Vol. 12(9), pp. 215-226, September 2018
DOI: 10.5897/AJPS2018.1694
Article Number: 6B2045558685
ISSN 1996-0824

http://www.academicjournals.org/AJPS

African Journal of Plant Science

Full Length Research Paper

Effects of seedling age and rates of phosphorus fertilizer on growth and yield performance of onion (*Allium cepa* L.) under irrigation at Alage, Central Rift Valley of Ethiopia

Tilaye Anbes[1*], Walelign Worku[2] and Hussien Mohammed Beshir[2]

[1]Department of Plant Sciences, Algae ATVET College, P. O. Box 77, Algae, Ethiopia.
[2]School of Plant and Horticultural Sciences, Hawassa University, P. O. Box 05, Hawassa, Ethiopia.

Received 21 July, 2018; Accepted 16 August, 2018

Onion is an important cultivated crop as a condiment as well as a source of income for many farmers in Ethiopia. However, the productivity of the crop is much lower due to different problems. A field experiment was conducted to determine the effect of seedling age and phosphorus rate on growth and yield performance of onion at Alage, Central Rift Valley of Ethiopia, during 2016/2017 season. The treatments comprised three seedling ages (6, 7 and 8 weeks of seedling age) and four phosphorus rates (0, 46, 92 and 138 kg P_2O_5ha^{-1}). The experiment was laid out in randomized complete block design (RCBD) with four replications. The result showed that seedling age and phosphorus rate significantly affected plant height, leaf length, days to maturity, fresh bulb weight, bulb dry matter fraction, bulb length, marketable bulb yield, total bulb yield, and harvest index. Among these parameters, marketable bulb yield, total bulb yield and harvest index were also significantly affected by the interaction of seedling age and phosphorus rate. On the other hand, leaf number per plant, bulb diameter, total biomass yield and unmarketable bulb yield were only influenced by the effect of phosphorus rates. In this study, transplanting at 8 weeks of seedling age fertilized with 138 kg P_2O_5 ha^{-1} recorded the highest total bulb yield (50.6 t ha^{-1}) and marketable bulb yield (48.33 t ha^{-1}), but no significant difference was shown with that obtained at 92 kg P_2O_5 ha^{-1} with the same seedling age. Treatment combinations of seedling age at 6 weeks and no P (control) produced the lowest amounts of total bulb yield (24.27 t ha^{-1}) and marketable bulb yield (21.63 t ha^{-1}). The partial budget analysis revealed that the highest net benefit with low cost of production was obtained in response to the application of 92 kg P_2O_5 ha^{-1} and the transplanting age of 8 weeks. The marginal rate of return for this treatment was 5657% which is found to be economically feasible for producing onion in the study area.

Key words: Onion, seedling age, phosphorus, bulb yield, partial budget analysis.

INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important monocotyledonous, herbaceous, cross-pollinated and cool season vegetable crops, which belongs to the genus *Allium* and the family Alliaceae (Griffiths et al., 2002). It is important in the daily diets of human's worldwide and in Ethiopia as well (MoARD, 2006).

Onion is grown from seed, transplants or sets for use as both green onions and dry onion (Decoteau, 2000). It is bulbous, biennial herb which gives off a distinctive and pungent odor when the tissues are crushed (Ray and

Yadav, 2005). It is a popular vegetable in Ethiopia and produced in many home gardens and commercially in different parts of the country. Its production is rapidly increasing both under rain-fed and irrigation conditions (Fekadu and Dandena, 2006). The mature bulb contains some starch, appreciable quantities of sugars, some protein, and vitamins A, B and C (Jilani et al., 2010). In the study area, onion crop plays an important role in contributing to the household food security. In addition to the nutritional value, these crops generate employment opportunities for the poor households in the district area. The crop is also one of the most important cash crops that generate income for the farmers in the study area. Ethiopia has diversified agro-climatic conditions which is suitable for the production of a broad range of vegetables and flowers, and allows successful production of onion crop (FAO, 1998). Onion is important cash crop for the farmers in Ethiopia; and hence the crop is produced in different parts of the country for local consumption and for export market. However, due to the various constraints the average productivity of onion in Ethiopia is 10.7 t ha^{-1} (CSA, 2013) which is far below the world average of 19.5 t ha^{-1} (FAO, 2011).

