leaf colour and firming of the bulbs. When the rate of nitrogen is high, bulb firmness reduces, because of the softness of internal tissue (GhanaVeg, 2018).

## 2.10 Shelf life and storage

It is clear that dry matter content and dormancy are some of the genetic factors, which affect bulb shelf life (Hygrotech, 2009). Thus photoperiod in bulb storage, indicate whether bulb can be stored longer or shorter. He reported again that intermediate day cultivars (6-7 months) store better than short day cultivars (4 months). According to Galvan *et al*. (1997), onion bulbs sown earlier have enough time to grow well, to produce large leaves. Large leaf areas make better photosynthesis and accumulate enough assimilates for the plant to complete well it life cycle and the bulbs to store well. Bosekeng (2012) indicated that harvesting onions bulbs too early cause lack of growth inhibitors translocation to onion bulbs.

Curing consists of drying harvested onion bulbs roots, outer skins and neck. The outer skins protect onion bulbs against postharvest pathogens during handling and storage. This postharvest practice increases bulbs shelf life and reduces all types of bulbs infection (Wright & Grant, 1997). The percentage of weight loss is minimized with long shelf life cultivars and maximized with short shelf life cultivars. Ramin (1999) observed that the loss of bulbs water content could be reduced with 65 to 75% relative humidity when stored. Bulbs shelf life and storage depend also on its firmness and the firmer the bulbs the better the storage (up to one month longer) than softer bulbs (NAD, 2009).

# CHARPTER THREE

## 3.0 MATERIALS AND METHOD

### 3.1 Description of the Experimental sites:

The research was carried out at two different locations that is the Forest - Savannah Transitional and Semi Deciduous Forest agro-ecological zones of Ghana.

#### *3.1.1 Climate and Geology of Asante – Mampong*

The first study site was at the Teaching and Research Farm of the College of Agriculture Education University of Education, Winneba, Mampong-Ashanti. The area lies between latitude 07 047"N and 01 024"W and 413 km above sea level (Meteorological Department, 2006) the climate is classified as Aw by the Kipper-Geiger System and lies in the transitional zone, between the forest zone and Northern savanna zone of Ghana. The mean annual temperature of the area ranges between $23^0$C to $35^0$C with daily mean of about 30.5°C (Meteorological Department, 2005).

The area has distinct wet and dry seasons with mean annual rainfall ranging from 1,250 to 4,000 mm. The wet season has double rainfall peaks during July and October with a short break in rainfall called "August break" in between the double peaks. Consequently, there are two cropping seasons (early cropping season: from March to July, and late cropping season: from August to December) in the area. The experimental site soil is derived from the Voltan sandstone of the Afram plains. It belongs to the savannah Ochrosol class of the Bediese series. The FAO classification of soil at the site is of Chromic luvisol. The soil is sandy loam, well drained with layer of organic matter with characteristics of deep yellowish red colour, friable and free from stones (SRI, 1999).

The pH ranges from 6.5-7.0 (Asiamah *et al*., 1993). It has moderate water holding capacity (Asiamah *et al.*, 1993).

### *3.1.2 Climate and Geology of Hohoe*

The second study site was at Afadjato Senior High School Research farm, located in semi deciduous forest agro-ecological zone of Ghana. It lies within longitude 00 15"E and 00 045"E and latitude 60 45"N and 70 015"N. The mean annual temperature of the area ranges between $23^0$C to $35^0$C with daily mean of about 30ºC. The area has distinct wet and dry seasons with mean annual rainfall ranging from 1100 mm to 1500 mm. The rainfall pattern of the study area is bi-modal and records a total annual rainfall of about 1300 mm. The major rainy season stretches from April to July. The minor rainy season covers the period from September through November. Occasionally the municipal bimodal pattern gives way to continuous rain from April to November. The experimental site soil is described as an Ochrosol and Oxysol (MoFA, 2018).

## 3.2 Experimental Design Treatment and Field Layout

Randomized Complete Block Design (RCBD) was used as an experimental design at both sites with 9 treatments and 3 replications.

### *3.2.1 Treatments and Planting Material Preparation*

Commonly cultivated variety in Ghana "Bawku-Red" onion seeds and different bulb sizes were gotten from local distributors and studied for their growth and yield performance based on agronomical measurements. Seeds, two whole bulb sizes viz. large (40-60 mm in diameter) and small (20-40 mm in diameter) bulbs as well as cuttings at 20%, 25% and 50% for both whole bulbs represented the treatments.

**Treatments were defined as follows:**

T1: SB = (small size whole bulb, 20-40 mm)

T2: BB = (large size whole bulb, 40-60 mm)

T3: 1/5 SB = (small size whole bulb, cutting at 20 %)

T4: 1/4 SB= (small size whole bulb, cutting at 25 %)

T5: 1/2 SB= (small size whole bulb, cutting at 50 %)

T6: 1/5 BB = (large size whole bulb, cutting at 20 %)

T7: 1/4 BB = (large size whole bulb, cutting at 25 %)

T8: 1/2 BB = (large size whole bulb, cutting at 50 %)

T9: Control = (Bawku onion seed)

### *3.2.2 Field Layout*

The space between blocks (replications) was 1 m and between plots in each block was 0.5 m. Field area was 5 m × 22 m = (110 m$^2$). There were 5 rows per plot. However, data were collected from five tagged selected onion plant per plot.\

### *3.2.3 Nursery preparation*

Nursery beds were prepared using cutlass and hoe after ploughing. Beds were raised at 15 cm high, 2 m length and 1 m width. Further leveling was done manually with a rake for a fine and even seedbed. Before sowing the soil was watered to field capacity. For raising of seedling, onion seeds were sown on 11$^{th}$ September, 2019 on raised bed at the Teaching and Research Farm of the College of Agriculture Education, University of Education, Winneba, Mampong-Ashanti, and on 15th September, 2019 another seeds were sown at Afadjato Senior High School Research farm at Hohoe. Seeds were sown by hand and covered with soil. A light irrigation was applied after sowing, using a watering can. The nursery bed was covered with palm fronds to conserve moisture particularly at the surface and to avoid seeds being picked up by insects. The palm fronds were removed as soon as seed emergence began.

### *3.2.4 Land Preparation, transplanting, direct planting of mother bulb and bulb cuttings*

After clearing the land using cutlass, ploughing was done at the two sites at a depth of 15 cm using a disc plough followed by harrowing. The experimental area of 5 m x 22 m was measured out using a tape measure, garden line and pegs. The total land area for the study in each location was 110 $m^2$ with a block size of 22 $m^2$. Field plot of 2 m x 1 m (2 $m^2$) with 5 rows per plot and a distance of 20 cm between rows and an interval of 20 cm within rows were prepared for this study. Beds were raised to 15 cm high. The bulb and the bulb cutting were also planted on the same day as the seedlings on the already prepared bed at 4 cm depth from the soil surface and at a planting distance of 20 cm between rows and an interval of 20 cm within rows. During the cutting, the knife was disinfected by ethanol to prevent microorganism infection; bulb and bulb cutting were also covered with ash to facilitate sprouting. Four weeks after sowing the seedlings were transplanted to their respective plots at 1 seedling per stand while the bulbs and bulb cuttings were also thinned to one per hill four weeks after planting.

### *3.2.5 Soil Sampling and Analyses*

The soil samples taken from the experimental sites and analysis were done in KNUST soil Science Laboratory. Soil samples were collected randomly from the entire experimental field following a zigzag fashion from 0 to 30 cm depth before planting using an augur. The soil samples were collected from the entire experimental field and it was made one kg composite sample. Determinations of some selected soil chemical properties were carried out based on the composite sample. The composite soil sample was air dried, crushed with wooden pestle and mortar to pass through a 2 mm sieve size for the analysis of physical and chemical properties. Total nitrogen, available phosphorus, potassium, organic matter, soil pH, cation exchange capacity (CEC), carbon nitrogen ratio and soil texture were determined at the Kwame Nkrumah University of Science and Technology Soil Science Laboratory in Kumasi, Asante Region of Ghana.

## 3.3 Cultural Practices

### *3.3.1 Onion fertilization*

Basic fertilization was done one week before planting the bulbs, bulb cuttings and also before transplanting the seedlings; using chicken manure at rate of 10 t/ha. Additional fertilizer were applied only at 14 days after planting using NPK 15:15:15 at a rate of 300 kg/ha.

### *3.3.2 Irrigation*

The field study was conducted in the minor rainy season, but when the rain stopped for some time plants were irrigated manually. Watering cans were used for irrigating the onion crop at the two sites at least four time per week.

### *3.3.3 Weed Control*

The use of hoe and hand picking of weeds was carried out throughout the field study. This was carried out four to five times depending on the experimental site. The dominant weeds recorded in the sites were *Euphorbia hirta* (Asthma weed) and *Cyperus rotundus* (nutgrass).

### *3.3.4 Pest and Disease Control*

Fungal diseases were prevented by spraying Topsin M (Thiophamate methyl) at a rate of 70 g per 15 liters of water. The application was done only once throughout the field experiment. Then, Lamda halometry, was also used as an insecticide to prevent insects attack on plants such as crickets at a rate of 2.5 cc per 16 liters of water.

## 3.4 Data Collection

Data on growth, yield and yield components of onion were recorded after eight weeks of sowing; the desired data were taken from the tagged plants from each plot.

