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Age Of Transplant And Row Spacing Effects On The Performance Of Onion (Allium Cepa L.)

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***Abstract:** Three field experiments were conducted for three years (2011, 2012 and 2013) at the Multipurpose crop nursery of the University of Education, Winneba, Mampong- Ashanti campus from May to September to evaluate the effects of three transplanting ages (30, 37 and 44 days) and three row spacing (20 x 15 cm, 30 x 15 cm, and 40 x 15 cm) on the growth and yield of Bawku red variety of onion. The experimental design used was a 3 x 3 factorial arranged in randomized complete block design with three replicates for all the three experiments. The results show that 44 aged transplant produced the highest number of leaves per plant, plant height and shoot dry weight per plot at 49 and 63 DAT during the 2011 and 2013 cropping seasons. The 44 aged transplants differed significantly from 30 and 37 aged transplant in number of plants harvested, number of bulb per plot, yield of marketable bulb, average bulb diameter and total bulb yield during the 2011 cropping season. The 20 x 15 cm row spacing produced the highest number of leaves per plant, shoot dry weight per plot, tallest plant height, highest number of plants harvested, number of bulb per plot, average bulb diameter, yield of marketable bulb and total bulb yield for the three year cropping seasons. In conclusion farmers are encouraged to grow 44 aged transplants of Bawku red variety of Onion with row spacing 20 x15 cm for maximum marketable yield.*

***Keywords:** Age of transplant, row spacing, onion, marketable bulb, bulb diameter*

I. INTRODUCTION

Onion (*Allium cepa* L.) belongs to the family of Alliaceae. It is ranked second in value in the list of cultivated vegetable crops Shaibu *et al*., (2015). The area under its cultivation is 3.44 million hectares and its total annual production in the world is 61.6 million tonnes Adsul *et al*., (2008). It is also regarded as one of the most important commercial vegetable cultivated in Ghana Dapaah *et al*., (2014). Even though the transition zone has very conducive soil and climatic conditions for its production, commercial onion production is concentrated in the Guinea savannah and coastal savanna agro-ecological zones of Ghana Dapaah *et al*., (2014). Onion is widely used in Ghana and many parts of the world as a vegetable for flavouring and seasoning foods, and for medication. The bulbs make an important contribution to human diet, having vitamins, flavonoids, macro and micro elements Jurgiel-Malecka and Suchorska-Orlowska, (2008). Onions form an essential part of the daily diet, creating all year round demand and consequently a major source of income to farmers Abbey and Oppong-Konadu, (1997). In Ghana more than 15,000 ha land area was planted to onion in 2012 (SRID, 2012), nevertheless the country imported more than half of its requirements from West African sub- region such as Burkina Faso and Niger to complement the quantity produced GNA, (2012). Onion yields in Ghana are low and extremely variable compared to those of other countries in Africa and elsewhere (Shaibu *et al*., 2015). The comparatively lower onion bulb yields in Ghana could be mainly being attributed to inappropriate agronomic practices and lack of genetically-improved progagules Abbey and Oppong-Konadu, (1997). Age of transplant and plant population density (spacing) (Bosekeng and Coetzer, 2014) are major factors that influence the vegetative growth of onions. Onion is one of the vegetable crops that are very sensitive to transplanting ages Bosekeng and Coetzer, (2014). The cultivar, soil type couple

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with the crop's micro-climate may result in variable growth and yield responses. It is therefore important that all planting start with the correct transplant age. The use of older aged transplants results in serious effects in terms of its normal development Vavrina, (1998). Following transplanting, older plants have only a limited time for the modification of their vegetative development before the onset of reproductive growth or the maturation of the vegetative phase Vavrina, (1998). Some researchers are of the view that the yield of late sown plants will be lower than earlier sown plants because leaf blade production changes to bulb initiation whereas leaf area index and light interception is still Brewster, (2008). Older transplants generally result in earlier yields while younger transplants will produce comparable yields, but take longer to do so Vavrina, (1998).

Plant spacing influences bulb size (Rumpel and Felczyski, 2000), bulb yield (Kanton *et al*., 2002), bulb shape (Hygrotech, 2010) and bulb mass and quality Bosekeng and Coetzer, (2014). As plant population increases, onion bulb yield also increases because the leaf canopy intercepts more light Brewster, (2008). Increasing plant population will increase bulb yield of onions up to a point below and beyond which further increase in plant population will result in a yield penalty Rumpel and Felczyski, (2000). Closer spacing however, results in higher competition and produces least response for plant height in onion Khan *et al.*, (2002). In Ghana little research work has been done on plant density effect on yield of onion and not much on ages of transplanting of seedlings. Most onion farmers continue to transplant seedlings in the field with undetermined spacing. The spacing between rows and plants is determined by individual farmers just in the process of transplanting as per their own idea and perception. Farmers pointed out that, practicing the recommended spacing in the field is impossible due to its additional labour and time requirement. There is paucity of information on the suitability of onions in different soils and climatic environment in Ghana, therefore creating a wide information gap for onion farmers in the selection of suitable ages of transplant and row spacing for optimum performance in different soils and climates. The study was therefore undertaken to investigate the effects of transplanting ages and row spacing on the growth and yield of Bawku red variety of onion.