Application of fertilizer is important for production of onion. Among the nutrients, nitrogen and phosphorus play the most important role for vegetative growth and root development of the crop which ultimately helps in increasing bulb size and total yield (Rai, 1981). Onions are generally established either by direct seeding or by bare root transplants. Compared to direct seeding, transplanted onions provide an immediate and complete stand. The effect of transplant age on yield is an issue often broached by growers of horticultural and agronomic crops in an effort to maximize production potential (Leskovau and Vavrina, 1999). Although production of onion variety is “Bombay Red”, expanding information on optimal phosphorus fertilizer application rate and proper age of seedling is scanty. Systematic study on fertilization to improve the growth and yield of bulb is lacking. Onion producers in the area use blanket recommendation of phosphorus fertilizer which was recommended at country level. As Ethiopia has a diversified agro-ecology and soil conditions, site specific fertilizer recommendation is needed to improve productivity and production of onion. On the other hand, farmers transplant onion based on their own judgment on the age/size of seedlings which critically influence the productivity and quality of the bulb. Both late and early age transplanting of seedlings may have significant influence on survival and growth performance of onion. In view of the existing problem, this study was proposed with the objective to determine the effect of seedling age and rates of phosphorus fertilizer on growth and bulb yield of onion.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Alage Agricultural Technical and Vocational Education and Training (ATVET) College during the 2016/2017 dry season under irrigation. The site is located at 217 km south of Addis Ababa city and 32 km west of Bulbula town in the vicinity of Abidjata and Shalla lakes. It is situated between 7° 65’ N latitude and 38° 56’ E longitude and at an altitude of 1600 m above sea level in the agro ecology of dry plateau of the southern part of the Ethiopian rift valley system. High amount of rainfall is received in the month of July and August. While the mean annual rainfall is 800 mm, the annual mean minimum and maximum temperatures are 11 and 29°C, respectively (Agerie and Afework, 2013).

Experimental Materials

Plant Material

The plant material for this study was Bombay Red variety of onion. The variety is widely accepted by farmers for its early maturity and higher bulb yield in the study area. It was released by Melkasa Agricultural Research Center (MARC) in 1980. It is well adapted to areas of 700 to 2000 m above sea level (EARO, 2004). It is one of the most commonly and widely used improved variety in Central Rift Valley of Ethiopia and particularly at Alage.

Fertilizer

The sources of the fertilizers were urea (46% N) and Triple Super Phosphate (TSP) (46% P_2O_5) for supplying nitrogen and phosphorus, respectively.

Treatments and experimental design

The experiment comprised of 3 × 4 factorial combinations involving age of seedling and varying rates of phosphorus (P). Three age of seedlings (6, 7 and 8 week of seedling age) and four varying rates of P (0, 46, 92, and 138 kg P_2O_5 ha^{-1}) were laid out in randomized complete block design (RCBD) with four replications. Each treatment combination was assigned randomly to the experimental units within a block. Double row planting was done on ridges of about 20 cm height adopting recommended spacing of 40 cm between water furrows, 20 cm between rows on the ridge and 10 cm between plants within the row. There were 48 plots corresponding to the 12 treatment combinations with four replications. The unit plot size of the experiment was 2.0 m × 2.0 m (4 m^2). The blocks were separated by a distance of 1.0 m whereas the space between each plot within a block was 50 cm. In each plot, there were 10 rows, and in each row there were 20 plants. Totally, there were 200 plants per plot. The outer two rows at both sides of the plot and two plants at both ends of the rows were considered as border plants. The plants in the six central rows were

*Corresponding author. E-mail: tilayean43@gmail.com. Tel: 0920512643.

used as net plot area to determine yield per plot and other parameters.

Agronomic practices and treatment applications

Raising onion seedlings

Seedlings of 'Bombay Red' onion variety were raised in a nursery at Alage ATVET College demonstration site on sunken beds with size of 1 m × 10 m. The seed of 'Bombay Red' was obtained from Melkasa Agricultural Research Center, Horticulture Division. After four sunken nursery beds were prepared, seeds were sown on December 15, 2016. The soil was cultivated to a fine tilth before sowing the onion seed. The seed was drilled in well pulverized sunken bed in rows 10 cm apart and lightly covered with soil in the required seedling age. Mulching with grasses was done until seedlings emerged. The mulch was removed after seedlings fully emerged (2 to 3 cm from the soil). All important cultural practices such as application of fertilizer (urea and DAP), watering, weed, diseases (Ridomil) and insect pest (Selecron) control activities, respectively were undertaken based on the recommendations made for the onion crop.