### *3.4.1 Growth parameters*

- Percentage Crops Establishment (%): Plants that successfully established were counted after eight weeks of sowing and expressed as percentage: the number of established plants was divided by the entire number of seedlings transplanted or sowing directly and expressing it as a percentage. The formula is as follow:

$$\textbf{Percentage Crop Establishment} = \frac{\text{Number of established plants}}{\text{Total number of seedlings planted per plot}} * 100$$

(Boateng, 2019)

- **Plant height:** Plant height for five tagged selected plants per plot was measured using ruler from base to tip of the main shoot. The mean plant height for each plot was determined

$$\textbf{Mean Plant Height} = \frac{\text{Sum of height of selected plants}}{\text{Number of plants selected}}$$

- **Number of leaves per plant:** The total number of leaves per plant for five tagged selected plants was counted using the hand. The mean number of leaves per plant for each plot was determined.
- $$\textbf{Mean Number of Leaves} = \frac{\text{Sum of number of leaves of selected plants}}{\text{Number of plants selected}}$$
- **Neck diameter:** The diameter of the neck was measured from five randomly selected plants using venier caliper. This was measured from the largest site or part of the neck. The mean neck diameter was then estimated and recorded
- **Leaf height:** This was measured at physiological maturity from the sheath to the tip of the leaf on the five leaves of the representative plants which was used to count the number of leaves per plant using a ruler.

*3.4.2 Yield and yield components*

- **Bulb diameter:** Bulb diameter of five randomly selected onion per plot was measured using venier caliper at the widest part of the bulb.
- **Bulb weight per plot:** The fresh bulb weight per plot was measured by using sensitive weighing scale and finally expressed in grams.
- **Total Bulb yield:** Bulb yield was estimated from the ratio of weight (kg) of selected onion per plot over harvested area and finally converted into t/ha.

$$\mathbf{Y} = \frac{W*10000}{A*10}$$

Where Y= Onion yield expressed in t/ha.

W = Weight of onions per plot expressed in kg.

A = Harvested Area.

(Baba- Moussa *et al,* 2015)

### 3.5 Data Analysis

Data collected was analyzed using the analysis of variance (ANOVA) for randomized complete block design (RCBD) with the help of the GenStat Eleventh Edition Software. Means which differed significantly were compared using the Fisher's Protected Least Significance Difference (LSD) at probability level of 5% of significance (P=0.05).

# CHAPTER FOUR

## 4.0 RESULTS

### 4.1 Climatic conditions during the experimental period

Table 4.1 shows the climatic data of the study sites from August – December, 2019. The average monthly temperature over the experimental period ranged from 21ºC to 27.4ºC. Generally, the rainfall recorded was low during the vegetative stage of the crop, while the highest amount of rainfall was recorded in September at Hohoe. At Asante Mampong, the amount of rainfall recorded was low during the onion crop growth phase.

**Table 4.1: Climatic conditions at the experimental sites at Asante-Mampong and Hohoe**

| Months | Average monthly rainfall (mm) | Average monthly temperature (º C) |
|---|---|---|
| **Asante-Mampong** | | |
| August | 75 | 21 |
| September | 71.1 | 21.7 |
| October | 176 | 22.4 |
| November | 52 | 23.1 |
| December | 23 | 23.1 |
| **Hohoe** | | |
| August | 106 | 25 |
| September | 206 | 26 |
| October | 182 | 26.7 |
| November | 83 | 27.4 |
| December | 34 | 27 |

*Source: https://en-climate.data.org.africa*

**Table 4.2: Physiochemical properties at Asante- Mampong and Hohoe**

| Soil analytical data | Mampong | Hohoe |
|---|---|---|
| Chemical properties | | |
| pH ($H_2O_{1:1}$) | 6.1 | 6.45 |
| Total Nitrogen (%) | 0.08 | 0.07 |
| Organic Matter (%) | 2.1 | 1.8 |
| Available Phosphorus (mg/kg) | 30 | 80 |
| Exchangeable Potassium | 73 | 71 |
| Cation Exchangeable | 10 | 9 |
| Capacity(meq/100g) | 15 | 13 |
| Carbon Nitrogen Ratio | | |
| Physical Properties | | |
| % Sand | 68.90 | 64.20 |
| % Silt | 9.21 | 10.86 |
| % Clay | 22.1 | 18.2 |
| Texture | Sandy Loam | Sandy Loam |

#### *4.1.2 Percentage Crop Establishment*

From the result in Table 4.3 above, the percentage crop establishments at 60 DAP showed a significant ($P < 0.05$) statistical difference between the treatments at both locations. Percent crop establishment ranged from 52% -100% at both locations. At Mampong, the BB and 1/4 BB produced the highest percentage crop establishment at 60 DAP (100%); the lowest was recorded by 1/5 BB (55.37%). At Hohoe, 1/5 BB produced the highest percentage crop establishment (97.94%) and the lowest was 1/4 BB (52.60%). However, at Mampong there were no significant difference between onion seed and 1/2 BB. Additionally, there was also no significant differences between SB, BB, 1/2 SB and 1/4 BB. At Hohoe also, no significant difference was observed between plants produced from SB, BB, 1/5 SB and 1/5 BB.

**Table 4.3: Percentage crop establishment of onion grown at Mampong and Hohoe at 60 DAP as affected by bulb size and cutting**

| Treatments | Percentage of Crop Establishment (%) | |
|---|---|---|
| | Mampong | Hohoe |
| Onion Seed | 85.07 | 82.19 |
| SB(20-40 mm) | 99.34 | 96.94 |
| BB(40-60 mm) | 100 | 97.27 |
| 1/5 SB | 65.03 | 97.60 |
| 1/4 SB | 75.03 | 62.27 |
| 1/2 SB | 99.34 | 73.27 |
| 1/5 BB | 55.37 | 97.94 |
| 1/4 BB | 100 | 52.60 |
| 1/2 BB | 82.37 | 79.60 |
| LSD (0.05) | 4.54 | 4.24 |
| CV (%) | 3.1 | 3.0 |

### *4.1.3 Number of Leaves per plant*

The number of leaves per onion plant differed significantly between treatments. At Mampong, 1/2 SB recorded greatest mean value of (5.74), followed by BB (5.44) and 1/5 SB had the lowest (3.54) at 60 DAP. There were no significant differences between Onion Seed and SB and also between BB, ¼ BB and ½ BB as well as between ¼ SB and 1/5 BB. At Hohoe, the greatest number of leaves (5.44) were recorded by 1/5 SB and 1/5 BB whiles 1/4 SB had the least (3.54) number of leaves per plant. However, no significant differences was observed between Onion Seed, SB and 1/5 SB and also between 1/5 SB, 1/5 BB and BB (Table 4.4).

**Table 4.4: Number of leaves per plant of onion crop at Mampong and Hohoe at 60 DAP as affected by bulb size and cutting**

| Treatments | Number of leaves per plant | |
|---|---|---|
| | Mampong | Hohoe |
| Onion Seed | 4.87 | 4.83 |
| SB(20-40 mm) | 4.84 | 4.84 |
| BB(40-60 mm) | 5.44 | 5.41 |
| 1/5 SB | 3.54 | 5.44 |
| 1/4 SB | 4.64 | 3.54 |
| 1/2 SB | 5.74 | 4.61 |
| 1/5 BB | 4.34 | 5.44 |
| 1/4 BB | 5.44 | 4.34 |
| 1/2 BB | 5.04 | 5.04 |
| LSD (0.05) | 0.64 | 0.39 |
| CV (%) | 7.6 | 4.7 |

***4.1.4 Leaf height***

At both locations, there were significant differences (Table 4.4) between the treatments. At Mampong, BB obtained the highest leaf height mean value (37.49 cm) and differed significantly from 1/5 SB and with the lowest value (15.69 cm). At Hohoe, 1/5 of SB recorded the highest leaf height mean value (31.92 cm) and differed significantly from the 1/4 SB which gave the lowest leaf height mean value (12.99 cm). No significant difference was observed between Onion Seed and 1/2SB and also between 1/4 BB and 1/2 SB at Mampong and between Onion Seed and BB at Hohoe in leaf height (Table 4.5)

**Table 4.5: Leaf heights of onion grown at Mampong and Hohoe at 60 DAP as affected by bulb size and cutting.**

| Treatments | Leaf Height (cm) | |
|---|---|---|
| | Mampong | Hohoe |
| Onion Seed | 25.24 | 22.59 |
| SB (20-40 mm) | 31.56 | 29.89 |
| BB (40-60 mm) | 37.49 | 22.79 |
| 1/5 SB | 15.69 | 31.92 |
| 1/4 SB | 21.89 | 12.99 |
| 1/2 SB | 25.49 | 19.79 |
| 1/5 BB | 21.03 | 25.89 |
| 1/4 BB | 27.59 | 18.00 |
| 1/4 BB | 21.19 | 19.46 |
| LSD (0.05) | 2.27 | 1.17 |
| CV (%) | 5.2 | 3.0 |

***4.1.5 Neck diameter***

Neck diameter was significantly different (P<0.05) among the treatments (Table 4.5). The biggest neck diameters of 1.45 cm and 1.31 cm were observed in the 1/2SB and BB treatment at Mampong and Hohoe respectively at 60 DAP whiles the smallest neck diameter of 0.85 cm was recorded by 1/5 SB and 1/5 BB at Mampong and 1/4 SB (0.78 cm) at Hohoe. However, no significant differences was observed between Onion Seed, SB, 1/4 BB and 1/2 BB and also no significant differences exist between 1/5 SB and 1/5 BB at Mampong.  At Hohoe there were also no significant differences among SB, 1/4 BB, 1/4 SB and 1/2 SB and also between BB, 1/5 BB and 1/2 BB (Table 4.6).