II. MATERIALS AND METHODS

A. DESCRIPTION OF STUDY AREA

Three field experiments were conducted at the Multipurpose crop nursery of the University of Education, Winneba, Mampong- Ashanti campus for three consecutive years (2011, 2012 and 2013) during the major rainy seasons from May to September. The soil type is the savanna ochrosol formed from the Voltaian sandstone of the Afram plains. Texturally, the soil is friable with a thin layer of organic matter and is deep and brown-sandy loam and well-drained. It however has a good water holding capacity. The soil has been classified by FAO / UNESCO legend as Chronic Luvisol and locally as the Bediesi series with a pH range of 4.0-6.5.

The weather conditions during the experimental periods show that differences in climatic factors (rainfall, temperature and relative humidity) were observed between cropping seasons. In the 2011 cropping season, the total monthly rainfall was 738.7 mm and it occurred from May to September with the peak in June and July (Table 1). The mean monthly temperature of the site for the 2011 cropping season ranged between 21.7°C to 32.7°C, with the highest daily of 32.7°C occurring in May. The mean monthly relative humidity ranged from 60.0 to 98.0 % with the peak occurring between June and September.

In the 2012 cropping season, the total monthly rainfall was 926.4 mm and it occurred from May to September with the peak in June (Table 1). The mean monthly temperature of the site for the 2012 cropping season ranged between 21.9 °C to 31.4 °C, with the highest daily of 31.4°C occurring in May. The mean monthly relative humidity ranged from 63.0 to 98.0 % with the peak occurring in June and September. For the 2013 cropping season, the total monthly rainfall was 686.1 mm and it occurred from May to September with the peak in May and September (Table 1). The mean monthly temperature of the site for the 2013 cropping season ranged between 21.5°C to 48.3°C, with the highest daily of 48.3°C occurring in July. The mean monthly relative humidity ranged from 63.0 to 97.0 % with the peak occurring in May, July and September.

B. EXPERIMENTAL DESIGN, PLANTING AND FERTILIZATION

The experimental design was a 3 x 3 factorial arranged in randomized complete block design (RCBD) with three replicates made up of three transplanting ages (30, 37 and 44 days) and three row spacing (20 x 15cm, 30 x 15cm, and 40 x 15cm) was assign to each block. The total field size of 18.8 m x 10.8 m (203.04 m^2) was cleared followed by ploughing and harrowing as there were no stumps. Each plot measured 2.4 m x 2.25 m, 3.6 m x 2.25 m and 4.8 m x 2.25 m based on the respective row spacing. Bawku red variety of onion was used. Each plot had 4 rows of 60 plants and 26 record plants. Inorganic mineral fertilizer, NPK (15:15:15) was applied to all plants two weeks after transplanting (WAT) at 300 kg/ha Norman, (1992).

Month	Total monthly Rainfall (mm)			Mean monthly Relative humidity (%) (hours GMT)						Mean monthly temperature (^oC)					
				06.00	06.00	06.00	15.00	15.00	15.00	Minimum			Maximum		
	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013
May	100.1	270.8	207.4	96	96	97	60	63	63	23.0	23.0	22.7	32.7	31.4	31.6
June	244.4	379.8	114.9	97	97	96	68	71	71	22.3	22.6	22.6	30.5	29.5	30.0
July	178.6	178.6	138.0	97	96	97	71	71	71	21.7	21.9	21.9	28.9	28.2	48.3
August	60.0	93.8	6.0	97	96	95	70	71	71	21.8	21.9	21.5	28.5	28.2	27.7
September	155.6	3.4	219.8	98	98	97	73	70	70	22.3	22.5	22.9	29.4	28.9	29.6
Total	738.7	926.4	686.1												

(Meteorological Department – Mampong Ashanti, 2011, 2012, 2013)

Table 1: Climate data for 2011, 2012 and 2013 Experimental periods

C. DATA COLLECTION AND ANALYSIS

Number of leaves per plant was counted on three plants from the two central rows, plant height was measured on three plants, while three plants were randomly sampled for the shoot dry weight. Data were collected at three weeks after transplanting and at two weeks interval. Number of plants harvested, total bulb yield and yield components including bulb diameter, yield of marketable and unmarketable bulbs were estimated from the two central rows. Marketable and unmarketable bulb diameter were classified as bulbs diameter less than (<) 3 cm as unmarketable and the bulbs greater than (>) 3 cm as marketable using the standard procedure described by CRI-CSRI (2003). Data analysis was done using analysis of variance and Statistical Analysis System software, version 9.0 SAS, (2002). Least significant difference (LSD) was used to separate means at 5% level of probability.

III. RESULTS AND DISCUSSION

A. GROWTH PERFORMANCE

a. NUMBER OF LEAVES PER PLANT

The production of leaves per plant was affected as all the ages of transplant had recorded increase in leaf number in each year. The 44 aged transplants differed significantly from 30 and 37 aged transplants in number of leaves per plant for the entire 2011 cropping season (Fig. 1). This might be due to older aged transplants used. The result was similar to the findings of (Vavrina, 1998) that older plants have only a limited time for the modification of their vegetative development before the maturation of the vegetative phase. However, 30 and 37 aged transplants produced the same number of leaves per plant at 63 days after transplanting (DAT). The 30 and 44 aged transplants produced the same number of leaves per plant at 21, 35, and 63 DAT during the 2012 cropping season. There was a significant difference between 30 aged transplants and the other aged transplant in number of leaves per plant at 49 DAT at the same period (Fig. 1). This might be due to early aged transplants used. The result agrees with (Cramer, 2003) that early sown plants have longer vegetative growth period than late sown plants resulting in high number of leaves per plant. There was no significant difference between ages of transplant in number of leaves per plant from 21 to 49 DAT during the 2013 cropping season. The result is similar to the findings of (Vachhani and Patel, 1990) that number of leaves of onions was not significantly affected by ages of seedlings at transplanting. The 37 and 44 aged transplants which produced the same number of leaves per plant differed significantly from 30 aged transplants at 63 DAT during the 2013 cropping season (Fig. 1). The result however, contradicts those found by Vavrina, (1998).