Management of experimental field

Before transplanting seedlings, the experimental field was ploughed and leveled by tractor; ridges and plots were made manually. Large clods were broken down in order to bring the land to a fine tilth, and then a total of 48 plots based on recommended size were prepared in which 12 plots were allocated in each of the four replications. Moreover, the required numbers of ridges and rows were marked in each plot. The seedlings were grown in the nursery with careful management and strict follow up until seedlings reached to the required stage as per the treatments. Seedlings were hardened before transplanting to the main field to enable them withstands the field conditions. The experiment was conducted under furrow irrigation method, which is the most commonly used irrigation system in the study area. A three to four days irrigation interval was maintained for the first four weeks. Thereafter, irrigation was applied at 7 days interval until 15 days remaining to harvest, when irrigation was stopped completely (EARO, 2004).

As per the recommendation made for the onion in the study area, half 50 kg ha^{-1} dose of N was applied uniformly to all plots during transplanting. The remaining half 50 kg ha^{-1} dose of nitrogen rates was side-dressed 45 days after transplanting for all plots (EARO, 2004; SARC, 2008; Anisuzzaman et al., 2009). Phosphorus (TSP) was applied as a single application as per specified rates at the time of transplanting based on the treatments. Weeding was done with hand hoe and by hand-pulling whenever necessary throughout the experimental period to keep the crop free from weeds, for better soil aeration and to break the crust. For the control of disease (purple blotch) and insect pest (onion thrips), the fungicides, Mancozeb 80 WP (3 kg ha^{-1}) plus Ridomil (3.5 kg ha^{-1}) and the insecticide, Selecron 720 EC (0.5 L ha^{-1}) were used, respectively. All other agronomic practices were applied uniformly for all the plots as per the recommendation made for the crop (EARO, 2004).

Soil sampling and analysis

Pre-planting soil samples were taken randomly in a zigzag fashion from the experimental field at the depth of 0 to 20 cm for determination of physical and chemical properties of the soil. Nine soil samples were collected using an Auger from the whole experimental field and combined to form a composite sample in a bucket. From this mixture, a sample weighing 1 kg was filled into a plastic bag. The soil samples were also analyzed for soil texture, total nitrogen, cation exchange capacity (CEC), exchangeable potassium, organic carbon and available phosphorous. All the analyses were made at Horticoop Ethiopia P.L.C. soil and water analysis laboratory in Debre Ziet.

Data collection

Days to maturity was registered on plot basis. Growth and yield components were recorded from twelve sample plants randomly taken from six central middle rows of each experimental plot. However, all plants in each net plot were harvested to collect data for bulb yield.

Partial budget analysis

Partial budget analysis was conducted to assess the economic feasibility of the treatments. It is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. Partial budget, dominance and marginal analysis were used. The analysis was based on data collected from respective district office of trade and transport, cooperatives and from onion fields. At Alage, the cost of 100 kg phosphorus (TSP) was 1095 birr and onion price of 400 birr per 100 kg was used for the net benefit analysis. A partial budget is a way of calculating the total costs that vary and the net benefits of each treatment (CIMMYT, 1988).

Statistical data analysis

The collected data on various parameters under study were subjected to analysis of variance (ANOVA) using the GLM procedures of Statistical Analysis System (SAS) version 9.2 computer software program (SAS Institute Inc, 2008). Significance of differences between means was expressed using the least significance difference (LSD) test at $P < 0.05$ probability level.

RESULTS AND DISCUSSION

Physico-chemical properties of the experimental soil

The results revealed that the texture of the composite soil sample from the site was silty clay loam. The soil had particle size distribution of 18% sand, 36% silt and 46% clay at the depth of 0 to 20 cm. The pH was slightly alkaline (pH=7.82). Brewster (1994) stated that for higher yield of onion, a pH of 6.0 to 6.8 is ideal. However, the pH of this soil is near optimum for onion crop production, although it is not ideal. According to the rating of Walkley and Black (1954) and Dewis and Freitas (1975), the soil of the study area is medium in organic carbon (2.10%) as well as total nitrogen (0.18%), respectively. The cation exchange capacity (CEC, 31.8 meq/100 g) of the experimental soil is also high according to the rating of Jackson (1975) and low in phosphorus (4.12 mg/kg) according to Olsen et al. (1954).

Phenology and growth parameters

Days to maturity

Days to maturity of onion were significantly ($P < 0.001$)

Table 1. Main effect of seedling age and P fertilizer rates on mean plant height, leaf length, number of leaves per plant, days to physiological maturity, bulb diameter and bulb length.