**Table 4.6: Neck diameters of onion grown at Mampong and Hohoe at 60 DAP as affected by bulb size and cutting.**

| | Neck Diameter (cm) | |
|---|---|---|
| Treatments | Mampong | Hohoe |
| Onion Seed | 1.14 | 1.01 |
| SB (20-40 mm) | 1.15 | 0.87 |
| BB (40-60 mm) | 1.35 | 1.31 |
| 1/5 SB | 0.85 | 1.08 |
| 1/4 SB | 1.05 | 0.78 |
| 1/2 SB | 1.45 | 0.88 |
| 1/5 BB | 0.85 | 1.17 |
| 1/4 BB | 1.25 | 0.87 |
| 1/2 BB | 1.15 | 1.14 |
| LSD (0.05) | 0.26 | 0.37 |
| CV (%) | 13.1 | 21 |

### 4.1.6 Plant Height

Table 4.7, indicates significant ($P<0.05$) differences in plant height among the treatments. The highest plant height (41.38 cm) was recorded by BB and the 1/5 SB recorded the lowest (17.95 cm) at Mampong. The 1/5 SB had the highest (34.45 cm) plant height at Hohoe with the 1/4 SB recording the lowest (16.92 cm). At Mampong there were significant differences among all the treatments with exception of 1/4 SB and 1/5 BB which observed no significant differences between them. At Hohoe there were no significant differences among Onion Seed and BB, 1/2 SB and 1/2 BB and the 1/4 BB and 1/2 BB as well (Table 4.7)

**Table 4.7: Plant height of onion grown at Mampong and Hohoe 60 DAP as affected by bulb size and cutting.**

| | Plant Height (cm) | |
|---|---|---|
| Treatments | Mampong | Hohoe |
| Onion Seed | 27.82 | 25.09 |
| SB (20-40 mm) | 34.62 | 32.15 |
| BB (40-60 mm) | 41.38 | 25.05 |
| 1/5 SB | 17.95 | 34.45 |
| 1/4 SB | 23.55 | 16.92 |
| 1/2 SB | 28.05 | 22.45 |
| 1/5 BB | 22.91 | 28.19 |
| 1/4 BB | 30.45 | 19.79 |
| 1/2 BB | 23.65 | 21.69 |
| LSD (0.05) | 1.85 | 1.99 |
| CV (%) | 3.8 | 4.6 |

## 4.2 Yield and yield components

### *4.2.1 Fresh Bulb Weight*

With respect to fresh bulb weight per plot, there were significant differences between treatments. Table 4.8 indicates that the maximum fresh bulb weight (72.95 g) was recorded by BB followed SB (66.25 g) and the minimum yield of (34.32 g) and (38.75 g) were recorded by the 1/5 BB and the 1/5 SB respectively, at Mampong. At Hohoe, the highest fresh bulb weight per plot (65.20 g) was observed from 1/5 SB followed by SB (53.54 g) and the least fresh bulb weight (25.54 g) was recorded by 1/4 BB. At Mampong there were significant differences between all treatments with exception of Onion Seed and 1/4 BB which observed no significant difference between them. At Hohoe, no significant differences was observed between 1/4 SB and 1/4 BB and also between 1/5 BB and 1/2 BB (Table 4.8)

**Table 4.8: Fresh bulb weight of onion at Mampong and Hohoe at 60 DAP as affected by bulb size and cutting.**

| | Fresh Bulb Weight per plot (g) | |
|---|---|---|
| Treatments | Mampong | Hohoe |
| Onion Seed | 52.00 | 41.12 |
| SB (20-40 mm) | 66.25 | 53.54 |
| BB (40-60 mm) | 72.95 | 36.54 |
| 1/5 SB | 38.75 | 65.20 |
| 1/4 SB | 43.15 | 28.04 |
| 1/2 SB | 47.28 | 32.44 |
| 1/5 BB | 34.32 | 43.54 |
| 1/4 BB | 53.05 | 25.54 |
| 1/2 BB | 60.25 | 44.14 |
| LSD (0.05) | 3.39 | 3.21 |
| CV (%) | 3.8 | 4.5 |

### *4.2.2 Bulb Diameter*

There weas significant (P>0.05) difference between treatments in bulb diameter in both experiments. At Mampong experiment, Table 4.9 shows that SB had the highest bulb diameter (5.42 cm) followed by 1/2 BB (5.32 cm) and least bulb diameter (3.12 cm) was 1/5 BB. At Hohoe, 1/5 SB had maximum bulb diameter (5.16 cm) followed by SB (4.55 cm) and least bulb diameter (2.16 cm) was 1/4 BB. However, no significant difference was observed between Onion Seed and 1/2 SB and also SB, BB, 1/4 BB and 1/2 BB were similar (P > 0.05) and that of 1/5 SB and 1/5 BB were also similar in bulb diameter at Mampong. At Hohoe there was also no significant difference between Onion seed and BB as well as 1/4 BB, 1/4 SB and 1/2 SB in diameter (Table 4.9).

**Table 4.9: Bulb diameter of onion at Mampong and Hohoe 60 DAP as affected by bulb size and cutting.**

| | Bulb Diameter (cm) | |
|---|---|---|
| Treatments | Mampong | Hohoe |
| Onion Seed | 4.47 | 3.67 |
| SB(20-40 mm) | 5.42 | 4.55 |
| BB(40-60 mm) | 5.21 | 3.66 |
| 1/5 SB | 3.22 | 5.16 |
| 1/5 SB | 3.72 | 2.44 |
| 1/2 SB | 4.62 | 2.76 |
| 1/5 BB | 3.12 | 4.16 |
| 1/4 BB | 5.12 | 2.16 |
| 1/2 BB | 5.32 | 4.46 |
| LSD (0.05) | 0.36 | 0.61 |
| CV (%) | 4.6 | 9.6 |

### *4.2.3 Bulb Yield*

Table 4.10 shows that there was a significant difference between treatments in the bulb yield in to 3.65 t/ha in both experiments. The BB was considered as the most productive with its best yield of (3.65 t/ha) at Mampong and 1/5 BS (3.28 t/ha) at Hohoe. In the second place was SB (3.37 t/ha) and (2.66 t/ha) and 1/2 BB in the third place (3.01 t/ha) and (2.18 t/ha) respectively at Mampong and Hohoe. both Mampong and Hohoe experiments. Results showed that the yield of onion ranged from 1.27 to 3.28 and 1.72 and 3.65 for Hohoe and Mampong respectively.

**Table 4.10: Bulb yield of onion at Mampong and Hohoe at 60 DAP as affected by bulb size and cutting.**

| Treatments | Bulb Yield (t/ha) | |
|---|---|---|
| | Mampong | Hohoe |
| Onion Seed | 2.60 | 2.05 |
| SB (20-40 mm) | 3.37 | 2.66 |
| BB (40-60 mm) | 3.65 | 1.82 |
| 1/5 SB | 1.95 | 3.28 |
| 1/4 SB | 2.16 | 1.40 |
| 1/2 SB | 2.40 | 1.64 |
| 1/5 BB | 1.72 | 2.17 |
| 1/4 BB | 2.65 | 1.27 |
| 1/2 BB | 3.01 | 2.18 |
| LSD (0.05) | 0.43 | 0.31 |
| CV (%) | 9.4 | 8.9 |

# CHAPTER FIVE

# 5.0 DISCUSSION

## 5.1 Climatic conditions during the experimental period

The climatic data obtained during the experimental period showed high values for both the average temperature and average rainfall and could have impacted on plant growth and development. According to Khokar *et al.* (2002), when temperature is above 30ºC and more than 80% relative humidity, it causes reduction in onion yield. Temperature ranged between 18 - 22°C can aid vegetative growth, but will slow bulbing rate. In order for proper and faster bulbing to occur right from bulb initiation to harvesting, temperature ranges between 25 - 28°C is required (SAKATA, 2014). The performance and development of the onion plant at every phase of growth is primarily controlled by temperature (Ansari, 2007; Abu-Rayyan & Abu-Irmaileh, 2004; Coolong & Randle, 2003).

## 5.2 Soil Analysis

The results of the soil analysis are presented in Table 4.2. The pH values were 6.1 and 6.51 which is slightly acidic according to the rating of Horneck *et al.* (2011). The optimum pH for onion production ranges between 6 and 8 (Nikus & Mulugeta, 2010). Accordingly, the pH of the soil was conducive for onion production. The available phosphorus was medium at both sites which is adequate for onion production. The total nitrogen content of the soil and available potassium for the two soils were low according to the rating of Horneck *et al.* (2011). This shows that application of external source of nitrogen and potassium are important for growing onions. In general, the field soil had low levels of minerals, hence their very low fertility level.

## 5.3 Effect of bulb size and cutting on vegetative growth of onion

### *5.3.1 Percentage Crop Establishment*

Results indicated that the percentage crop establishment was high in both locations; however, Mampong experiment was relatively better in terms of percentage establishment of crop compared to the Hohoe experiment. This was possible because of the regular watering and rainfall received during the growing period of the onion in both locations. Good land preparation combined with correct application of both organic and inorganic fertilizers, as well as the use of good quality planting materials resulted in a higher percentage crop establishment (Tweneboah, 2000). The highest percent of crop establishment (100%) was recorded from large BB and 1/4 of BB, followed by SB and 1/2 SB at 99.34% and the lowest percent of establishment of 55.37% was recorded from 1/5 BB at Mampong. This result confirmed a report by Ali *et al.* (2015) and Muktadir *et al.* (2001) that, highest percentage of crop establishment was obtained from the BB. Increase in crop establishment percentage might be due to high food reserves present in the BB which, in turn, might supply nutrient to the plant.

Different trend was observed in Hohoe. 1/5 BB had the highest crop establishment, followed by 1/5 of SB at 97.94% and 97.60% respectively. These findings are similar to Firmansyah *et al*. (2017) who observed that, treatment cuts of 1/4 slightly cause plants to die (16.3%) at the age of 45 DAP while for cutting bulb at 1/2 increase mortality by 34.3% at 45 DAP. The high percentage of deaths of bulb cut at 1/2 is most likely due to the high contamination of disease caused by the extent of bulb cut.