In the case of row spacing, there was no significant difference between spacing treatments in number of leaves per plant for the three year cropping periods although 20 x 15 cm and 30 x 15 cm produced the highest number of leaves per plant at 63 DAT during the 2011 and 2013 cropping seasons respectively. The 40 x 15 cm had the lowest number of leaves per plant at 63 DAT during the 2012 and 2013 cropping seasons (Fig. 1). The result however, contradicts those found by (Kahsay et al., 2014) that increasing plant density resulted in reduction in number of leaves because of shortage of mineral nutrients, light, moisture and space.

b. PLANT HEIGHT

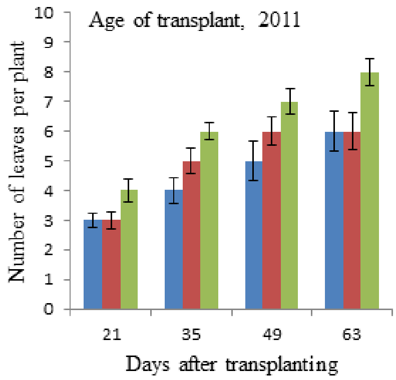
The plant height responded significantly to variation in ages of transplant during the three year cropping seasons. There was a significant difference between 44 aged transplants from 30 and 37 aged transplants in plant height from 21 to 49 DAT during the 2011 cropping season (Fig. 2). This might be due to older aged transplants used. This result is similar to the findings of (Lannoy, 2001) that it is better to transplant onion seedlings after 45 and 55 days when they have 5 or 6 leaves and are about 15 cm in height. Similar result was reported by (Umar et al., 2000) that plant height ranged from 37, 44, and 49 cm at 40, 50 and 60 days after transplanting. However, plant height was not significantly affected by age of transplant at 63 DAT at the same cropping period. In the 2012 cropping season, the 30 aged transplants differed significantly from 37 and 44 aged transplants in plant height for the entire growing period. This might be due to the early aged transplants used that led to longer vegetative growth. This result agrees with those found by (Cramer, 2003) that early sown plants were taller than late sown plants due to a longer vegetative growth period. There was a significant difference between 37 aged transplants from 30 and 44 aged transplants in plant height for the entire 2013 cropping season (Fig. 2). This might be due to differences in ages of transplanting and its response to differences in climatic condition experienced during the cropping periods. This agrees with (Yemane et al., 2013) that onion cultivar performs differently under diverse agro-climatic conditions. The performance of an onion cultivar depends on the interaction of genetic makeup and environment Jilani and Ghaffor, (2003).

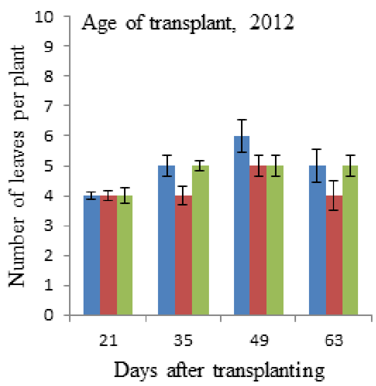
In the case of row spacing 30 x 15 cm produced the highest plant height for the entire 2011 cropping season (Fig. 2). This might be due to wider spacing of transplants. This agrees with the findings of (Khan et al., 2003) that closer spacing results in higher competition thereby producing least response for plant height in onion. The 20 x 15 cm spacing differed significantly from 30 x 15cm and 40 x 15 cm in plant height for the entire 2012 cropping season (Fig. 2). This might be due to closer spacing of transplants, initial high rainfall experienced during the cropping season and plants' competition for sunlight. The plants ability to grow tall enhanced its capability to exploit light to the maximum in the denser plant population. This substantiates the findings of (Dawar et al., 2007) that plant height increased significantly as plant population increased. The 40 x15 cm spacing produced the lowest plant height for the entire 2011 and 2012 cropping seasons. The reduction in plant height might be due to wider spacing. This result however, contradicts those found by (Khan et al., 2002) that closer spacing result in higher competition; it produced least response for plant height in onion, as it was in the case of (Karaye and Yakubu, 2006) that there was the possible of competition for soil moisture and nutrients. There was no significant difference between spacing treatments in plant height during the 2013 cropping seasons although 30 x 15cm produced the highest plant height at 63 DAT at the same period (Fig. 2).