Treatment	Days to maturity	Plant height (cm)	Leaf length (cm)	Number of leaves/plant	Bulb diameter (cm)	Bulb length (cm)
Seedling age(weeks)						
6	102.06[a]	55.26[b]	44.24[b]	11.97	4.39	4.46[b]
7	99.00[b]	57.27[ab]	45.49[b]	11.43	4.32	4.52[b]
8	96.75[c]	59.30[a]	47.78[a]	11.89	4.49	4.98[a]
LSD(0.05)	1.07	2.041	1.92	-	-	0.40
Significance level	***	**	**	NS	NS	*
P_2O_5 (kg ha^{-1})						
0	101.17[a]	53.58[c]	42.00[c]	10.44[c]	4.11[b]	4.10[c]
46	100.00[a]	56.17[b]	44.90[b]	11.44[b]	4.33[ab]	4.41[bc]
92	98.58[b]	60.35[a]	48.87[a]	12.58[a]	4.58[a]	4.75[b]
138	97.33[c]	59.00[a]	47.57[a]	12.59[a]	4.59[a]	5.35[a]
LSD(0.05)	1.23	2.36	2.22	0.96	0.31	0.46
Significance level	***	***	***	***	**	***
CV (%)	1.49	4.95	9.86	5.82	8.38	11.91

Means followed by the same letters within a column are not significantly different at ($P < 0.05$).

affected by the main effects of seedling age and phosphorus treatments, but not significantly affected by the interaction effects of the treatments.

The present result showed that, seedling age at 6 and 7 weeks took relatively longer days for onion bulb to mature as compared to the 8 weeks of seedling age. Onion plants with 8 weeks of seedling age reached maturity six and three days earlier than 6 and 7 weeks of seedling age, respectively (Table 1). This result is in agreement with that of Kumbhkar et al. (2016) and Bijarniya et al. (2015), who reported that onion seedlings that were transplanted at early stage were delayed to attain maturity. Early maturity of bulbs might be due to vigorous growth of plants because of stored food in older seedlings which results in faster development and earlier maturity of bulb as compared to other young seedlings (Bijarniya et al., 2015). These results are also in accordance with those of Deepika (2013) who reported that plants produced from 30 day old seedlings took more time to mature than those obtained from 40, 50 and 60 day old seedlings.

Days to maturity was also significantly delayed (101 days) in plants from unfertilized plots by phosphorus, while plots received phosphorus at the rate of 138 kg P_2O_5 ha^{-1} matured earliest (97 days) followed by 92 kg ha^{-1} P rate (99 days) (Table 1). However, no significant difference was observed between unfertilized treatments and those received 46 kg P_2O_5 ha^{-1} plots. Generally, plants grown under higher phosphorus rates tended to be early matured. The result indicates that the shortened time required by the plants to reach maturity at higher rates of phosphorus fertilizers might be attributed to the role of P in plants, that it is used in dry matter distribution which facilitates plant development, as a result, early maturity of the plants. The significant function of phosphorus enhances photosynthesis, reproduction, flowering, fruiting, including seed production and maturation of plants (Brady and Weil, 2002). The current observation is in line with Ahn (1993) who indicated that P is concentrated in the fast growing parts of the plant; therefore, it hastens the maturing period of crops.

Plant height

Result from the ANOVA revealed that the main effects of seedling age ($P<0.01$) and phosphorus ($P < 0.001$) significantly influenced plant height of onion. However, the interaction of the two factors did not influence plant height.

There was a significant difference in plant height at maturity among the various weeks of seedling age recorded (Table 1). Numerically, the highest plant height was obtained from the plant when they were transplanted at 8 weeks of seedling age followed by the plants at 7 weeks of seedling age, while the shortest was obtained under 6 weeks of seedling age but statistically similar with 7 weeks of age. In general, the longer plant height at the oldest seedling might be due to more time of completion before transplanting stimulating height of seedlings as compared to the youngest seedling age which resulted in better establishment and vigorous growth of plant but shorter in height. Similarly, Bijarniya et al. (2015) reported that the more plant height at 8 weeks old seedling stage might be due to their greater stored food present in them as compared to the 6 old ones. This result is also in line with that of Sultana (2015) who found that the maximum plant height was recorded from 7 weeks old seedlings.