### *5.3.2 Number of Leaves per plant*

The number of leaves per plant differed statistically between treatments used. 1/2 SB recorded greatest number of leaves, followed by BB and 1/4 BB at Mampong while 1/5 SB and 1/5 BB recorded greatest at Hohoe. The results are similar to reports by Addai *et al.* (2014), Setiawan *et al* (2014), Hussain *et al.* (2001) and Mosleh ud-Deen (2008) indicating that variations obtained in production of number of leaves per plant at different locations, may be attributed mainly to the treatments. The environmental conditions such as rainfall, temperature, and photoperiod might also influence plant leaf production differences between the two locations. This is in agreement with research conducted by Ijoyah *et al.* (2008) that environmental conditions in which plants grow contribute to the development of leaves. Furthermore, the high percentage crop establishment contributed to increase in leaf number per plant. Similar results were obtained by Rizk (1997), who reported that the high percentage crop establishment might also contribute to crop growth and hence the high leaf number per plant.

### *5.3.3 Plant and leaf height*

Results indicated that plant height was significantly different between the treatments. At Mampong, the maximum plant and leaf height was produced by BB (41.34 cm) which was significantly higher than other treatment. Addai and Scott (2011) credited plant height differences to onion bulb size. They confirmed that in onion production the bulbs which are larger produce the maximum vegetative growth. The average sized bulb produce the next highest vegetative growth and the smallest sized bulb produced the lowest vegetative growth. The larger bulb sized onions were again seen to have more carbohydrates, as well as other nutrients than both average and small sized bulbs. Addai *et al.* (2014) and Mosleh (2008), observed similar result in their study. In fact, it has already been established by Tsitsia (2012) that, reserves stored in bulbs are used for the development of newly formed organs and once the leaves mature to become the photosynthetic source, resources may be stored in the old and new leaf bases.This may also be due to the high percentage crop establishment. The findings of this study are similar to those observed by Rizk (1997), who reported that the high percentage crop establishment might have also contributed generally to enhanced crop growth and hence the high plant and leaf height.

At Hohoe 1/5 SB and SB recorded the highest plant height and leaf height values of 34.45 cm, 32.15 cm and 31.92 cm, 29.89 cm respectively. This is in conformity with the work of Ali *et al.* (2015) and Setiawan *et al.* (2014), who reported that, the highest plant height in their study was produced by small bulb size and also cutting bulb by one third can significantly improve or increase plant height comparing to cutting bulb by half.
From the study, Mampong plants were observed to be generally taller than Hohoe plants. This is in conformity with the research conducted by Mohanty and Prusti (2001), who reported that, differences in height of onion plants may not only be due to genetic factors or treatment given to the plant but also to environmental factors, especially temperature, photoperiod and soil characteristics.

### *5.3.4 Neck diameter*

Results of the current study indicated that wide variations in neck diameter were observed between different onion treatments. It was established that, the larger the mother bulb size, the greater the neck diameter. A similar observation has been reported elsewhere by Yemane *et al.* (2013), Tsitsia (2012), Jilani *et al.* (2009) and Dawar *et al.*

(2005) and this was attributed to the relatively higher growth exhibited by plants produced from the big bulbs. The growth parameters decreased with decreasing bulb and cutting size. The difference observed between the parameters of the two locations might also be due to the variation of climate and soil.

## 5.4 Effect of bulb size and cutting on yield and yield component of onion.

### *5.4.1 Fresh bulb weight per plot and Bulb diameter*

The result of the study showed significant differences among the treatments and that bulb size and bulb cutting size influenced bulb weight and diameter. The highest fresh bulb weight per plot and diameter (72.95g, 5.42cm) was recorded from large size bulbs, followed by small size bulb (66.25g, 5.21cm), 1/2 BB at (60.25g, 53.32cm) and the lowest (34.32g 3.12cm) was recorded from 1/5 BB at Mampong. This result confirmed a report by Mosleh (2008), MoIlah *et al.* (1997) and Karim *et al.* (1999), that large mother bulb showed better performance in production of onion weight and diameter compared to that of medium and small mother bulb. The findings in this study is in total agreement with Addai and Anning (2015), who confirmed that highest bulb weight are produced from plants from large bulbs, this he attributed to the numerous leaves such plants possessed.

Deviana *et al*. (2014) state that, cutting of bulb to become four parts produce lower bulb weight and diameter compared to bulb without cutting. Thus in the present study, increase in onion weight and diameter might be due to high food and water reserves present in the large bulb. Different trend was observed in Hohoe. The 1/5 SB had the highest fresh bulb weight and diameter, followed by SB at 65.20g, 5.16cm and 53.54g, 4.55cm respectively. These findings are similar to Jumini *et al.* (2010), who observed that, cutting the bulb into four tended to be better than cutting into three or two parts.

It has been reported by Mohanty & Prusti, (2001), that environmental conditions prevailing in an area may favour some treatments over others and in this results some treatments became relatively more adapted and superior to others at the two different locations.

### *5.4.2 Bulb yield*

Significant variations due to different bulb size and bulb cutting were observed in respect to bulb yield (t\ha). The BB produced the highest bulb yield/ha (3.65 t/ha) which was followed by SB (3.37 t/ha) and the 1/5 BB produced the lowest bulb yield/ha (1.72 t/ha). It was evident that the bulb yield/ha increased with the increase in bulb size at Mampong. For Hohoe, 1/5 SB recorded the highest value (3.28 t/ha) while 1/4 BB recorded lowest value (1.27 t/ha) This result agrees with the findings of Mosleh (2008) and Jumini *et al.* (2010), who reported that onion bulb yield per hectare could be affected by the mother bulb size as well as cutting size. The result of this study also showed variation in yield between the two locations which Mampong generally had the highest yield compared to Hohoe. This result agrees with the findings of Sinnadurai and Abu (1977), which indicated that, yield is very much dependent on the climate during the growing season.

# CHAPTER SIX

## 6.0 CONCLUSION AND RECOMMENDATION

### 6.1 Conclusion

The study has revealed that the size of the bulb used for planting onion is very important for the growth and bulb production of the crop. Large bulb size (40 – 60 mm) resulted in better result at 60 DAP for crop establishment, plant height, fresh bulb weight per plot, and bulb yield. The highest number of leaves per plant and neck diameter were recorded by 1/2 SB.

### 6.2 Recommendation

- Based on the study it is therefore recommend that farmers use large bulb size (40-60 mm in diameter) of 'Bawku red' as planting materials, to obtain good bulb production**.**
- Considering the above-mentioned results, it would be advisable to further investigate on bulb size and bulb cutting potential as planting materials on different onion types at different locations to come up with the best recommendation.
- In addition, plant spacing, fertilizer rate application methods of onion should also be considered.
- It would be also advisable to use sterilized knifes to cut bulb to avoid contamination

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# APPENDICES

## APPENDIX

### Appendix 1: Field layout

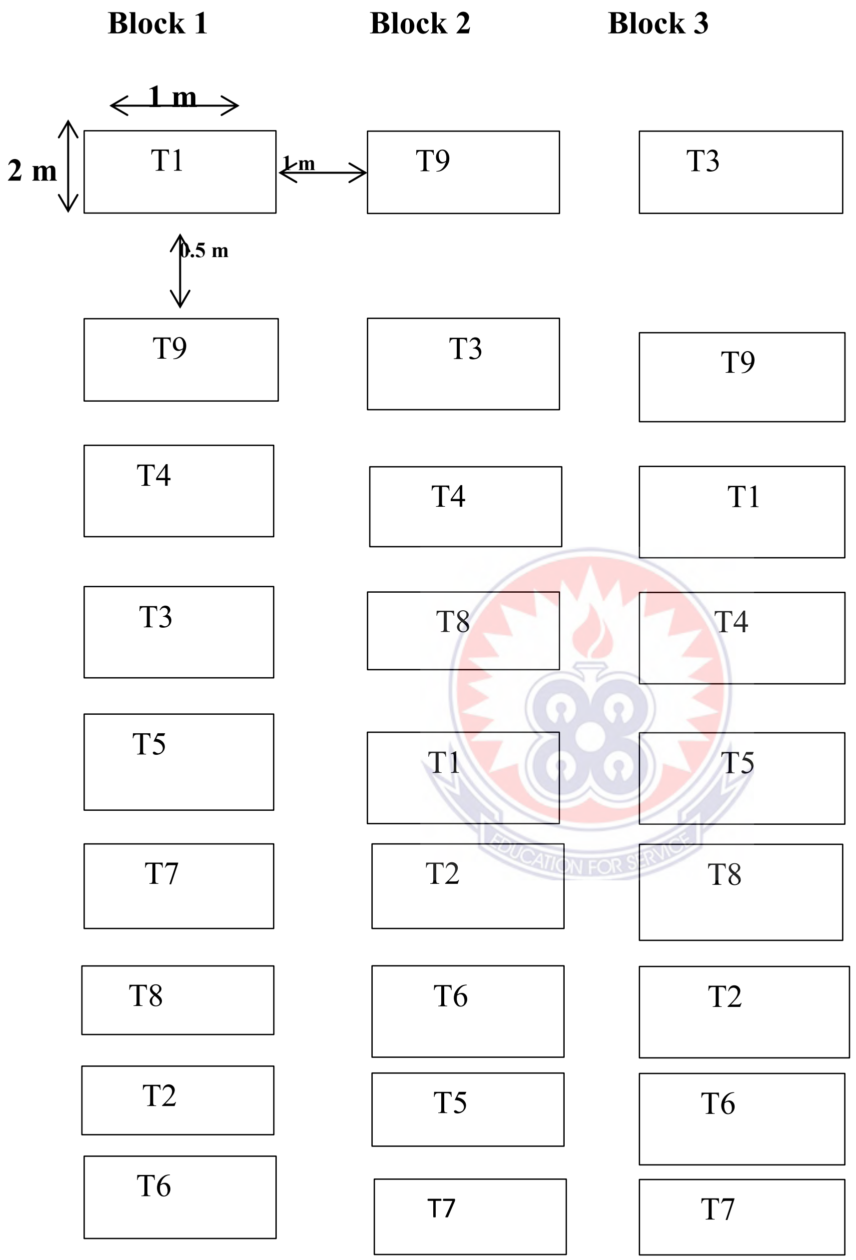



**Figure 1: Field layout**

**Appendix 2: Nutrition fact about onion**

| **Nutrition fact onion** | **Serving Size 1 Medium Onion (100g)** | **Percent Daily Values *** |
|---|---|---|
| Calories | 40 | 0% |
| Total fat | 0.1 | 0% |
| Saturated fat | 0 | 0% |
| Polyunsaturated | 0 | 0% |
| Monounsaturated | 0 | 0% |
| Cholesterol | 0 | 0% |
| Total carbohydrate | 9 | 3% |
| Dietary | 1.7 | 6% |
| Sugar | 4.2 | |
| Protein | 1.1 | 2% |
| Vitamin A | | 0% |
| Vitamin C | | 12% |
| Vitamin D | | 0% |
| Vitamin B-6 | | 0% |
| Sodium | 0.004 | 0% |
| Potassium | 0.146 | 4% |
| Calcium | | 2% |
| Iron | | 1% |
| Magnesium | | 2% |
| Cobalamin | | 0% |