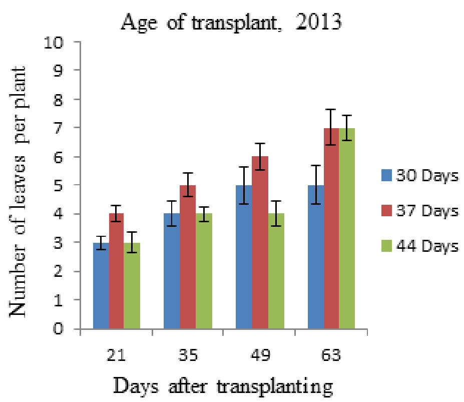
c. *SHOOT DRY WEIGHT PER PLANT*

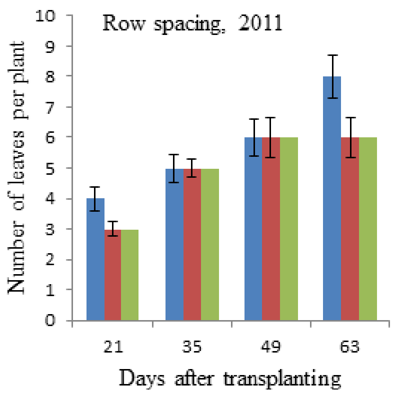
The production of shoot dry weight per plant was affected as all the ages of transplant had recorded increase in shoot dry weight per plant in each year. Shoot dry weight per plant was not significantly influenced by age of transplant from 21 to 35 DAT during the 2011 cropping season (Fig. 3). The 44 aged transplants differed significantly from the 30 and 37 aged transplants in shoot dry weight per plant from 49 to 63 DAT at the same cropping period. This might be due to older aged transplants used. There was a significant difference between 30 aged transplants and the 37 and 44 aged transplants in shoot dry weight per plant from 35 to 63 DAT during the 2012 cropping season. This might be due to early aged transplants used. This substantiates those found by (Cramer, 2003) that early sown plants had longer vegetative growth period which resulted in high number of leaves that intercept more light and eventually increase shoot dry weight. The 37 aged transplants differed significantly from the 30 and 44 aged transplants in shoot dry weight per plant from 49 to 63 DAT during the 2013 cropping season (Fig. 3). This result however, contradicts those found by Vavrina, (1980).

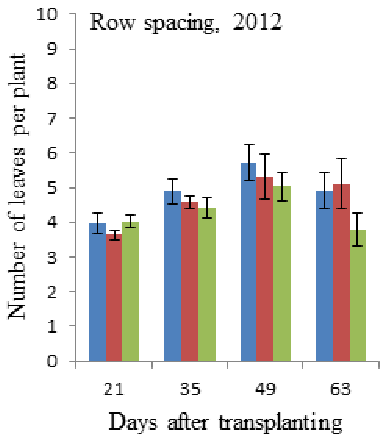
There was no significant difference between spacing treatments in shoot dry weight per plant from 21 to 35 DAT during the 2011 cropping season (Fig. 3). There was a significant difference between 40 x 15cm and 30 x 15cm and the 20 x 15cm in shoot dry weight per plant at 49 DAT during the 2011 cropping season. This was followed by 30 x 15 cm which differed significantly from the other row spacing in shoot dry weight per plant at 63 DAT during the same period.











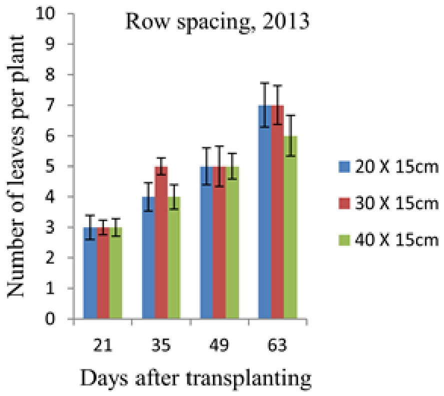


Figure 1: Effect of age of transplant and row spacing on number of leaves per plant of onion during the 2011, 2012 and 2013 cropping seasons

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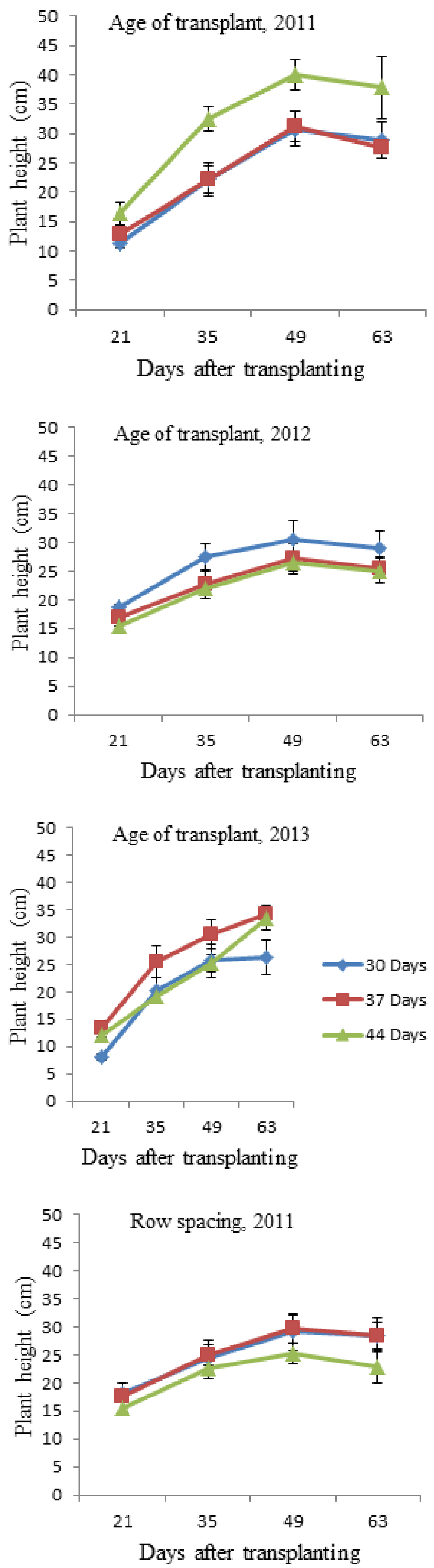

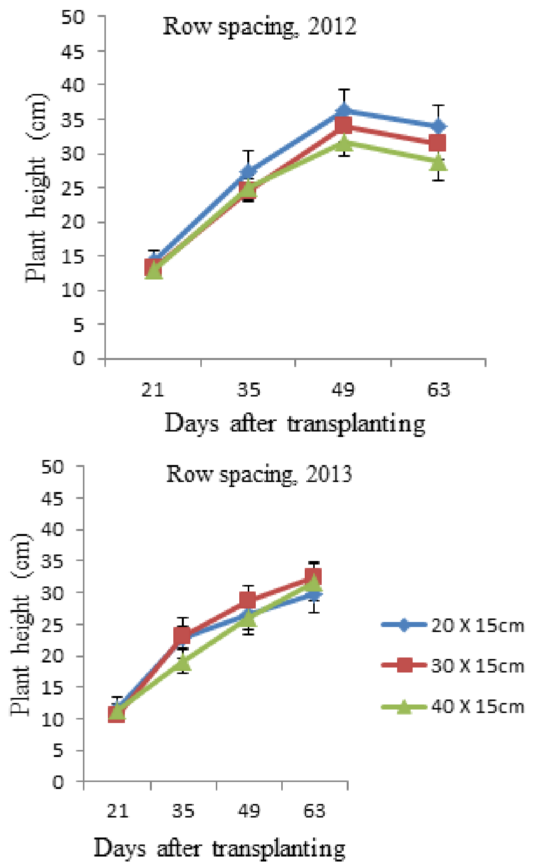

Figure 2: Effect of age of transplant and row spacing on plant height of onion during the 2011, 2012 and 2013 cropping seasons

The 20 x15 cm spacing produced the lowest shoot dry weight per plant from 35 to 63 DAT during the 2011 cropping period (Fig. 3). This might be due to closer spacing that resulted in increased competition for soil moisture and nutrients, light and space. This is similar to those found by (Khan et al., 2002; Karaye and Yakubu, 2006) that closer spacing result in higher competition for soil moisture and nutrients that produced least response for vegetative growth in onion. There was a significant difference between 20 x 15 cm and 30 x 15 cm and the 40 x 15 cm in shoot dry weight per plant from 21 to 35 DAT during the 2012 cropping season (Fig. 3). This however, contradicts those found by (Khan et al., 2002; Karaye and Yakubu, 2006). There was no significant difference between spacing treatments in shoot dry weight per plant at 49 DAT at the same period. The 40 x 15 cm differed significantly from the other row spacing in shoot dry weight per plant at 63 DAT during the 2012 cropping season. This might be due to wider spacing that resulted in reduced competition for soil mineral nutrients and moisture, space and light. The 30 x 15 cm produced the least shoot dry weight per plant at 63 DAT during the same cropping period (Fig. 3). Shoot dry weight per plant for the entire 2013 cropping season was not influenced significantly by row spacing although 20 x 15cm produced the highest shoot dry weight per plant at 63 DAT during the same cropping period.

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B. YIELD AND YIELD COMPONENTS OF ONION