**Percent (%) Daily Values are based on a 2,000 calorie diet. Your Daily Values may be higher or lower depending on your calorie needs*

***Sources:** USDA*

**Appendix 3:** A matured onion plant and longitudinal section of onion showing the various parts

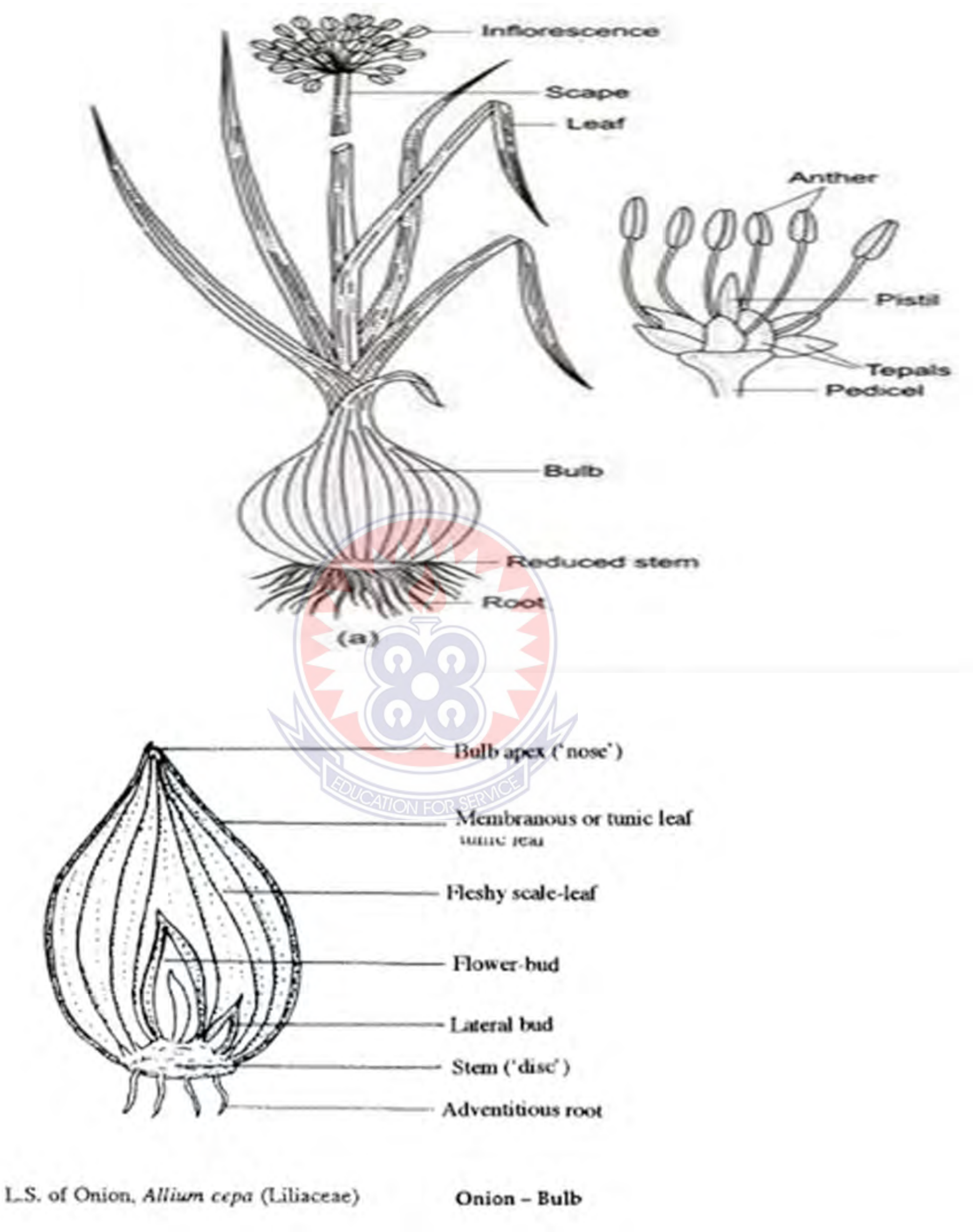



**Figure 2: A matured onion plant and longitudinal section of onion showing the various parts (Brewster, 1994) .**

**Appendix 4: Plant structure of a young onion plant in the vegetative growth stage**

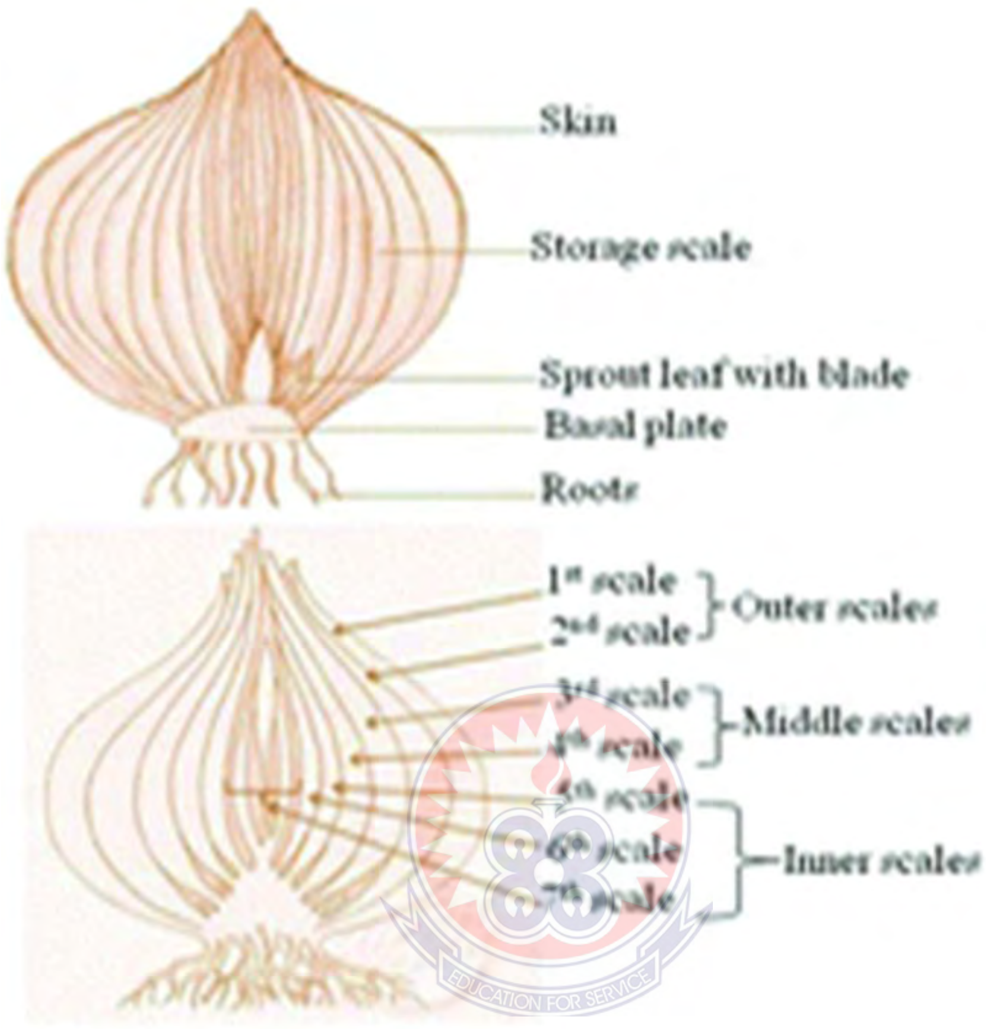



**Figure 3: Plant structure of a young onion plant in the vegetative growth stage (Brewster, 1994)**

**Appendix 5: Different shapes of onion bulb**

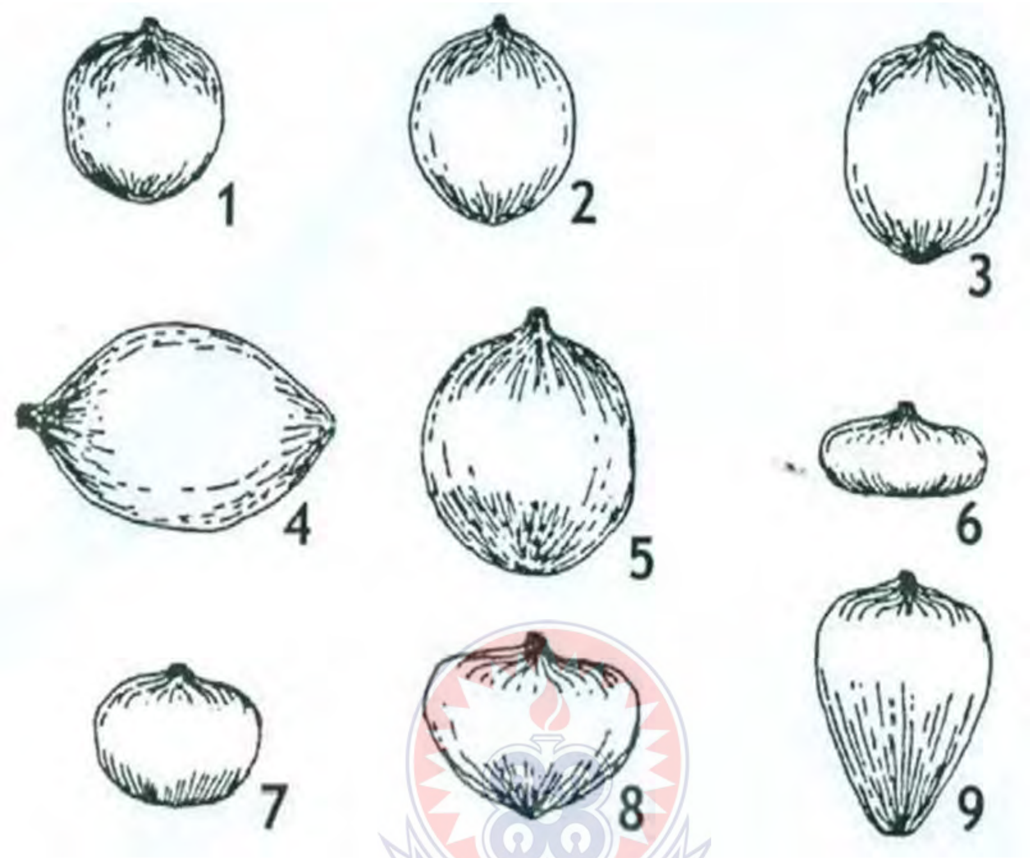



**Figure 4: Different onion bulb shapes (1) Flattened (2) Globe (3) High globe (4) Spindle (5) Spanish (6) Flat (7) Thick flat (8) Granex (9) Top (Boyhan & Kelley, 2008)**

**Appendix 6: Analysis of variance for Mampong experiment**

**Variate: Bulb Diameter (cm) 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 0.80934 | 0.40467 | 9.43 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 3.53946 | 3.53946 | 82.45 | <.001 |
| Cutting | 4 | 15.90531 | 3.97633 | 92.63 | <.001 |
| Size | 2 | 1.19260 | 0.59630 | 13.89 | <.001 |
| Cutting size | 2 | 2.5681 | 1.28391 | 29.91 | <.001 |
| Residual | 15 | 0.64393 | 0.04293 | | |
| Total | 26 | 24.65845 | | | |

**Variate: Crop Establishment (%) 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 29.852 | 14.926 | 2.19 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 623.560 | 623.560 | 91.57 | <.001 |
| cutting | 4 | 5467.458 | 1366.865 | 200.72 | <.001 |
| Size | 2 | 0.375 | 0.188 | 0.03 | 0.973 |
| Cutting size | 2 | 1640.458 | 820.229 | 120.45 | <.001 |
| Residual | 15 | 102.148 | 6.810 | | |
| Total | 26 | 7863.852 | | | |

**Variate: Fresh Bulb weight 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 33.249 | 16.625 | 4.37 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 3901.500 | 3901.500 | 1024.84 | <.001 |
| cutting | 4 | 3403.853 | 850.963 | 223.53 | <.001 |
| Size | 2 | 236.882 | 118.441 | 31.11 | <.001 |
| Cutting size | 2 | 259.152 | 129.576 | 34.04 | <.001 |
| Residual | 15 | 57.104 | 3.807 | | |
| Total | 26 | 7891.740 | | | |

**Variate: Number of leaves 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 0.3822 | 0.1911 | 1.38 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 4.2504 | 4.2504 | 30.68 | <.001 |
| cutting | 4 | 7.4212 | 1.8553 | 13.39 | <.001 |
| Size | 2 | 0.8438 | 0.4219 | 3.05 | 0.078 |
| Cutting size | 2 | 2.3513 | 1.1756 | 8.49 | 0.078 |
| Residual | 15 | 2.0778 | 0.1385 | | |
| Total | 26 | 17.3267 | | | |

**Variate: Plant Height 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 9.857 | 4.929 | 4.34 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 284.396 | 284.396 | 250.49 | <.001 |
| cutting | 4 | 977.069 | 244.267 | 215.14 | <.001 |
| Size | 2 | 75.935 | 37.967 | 33.44 | <.001 |
| Cutting size | 2 | 130.139 | 65.069 | 57.31 | <.001 |
| Residual | 15 | 17.031 | 1.135 | | |
| Total | 26 | 1494.427 | | | |

**Variate: Neck Diameter (cm) 60 days after planting**

| Sourceof variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 0.13709 | 0.06854 | 3.06 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 0.70042 | 0.70042 | 31.24 | <.001 |
| Cutting | 4 | 0.73125 | 0.18281 | 8.15 | 0..001 |
| Size | 2 | 0.00375 | 0.00187 | 0.08 | 0.920 |
| Cutting size | 2 | 0.25125 | 0.12562 | 5.60 | 0.015 |