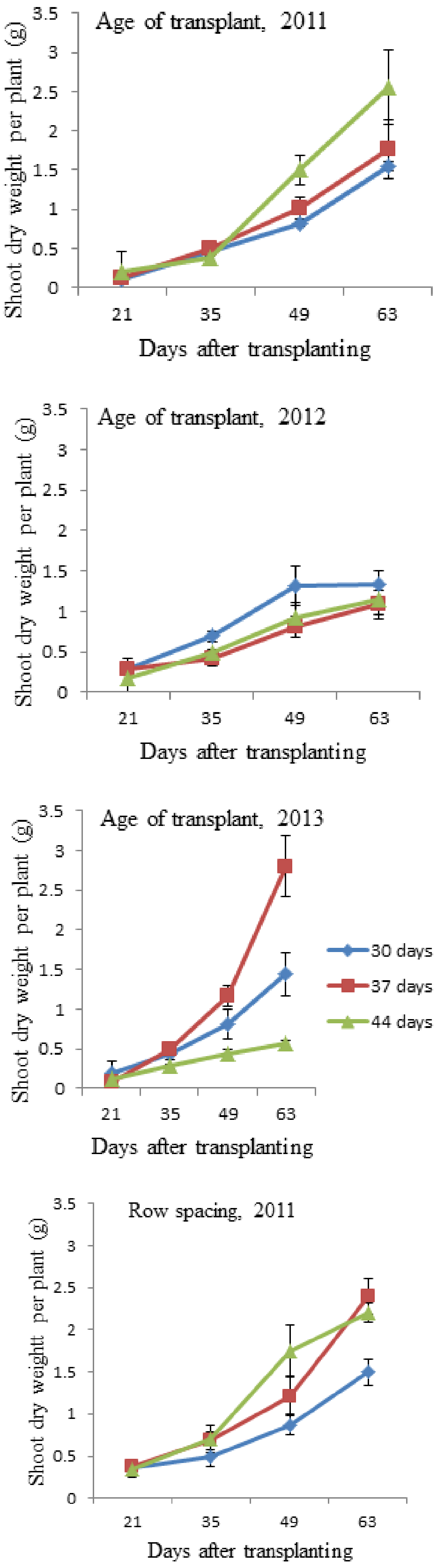
a. NUMBER OF PLANTS HARVESTED

The plants were harvested plot-wise at full maturity stage. The number of plants harvested during the 2011, 2012 and 2013 cropping seasons for the 30, 37 and 44 aged transplants ranged from (9.0 -21.0) and the 20 x 15 cm, 30 x 15 cm and 40 x 15 cm row spacing ranged from (11.0- 21.0) respectively (Table 2). The least number of plants harvested for the 30 aged transplants and 40 x 15 cm row spacing during the 2013 cropping season might be due to younger transplants used, wider spacing coupled with low rainfall experienced during the later plant growth stage and initial high temperature during the 2013 cropping season. The 44 aged transplants differed significantly from 30 and 37 aged transplants in number of plants harvested during the 2011 cropping season (Table 2). This might be due to old transplants used and its response to initial high rainfall during the 2011 cropping season. There was no significant difference between ages of transplants in number of plants harvested during the 2012 cropping season. The 37 aged transplants differed significantly from the 30 and 44 aged transplants in number of plants harvested during the 2013 cropping season. The number of plants harvested was higher during the 2012 cropping season than the other cropping seasons (Table 2). This might be due to differences in ages of transplant and initial high rainfall experienced during the 2012 cropping period. The high rainfall might have contributed to early crop establishment and better plant growth. There was no significant difference between row spacing in number of plants harvested for the entire three year period although the 20 x15 cm had the highest number of plants harvested at the same period (Table 2).

b. NUMBER OF BULBS PER PLOT

The number of bulbs per plot responded significantly to variation in ages of transplant during the 2011 and 2013 cropping seasons. The 44 aged transplants differed significantly from 30 and 37 aged transplants in number of bulbs per plot during the 2011cropping season (Table 2). There was no significant difference between ages of transplant in number of bulbs per plot during the 2012 cropping season although 30 aged transplants produced the highest number of bulbs per plot. The 37 aged transplants differed significantly from 30 and 44 aged transplants in number of bulbs per plot during the 2013 cropping season (Table 2).

The year to year differences in number of bulbs per plot with respect to ages of transplant might be attributed to differences in agro- climatic condition experienced during the period of bulb bulking and maturing. This agrees with the findings of (Yemane et al., 2013) that an onion cultivar performs differently under diverse agro-climatic conditions which often yield differently. In temperate climates year to year differences of some weeks in dates of onion bulb maturity are often associated with the type of weather experienced during the period when the bulbs are forming and maturing Currah and Proctor, (1990). There was no significant difference between row spacing in number of bulbs per plot for the entire three year cropping seasons (Table 2). Although there was no significant difference between spacing treatments, there is difference across treatments in mean number of bulbs per plot with the 20 x15 cm recording the highest number of bulbs per plot for the three year cropping seasons (Table 2).



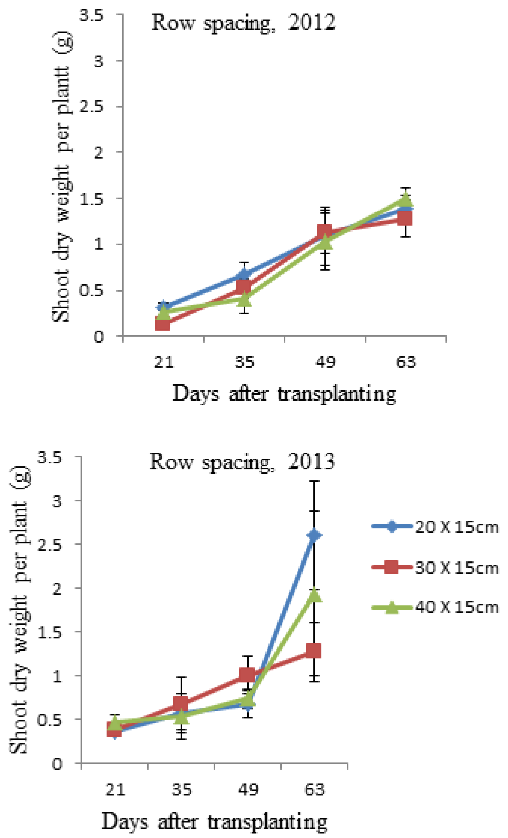


Figure 3: Effect of age of transplant and row spacing on shoot dry weight per plant of onion during the 2011, 2012 and 2013 cropping seasons

Treatments	Number of plants harvested			Number of bulb per plot		
	2011	2012	2013	2011	2012	2013
Age of transplant						
30 days	16.0	21.0	9.0	13.0	22.0	8.0
37 days	16.0	19.0	17.0	13.0	19.0	17.0
44 days	21.0	21.0	10.0	21.0	21.0	10.0
LSD (0.05)	3.0*	NS	4.4*	4.0*	NS	4.3*
Row spacing						
20 X 15cm	18.0	21.0	14.0	16.0	21.0	13.0
30 X 15cm	17.0	20.0	12.0	15.0	20.0	12.0
40 X 15cm	18.0	20.0	11.0	14.0	21.0	10.0
LSD (0.05)	NS	NS	NS	NS	NS	NS
Age x Row spacing interaction	NS	NS	NS	NS	NS	NS
CV (%)	30.5	29.6	36.3	28.6	23.9	36.3

Table 2: Effect of age of transplant and row spacing on number of plants harvested and number of bulbs per plant of onion during the 2011, 2012 and 2013 cropping seasons

c. YIELD OF MARKETABLE BULBS

Results for the three years elicit significant effect of ages of transplant in yield of marketable bulbs. The 44 aged transplants differed significantly from 30 and the 37 aged transplants in yield of marketable bulbs during the 2011 cropping season (Table 3). There was a significant difference between 30 aged transplants from 37 and the 44 aged transplants during the 2012 cropping season. The 37 aged differed significantly from the 30 aged transplants during the 2013 cropping season (Table 3). The differences in performance might be due to differences in climatic conditions experienced during the cropping periods. This agrees with Jilani and Ghaffor, (2003); Yemane *et al.*, (2013).