| Residual | 15 | 0.33631 | 0.02242 | | |
| Total | 16 | 2.16007 | | | |

**Variate: leave height 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 6.402 | 3.201 | 1.87 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 258.727 | 258.727 | 151.41 | <.001 |
| Cutting | 4 | 824.523 | 206.131 | 120.63 | <.001 |
| Size | 2 | 60.167 | 30.083 | 17.61 | <.001 |
| Cutting size | 2 | 111.777 | 55.888 | 32.71 | <.001 |
| Residual | 15 | 25.631 | 1.709 | | |
| Total | 16 | 1287.227 | | | |

**Variate: Bulb Yield (t/h) 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 0.08250 | 0.04125 | 0.67 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 9.59292 | 9.59292 | 156.95 | <.001 |
| Cutting | 4 | 8.76257 | 0.24368 | 35.84 | <.001 |
| Size | 2 | 0.48735 | 0.24368 | 3.99 | 0.041 |
| Cutting size | 2 | 0.60795 | 0.30397 | 4.97 | 0.022 |
| Residual | 15 | 0.91684 | 0.06112 | | |
| Total | 26 | 20.45012 | | | |

**Appendix 7: Analysis of variance for Hohoe experiment**

**Variate: Bulb Diameter 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 0.1996 | 0.0998 | 0.79 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 5.9203 | 5.9203 | 47.07 | <.001 |
| Cutting | 4 | 18.2902 | 4.5726 | 36.35 | <.001 |
| Size | 2 | 0.0840 | 0.0420 | 0.33 | 0.721 |
| Cutting size | 2 | 7.0866 | 3.5433 | 28.17 | <.001 |
| Residual | 15 | 1.8868 | 0.1258 | | |
| Total | 26 | 33.4675 | | | |

**Variate: Crop Estabment (%) 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 14.741 | 7.370 | 1.24 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 115.574 | 115.574 | 19.42 | <.001 |
| Cutting | 4 | 6665.833 | 1666.458 | 0.22 | <.001 |
| Size | 2 | 2.667 | 1.333 | 0.22 | 0.802 |
| Cutting size | 2 | 198.000 | 99.000 | 16.64 | <.001 |
| Residual | 15 | 89.259 | 5.951 | | |
| Total | 16 | 7086.074 | | | |

**Variate: Fresh Bulb weight 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 7.515 | 3.757 | 1.10 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 2699.962 | 2699.962 | 790.37 | <.001 |
| Cutting | 4 | 2425.963 | 606.491 | 177.54 | <.001 |
| Size | 2 | 325.680 | 162.840 | 47.67 | <.001 |
| Cutting size | 2 | 1026.721 | 513.361 | 150.28 | <.001 |
| Residual | 15 | 51.241 | 3.416 | | |
| Total | 26 | 6537.083 | | | |

**Variate: Number of leaves 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 0.38127 | 0.19063 | 3.77 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 4.47207 | 4.47207 | 88.37 | <.001 |
| Cutting | 4 | 7.50167 | 1.87542 | 37.06 | |
| Size | 2 | 1.21500 | 0.60750 | 12.00 | |
| Cutting size | 2 | 0.50833 | 0.25417 | 5.02 | 0.021 |
| Residual | 15 | 0.75913 | 0.05061 | | |
| Total | 26 | 14.83747 | | | |

**Variate: Plant Height 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 5.724 | 2.862 | 2.18 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 455.301 | 455.301 | 347.06 | <.001 |
| Cutting | 4 | 633.957 | 158.489 | 120.81 | <.001 |
| Size | 2 | 47.602 | 23.801 | 18.14 | <.001 |
| Cutting size | 2 | 100.128 | 50.064 | 38.14 | <.001 |
| Residual | 15 | 19.678 | 1.312 | | |
| Total | 26 | 1262.389 | | | |

**Variate: Neck Diameter (cm) 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 0.07187 | 0.03594 | 0.79 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 1.28652 | 1.28652 | 28.33 | <.001 |
| Cutting | 4 | 0.32301 | 0.08075 | 1.78 | 0.186 |
| Size | 2 | 0.29704 | 0.14852 | 3.27 | 0.066 |
| Cutting size | 2 | 0.11668 | 0.05834 | 1.28 | 0.305 |
| Residual | 15 | 0.68113 | 0.04541 | | |
| Total | 26 | 2.77625 | | | |