Yield of marketable bulbs responded significantly to variation in row spacing during the 2011 and 2012 cropping seasons. The 20 x 15 cm spacing differed significantly from 30 x 15 cm and the 40 x 15 cm in yield of marketable bulbs during the 2011 cropping season (Table 3). This however, contradicts those found by (Geremew *et al.*, 2009) that onion varieties planted with wider spacing give maximum marketable bulb yield. There was a significant difference between 20 x 15 cm spacing from 40 x 15 cm in yield of marketable bulbs during the 2012 cropping season. The high yield of marketable bulbs with 20 x 15 cm spacing might be due to closer plant spacing that led to increase in bulb yield. As plant population increase plant height increase significantly thereby intercepts more sunlight and this eventually increase bulb yield. This agrees with the findings of (Viloria *et al.*, 2003) that increasing plant population from 12 x 20 cm to 6 x 20 cm spacing resulted in increased yield. The 40 x 15 cm had the lowest yield of marketable bulbs during the 2011 and 2012 cropping seasons. This result substantiates the findings of (Geremew *et al.*, 2009) that plant density has effect on marketable yield. There was no significant difference between row spacing treatments in yield of marketable bulbs during the 2013 cropping season (Table 3).

d. YIELD OF UNMARKETABLE BULBS

There was no significant difference between ages of transplant in yield of unmarketable bulbs during the 2011 and 2012 cropping seasons, although there are differences in mean yield of unmarketable bulbs across treatments with the 30 aged transplants recording the highest yield of unmarketable bulbs in both cropping seasons (Table 3). The 37 aged transplants differed significantly from 30 and the 44 aged transplants in yield of unmarketable bulbs during the 2013 cropping season. This might be due to differences in ages of transplant and their response to climatic condition experienced during the cropping period.

The 20 x 15 cm spacing differed significantly from 30 x15 cm in yield of unmarketable bulbs during the 2011 cropping season (Table 3). This might be due to closer spacing that led to high unmarketable bulb yield. This result is similar to the findings of (Gupta and Sharma, 2000) that 10 x 5 cm spacing had greater overall yields, but smaller bulbs. Plant density had an impact on marketable bulb size as the higher the plant density the smaller the marketable bulb size Seck and Baldeh, (2009); Kahsay *et al.*, (2014). This agrees with the findings of other researchers that the trend of increasing yield with higher closer plant population and smaller bulb size appears to be consistent across many studies throughout the world. There was no significant difference between row spacing in yield of unmarketable bulbs during the 2012 cropping season although there are differences between mean yield of unmarketable bulbs across the spacing treatments with 30 x 15 cm recording the highest unmarketable bulb yield. There was no significant difference between row spacing in yield of unmarketable bulbs during the 2013 cropping season although 20 x 15cm spacing had the highest yield of unmarketable bulbs during the same cropping period.

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Treatments	Yield of marketable bulbs (kg/ha)			Yield of unmarketable bulbs (kg/ha)		
	2011	2012	2013	2011	2012	2013
Age of transplant						
30 days	3035.0	4022.2	1299.0	225.0	1014.8	174.0
37 days	2819.0	2881.5	2363.0	179.0	977.0	430.0
44 days	7293.0	2629.6	2220.0	181.0	964.4	237.0
LSD (0.05)	3118*	1042.9*	891.7*	NS	NS	157.7*
Row spacing						
20 X 15cm	7007.0	3970.4	2086.3	259.0	982.9	334.0
30 X 15cm	3660.0	3022.2	2428.7	158.0	1032.5	285.0
40 X 15cm	2480.0	2540.7	1960.7	168.0	940.7	222.0
LSD (0.05)	3118.0*	1042.9*	NS	100.0*	NS	NS
Age x row spacing interaction	NS	NS	NS	NS	NS	NS
CV (%)	38.9	35.1	30.3	24.7	33.5	31.8

Table 3: Effect of age of transplant and row spacing on yield of marketable and unmarketable bulbs of onion during the 2011, 2012 and 2013 cropping seasons

e. AVERAGE BULB DIAMETER

There was a significant difference between 44 aged transplants from 30 and 37 aged transplants in average bulb diameter during the 2011 cropping season (Table 4). This might be due to older aged transplant used coupled with higher number of leaves per plant and taller plant height produced than the other treatments. The high number of leaves and plant height might have resulted in plants intercepting more light and thus eventually increase bulb diameter. Higher dry matter yield might be due to differences in plant morphology. This however, contradicts those found by Cramer, (2003). There was no significant difference between ages of transplant treatment during the 2012 and 2013 cropping seasons although 30 and 37 aged transplants produced the highest average bulb diameter during the same cropping seasons respectively (Table 4). This agrees with the findings of (Vachhani and Patel, 1990) that bulb diameter of onions was not significantly affected by ages of seedling at transplanting.

There was a significant difference between 20 x 15 cm spacing from 30 x 15 cm and 40 x 15 cm in average bulb diameter during the 2011 cropping season (Table 4). The high average bulb diameter in 20 x 15 cm spacing might be due to sufficient leaf growth and initial high rainfall experienced during the 2011 cropping season for bulb development. This result however, contradicts those found by (Rashid and Rashid, 1987; Shock *et al.*, 2004; May *et al.*, 2007; Bosekeng, and Coetzer, 2014) that as plant population increased the bulb diameter decreased. There was no significant difference between row spacing in average bulb diameter in both 2012 and 2013 cropping seasons although 20 x 15cm produced the highest average bulb diameter during the same cropping seasons. The interaction between ages of transplants and row spacing did not significantly affect onion bulb diameter for the three year cropping periods (Table 4). This however, contradicts those found by (Bosekeng, and Coetzer, 2014) that the interaction between plant population and sowing date significantly affected onion bulb diameter, as plant population increased the size of bulbs decreased, irrespective of sowing date.

Treatments	Average Bulb diameter (cm)			Total bulb yield (kg/ha)		
	2011	2012	2013	2011	2012	2013
Age of transplant						
30 days	4.0	4.3	3.8	3260.0	5037.0	1787.7
37 days	4.0	4.0	4.2	2998.0	3858.5	3725.0
44 days	5.0	3.8	3.9	7474.0	3594.0	1770.3
LSD (0.05)	1.0*	NS	NS	3018.0*	1101.5*	981.6*
Row spacing						
20 X 15cm	5.0	4.3	4.1	7266.0	4953.3	2415.0
30 X 15cm	4.0	4.0	4.0	3818.0	4054.7	2713.3
40 X 15cm	4.0	3.8	3.8	2648.0	3481.4	2154.7
LSD (0.05)	1.0*	NS	NS	3018.0*	1041.5*	NS
Age x Row spacing interaction	NS	NS	NS	NS	NS	1700.2*
CV (%)	12.4	11.7	10.9	35.6	30.8	40.5

Table 4: Effect of age of transplant and row spacing on average bulb diameter and total bulb yield of onion during the 2011, 2012 and 2013 cropping seasons

f. TOTAL BULB YIELD

Total bulb yield responded significantly to variation in ages of transplant, although the performance of the crop under ages of transplant was not consistent for the three year period. The 44 aged transplants differed significantly from 30 and 37 aged transplants in total bulb yield during the 2011 cropping season (Table 4). The 30 aged transplants differed significantly from 37 and the 44 aged transplants in total bulb yield during the 2012 cropping season. The 37 aged transplants differed significantly from 30 and 44 aged transplants in total bulb yield during the 2013 cropping season. The differences in the crop performance might be due to differences in climatic conditions experienced during the three year cropping periods Yemane *et al.*, (2013). The 44 aged transplants produced the highest total bulb yield during the 2011 cropping season compared with the bulb yield produced for the 30 and 37 aged transplants during the 2012 and 2013 cropping seasons respectively. This might be due to late sown plants, high number of leaves and plant height coupled with moderate initial rainfall experienced during the 2011 cropping season when the bulbs were bulking and maturing. The high vegetative growth of 44 aged transplants might have resulted in more light interception and ultimately increased bulb yield. The lowest total bulb yield was however, produced by the 44 aged transplants during the 2012 and 2013 cropping seasons (Table 4). This might be due to differences in climatic conditions experienced during the cropping seasons (Yemane *et al.*, 2013).

The 20 x 15 cm spacing differed significantly from 30 x 15 cm and 40 x 15 cm in total bulb yield during the 2011 cropping season (Table 4). There was a significant difference between the 20 x 15 cm spacing and the 40 x 15 cm in total bulb yield during the 2012 cropping season. This might be due to closer spacing and tall plants produced compared with the other spacing treatments. The closer spacing resulted in higher competition for sunlight. The plants ability to grow tall enhanced its capability to exploit light to the maximum in the denser plant population for high bulb yield. This agrees with the findings of (Rashid and Rashid, 1987; Jan *et al.*, 2003; Kantona *et al.*, 2003; Viloria *et al.*, 2003; Shock *et al.*, 2004; Brewster, 2008; Yemane *et al.*, 2013) that onion yield increased as plant population increased. This result

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substantiates the findings of (Rekowska and Skupien, 2007) that higher yield of bulbs of garlic was obtained in closer intra-row spacing. There was no significant difference between row spacing treatments in total bulb yield during the 2013 cropping season although the 30 x 15 cm spacing produced the highest total bulb yield. The 40 x 15 cm spacing had the lowest total bulb yield for the three year cropping seasons (Table 4). The least total bulb yield in 40 x 15 cm spacing might be due to the wider spacing and its response to the climatic conditions experienced during the cropping seasons. This is similar to the findings of (Ademe *et al.*, 2012) that low planting density resulted in the production of reduced total bulb yield.

IV. CONCLUSION

The control of ages of transplant and row spacing is an important way of controlling vegetative growth, bulb size and yield of onion under favourable climatic conditions. From the results different ages of transplant and row spacing have different effect on shoot and root growth as well as bulb size and yield under different agro-climatic conditions. The higher yield and larger bulb size could be obtained if plants are grown using 44 aged transplants under moderate rainfall and temperature at 20 x 15 cm row spacing. However, farmers could use 30 aged transplants under high rainfall at 20 x 15 cm spacing for larger bulb size and yield.

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