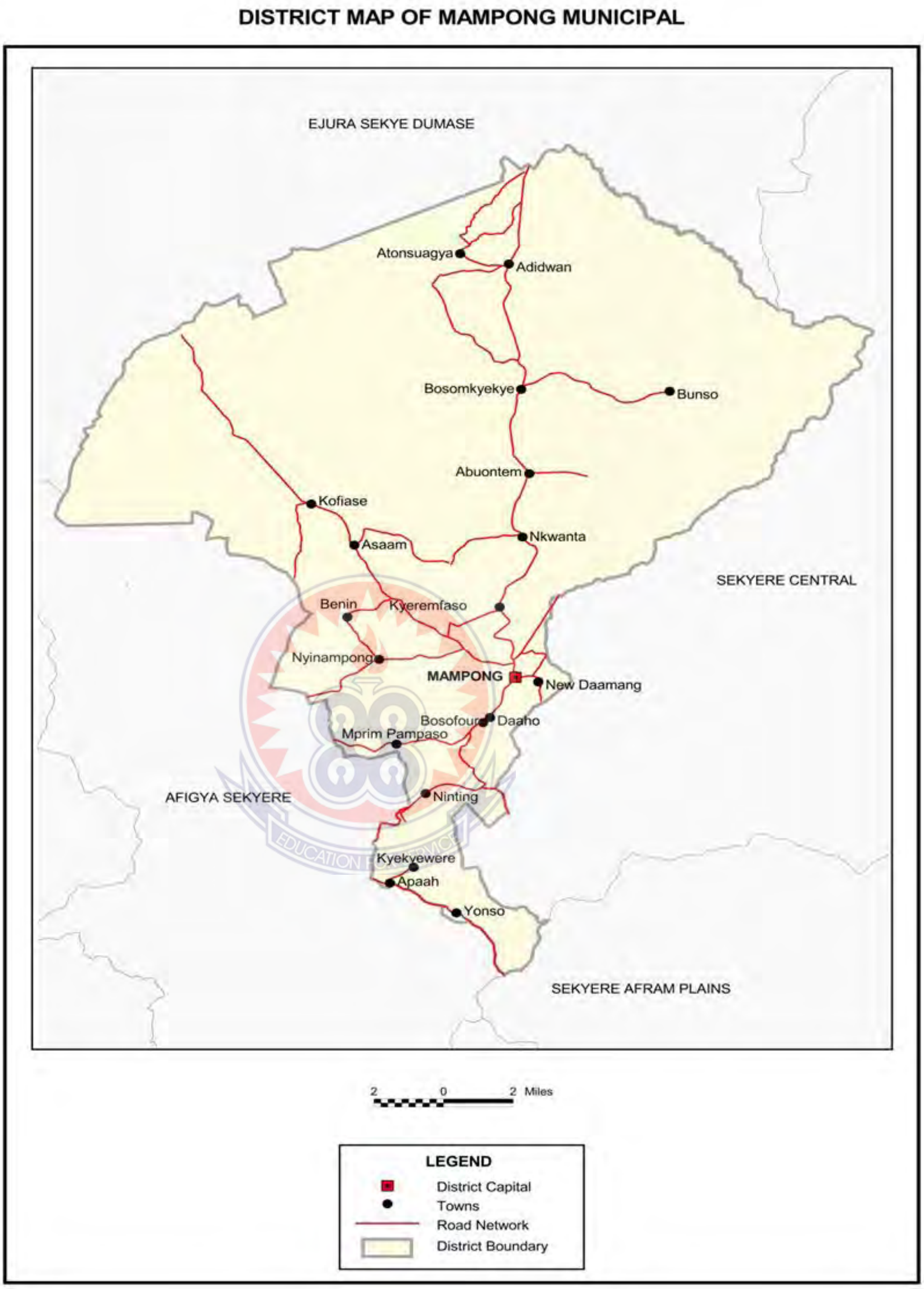
**Variate: leave Height 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 13.1523 | 6.5761 | 14.41 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 416.5833 | 416.5833 | 912.55 | <.001 |
| Cutting | 4 | 678.7000 | 169.6750 | 371.68 | <.001 |
| Size | 2 | 26.8605 | 13.4303 | 29.42 | <.001 |
| Cutting size | 2 | 141.1262 | 70.5631 | 154.57 | <.001 |
| Residual | 15 | 6.8476 | 0.4565 | | |
| Total | 26 | 1283.2700 | | | |

**Variate: Bulb Yield 60 days after planting**

| Source of variation | d.f | s.s | m.s | v.r | Fpr. |
|---|---|---|---|---|---|
| REP stratum | 2 | 0.14223 | 0.07111 | 2.15 | |
| REP.*Units* stratum | | | | | |
| Onion | 1 | 6.73807 | 6.73807 | 203.27 | <.001 |
| Cutting | 4 | 6.11995 | 1.52999 | 46.15 | <.001 |
| Size | 2 | 0.87784 | 0.43892 | 13.24 | <.001 |
| Cutting size | 2 | 2.46365 | 1.23182 | 37.16 | <.001 |
| Residual | 15 | 0.49724 | 0.03315 | | |
| Total | 26 | 16.83896 | | | |

## Appendix 8: Map showing the location of Ashanti- Mampong




***Source:*** *Ghana Statistical Service, GIS*

**Figure 5: Map showing the location of Ashanti- Mampong**

## Appendix 9: Map showing the location of Hohoe


***Source:*** ***Ghana Statistical Service, GIS***

**Figure 6: Map showing the location of Hohoe**

**Appendix 10: Map showing the ecological zone of Ghana**

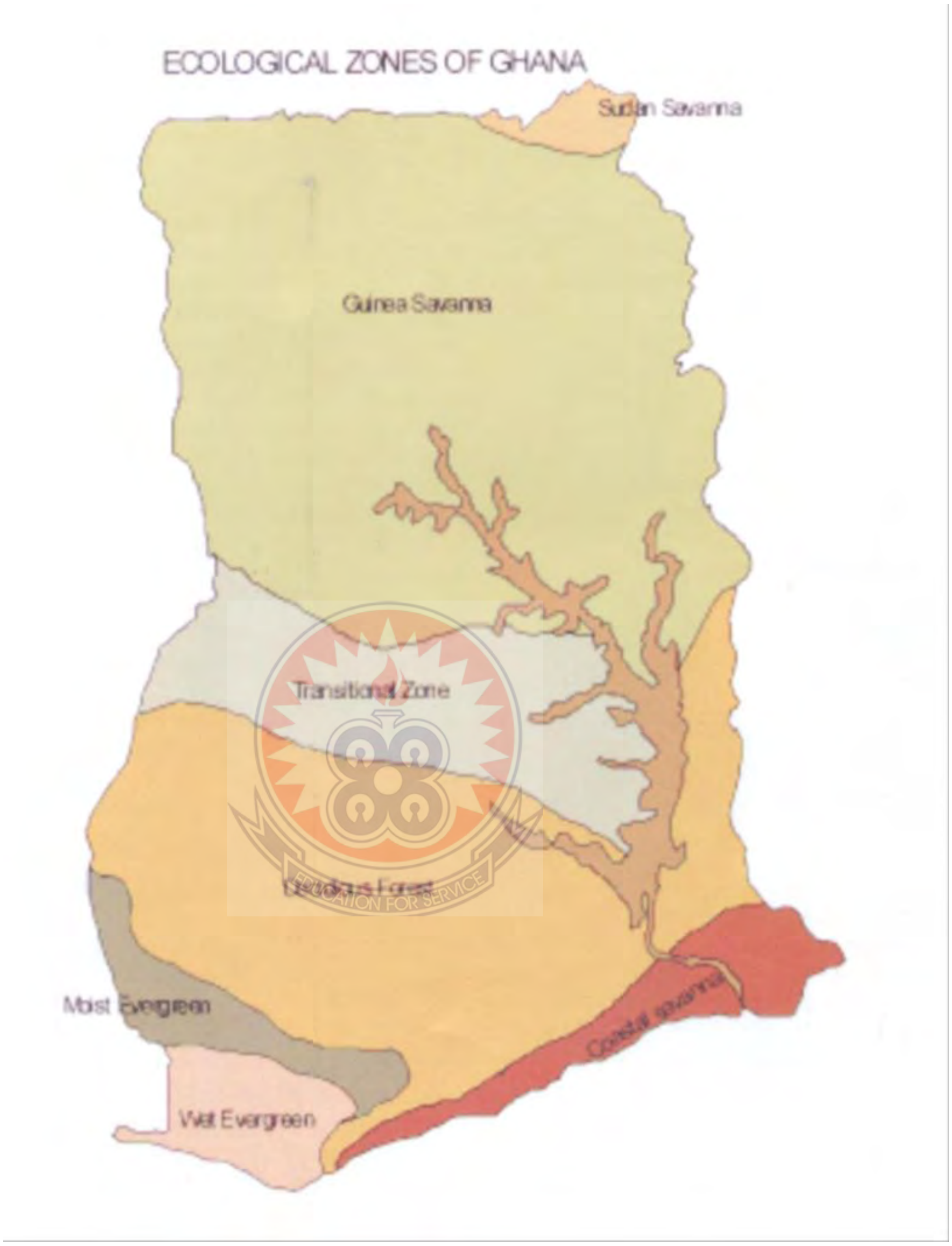
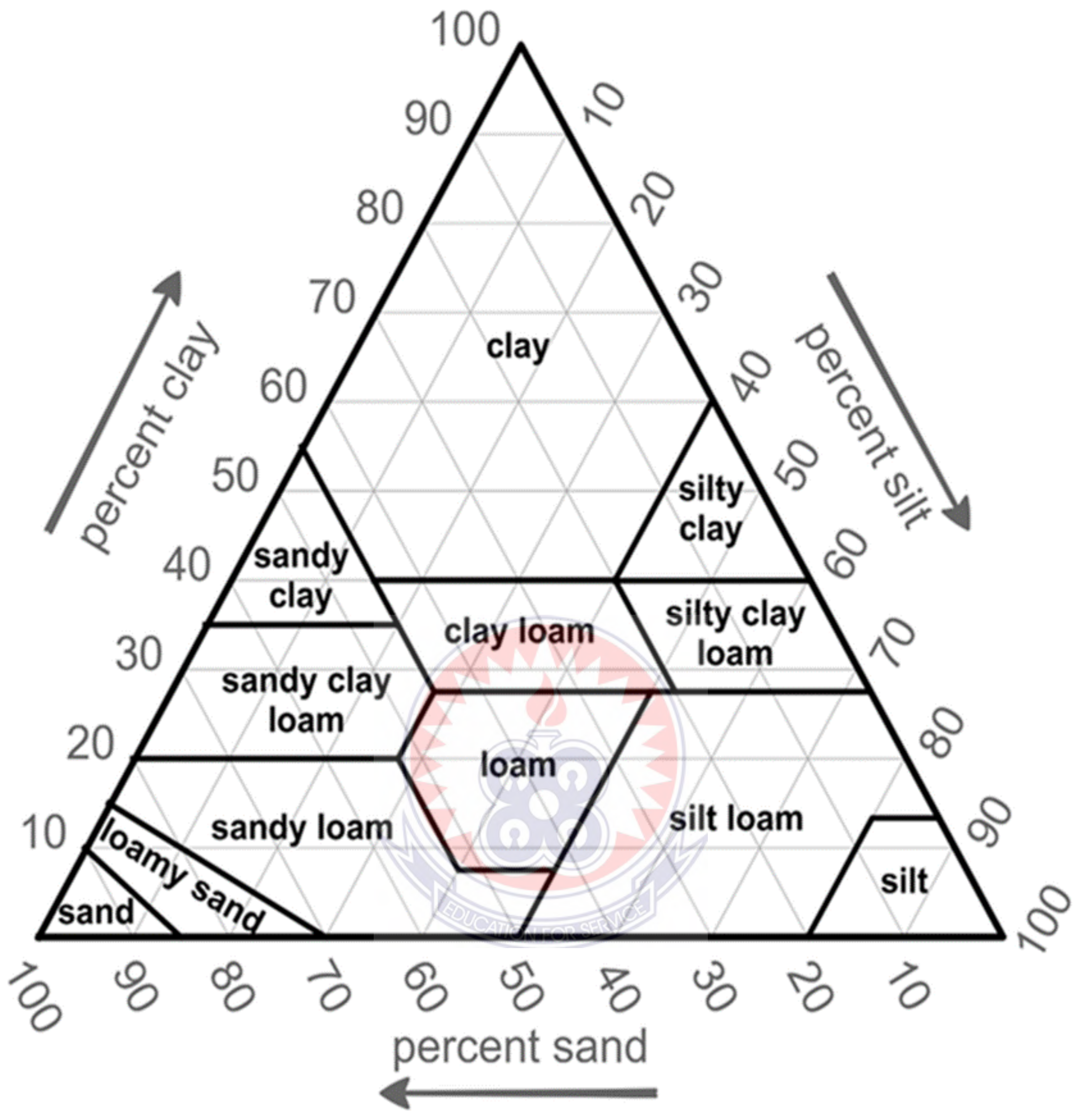



**Figure 7: Map showing the ecological zones of Ghana**

**Appendix 11: Soil texture triangle**




***Source:*** *USDA textural triangle*

**Figure 8: Soil texture triangle**

## Appendix 12: Soil test interpretation guide

**Soil PH (water)**

| Rating | Interpretation |
|---|---|
| below 5.1 | Strongly acid |
| 5.2-6.0 | Moderately acid |
| 6.1-6.5 | Slightly acid |
| 6.6-7.3 | Neutral |
| 7.4-8.4 | Moderately alkaline |
| Above 8.5 | Strongly alkaline |

***Source:*** *Horneck et al. (2011).*

**Residual Soil Nitrate-nitrogen for evaluating N management.**

| Rating | $NO_3$-N in surface foot (ppm) |
|---|---|
| Low | <10 |
| Medium | 10-40 |
| High | 30-100 |
| Excessive | >30 |

***Source:*** *Horneck et al. (2011).*

**Soluble salts determined from a saturated paste extract.**

| Rating | EC (mmhos/cm)* | ppm salt† | Suitability for crop production |
|---|---|---|---|
| low | <1.0 | <640 | Suitable |
| Medium | 1.0–2.5 | 640–1,600 | Marginal |
| High | >2.5 | >1,600 | Poor, unsuitable for many crops |

Note: Some laboratories determine EC using a 1:1 or 2:1 ratio of water to soil, which provides a substantially lower value than the saturated paste extract. No relationship has been established for converting 1:1 or 2:1 EC to saturated paste EC. * mmhos/cm is equivalent to deci-siemen/m (dS/m) and milli-siemen/cm (mS/cm). † Multiply mmhos/cm by 640 to estimate ppm salt.

**Source:** Horneck *et al.* (2011)

**Phosphorus (P) soil test categories and suggested fertilizer rate recommendations.**

| Rating | West of Cascades Bray P1 test P (ppm) | East of Cascades Olsen test P (ppm) | Recommendation(lbP2O5/acre) |
|---|---|---|---|
| low | <20 | <10 | 0–300 |
| Medium | 20-40 | 10-25 | 0-200 |
| High | 40-100 | 25-50 | 0-30 |
| Excessive | >100 | >50 | 0 |

***Source:** Horneck et al. (2011).*

**Extractable potassium (K) soil test categories and suggested fertilizer rate recommendations.**

| Rating | Extractable or soil test K | Recommendation (lb K2O/acre |
|---|---|---|
| Low | <150 ppm*<br><0.4 meq/100 g soil | 100–300 |
| Medium | 150–250 ppm<br>0.4–0.6 meq/100 g soil | 60–250 |
| High | 250–800 ppm<br>0.6–2.0 meq/100 g soil | 0 |
| Excessive | >800 ppm | 0† |

** For ammonium acetate or sodium bicarbonate extraction method. † When extractable K is excessive, determine soil and irrigation water electrical conductivity.*

***Source:*** *Horneck et al. (2011)*

**Extractable magnesium (Mg) soil test categories and suggested fertilizer rate recommendations.**

| Rating | Extractable or soil test Mg | Recommendation (lb Mg/acre |
|---|---|---|
| Low | <60 ppm<br><0.5 meq/100 g soil | 10–10 |
| Medium | 60–300 ppm<br>0.5–2.5 meq/100 g soil | 0–60 |
| High | >300 ppm<br>>2.5 meq/100 g soil | 0 |

***Source***: *Horneck et al. (2011).*

**Extractable Calcium (Ca)**

| Rating | Extractable or Soil test Ca (ppm) |
|---|---|
| Low | <1000 ppm<br><5meq/100 g soil |
| Medium | 1000 – 2000<br>5meq/100 g soil |
| High | >180 ppm<br>>1.5 meq/100 g soil |

***Source:*** *Horneck et al. (2011).*

**Ratings for DTPA extractable micronutrient soil test levels.**

| Soil Test Rating | Zinc | Iron | Manganese | Copper |
|---|---|---|---|---|
| Low | 0-0.5 ppm | 0-2.0 ppm | 0-1.0 ppm | 0-0.2 ppm |
| Medium | 0.5-1.0 ppm | 2.1-4.5 ppm | - | - |
| High | 1.0+ | 4.6+ | 0.1+ | 0.2+ |

***Source:*** *Horneck et al. (2011).*

**Sulfate-sulfur soil test categories and suggested fertilizer rate recommendations**

| Rating | Soil test sulfate-S (ppm) | Recommendation (lb S/acre) |
|---|---|---|
| Very low | <2 | 30–60 |
| Low | 2–5 | 10–30 |
| Medium | 5–20 | 0–20 |
| High | >20* | 0 |

** When sulfate-S soil test values are high, determine soil and irrigation water electrical conductivity.*

***Source:*** *Horneck et al. (2011)*

**Extractable boron (B) soil test categories and suggested fertilizer rate recommendations.**

| Rating | Soil test B (ppm) | Recommendation (lb B/acre)* |
|---|---|---|
| Very low | <0.2 | 1–3 |
| Low | 0.2–0.5 | 0–3 |
| Medium | 0.5–1 | 0–1 |
| High | 1–2 | 0 |
| Excessive | >2† | 0 |

** Do not apply B in a concentrated area such as a fertilizer band. † When soil test B is excessive, determine soil and irrigation water electrical conductivity and B in irrigation water.*

***Source:*** *Horneck et al. (2011).*

**Chloride (Cl) soil test categories and suggested fertilizer rate recommendations.**

| Rating | Soil test Cl (ppm) | Recommendation(lbpotassium chloride [0-0-60]/acre) |
|---|---|---|
| Very low | 0–5 | 0–150 |
| Low | 5–10 | 0–150 |
| Medium | 10–20 | 0–50 |
| High | 20–50 | 0 |
| Excessive | >50* | 0 |

** When soil test Cl is excessive, determine soil and irrigation water electrical conductivity and B in irrigation water.*

***Source:*** *Horneck et al. (2011).*

**Base saturation**

Base saturation is the percentage of the soil CEC that is occupied by basic cations (calcium, magnesium, potassium, sodium) at the current soil pH value. Base saturation and CEC are nearly equivalent (base saturation is 100 percent) when soil pH is near 7. An acidic soil has a base saturation of about 50 percent when the soil pH is about 5. Since base saturation is simply an indirect expression of soil pH, it is not required for making fertilizer or lime recommendations. In acidic soils, base saturation and soil pH change simultaneously. Liming increases base saturation and soil pH. Sulfur application will reduce base saturation and pH. Base saturation is not a useful concept in alkaline soils, where base saturation equals or exceeds 100 percent Horneck *et al.* (2011).