Increasing the rate of phosphorus fertilizer from nil up to 92 kg P_2O_5 ha^{-1} resulted in a significant increase in plant height. However, increasing the rate of phosphorus from 92 to 138 kg P_2O_5 ha^{-1} did not change the height of the onion plants. The tallest mean plant heights were attained at 92 kg P_2O_5 ha^{-1}, while the shortest plant height was obtained under the control treatment. The mean height of onion plants grown at the rate of 92 kg P_2O_5 ha^{-1} exceeded the mean height of plants grown at the rates of 46 and 0 kg P_2O_5 ha^{-1} by about 7 and 13% , respectively (Table 1). This might be attributed to the fact that phosphorus enhances plant vigor and strength of the stem of the plant (Bahadur et al., 2002). The result of this study confirms the findings of Ali et al. (2008), Aliyu et al. (2007) and Tibebu et al. (2014) who reported that different phosphorus levels resulted in significantly different plant heights where the tallest plants were observed at higher rates of applied phosphorus, while the shortest plants were from the control plots. The result also agreed with the findings of Lemma and Shimeles (2003) who reported that at 92 kg P_2O_5 ha^{-1} there was better vegetative growth which resulted in increased heights of onion plants. Similarly, Getachew (2014) reported that the height of the plants was increased as the level of phosphorus fertilizer increased from 0 to 115 kg P_2O_5 ha^{-1}, but further increase of fertilizer application, decreased the height of the plants.

Leaf length

Leaf length of onion plants was significantly affected by the main effects of seedling age and phosphorus treatments. However, leaf length was not significantly affected by the interaction effect of those treatments. This study indicated that, the longest leaf was observed when seedlings are transplanted at 8 weeks of age, while numerically the shortest leaf length was obtained under 6 weeks of seedling age (Table 1). The result is supported by observations of Singh and Chaure (1999) who reported that longer leaves were recorded at old seedling age as compared to treatments of the young ones. Muhammad et al. (2017) and Sultana (2015) also reported that the length of leaf was significantly influenced by the different age of seedling of onion.

Application of 138 kg P_2O_5 ha^{-1} gave significantly longer leaf length than the lower doses (0 and 46 kg ha^{-1}), whereas the 92 kg ha^{-1} P treatment is not significantly different from 138 kg P_2O_5 ha^{-1} in leaf length (Table 1). The shortest leaf length was obtained under the control treatments. Also significant difference was observed between the 46 and 92 kg ha^{-1} P rates. In general, leaf length tended to show an increasing trend as phosphorus rate increases. The leaf length response to phosphorus fertilizer rate is in agreement with Fageria (2003) who reported that higher rates of phosphorus resulted in longer leaves of onion. The positive effect of phosphorus on leaf length might be due to the fact that it contains an essential component of nucleic acids, phospholipids, and some amino acids and absorbed phosphorus helped a direct stimulation of cellular activity in roots and leaves (Jawar et al., 2016).

Number of leaves per plant

The main effect of phosphorus fertilizer application significantly ($P < 0.001$) influenced the number of leaves per plant of the onion at physiological maturity. However, neither the main effect of seedling age nor its interaction with phosphorus influenced this parameter of the onion.

The result indicated that, effect of different rates of phosphorus on the number of leaves per plant increased with the increase in phosphorus level. The highest number of leaves was obtained from 138 kg P_2O_5 ha^{-1}, whereas the lowest leaf number was obtained under the control treatment. Increasing the rate of phosphorus from nil to 92 kg P_2O_5 ha^{-1} significantly increased the number of leaves per plant of onion. But, the mean leaf number per plant did not show significant difference with further increase in phosphorus rate from 92 to 138 kg ha^{-1}. Thus, the mean leaf number per plant of onion treated with phosphorus at the rate of 92 kg ha^{-1} exceeded the leaf number per plant of onion treated with nil and 46 kg P_2O_5 ha^{-1} by about 21 and 10%, respectively (Table 1). This might be attributed to the role of P in plants, that it is used in dry matter distribution, which facilitates plant development.

The increase in the number of leaves as a result of the increased rates of phosphorus application may be attributed to the useful role of P for the process of cell division and meristematic growth. Vachhani and Patel (1993) also observed that increased application of phosphorus rate increased the number of leaves per plant. Similarly, Fatma et al. (2012) reported that the higher level of P fertilizer at 103 kg ha^{-1} significantly increased plant height, number of green leaves per plant, bulb and neck dimensions and fresh and dry weights of whole plant and its different organs as compared with the lower level of 69 kg ha^{-1}.

Yield and yield components of onion

Bulb diameter: Phosphorus had significant ($P<0.01$) effect on mean bulb diameter of onion plants. However, the main effect of seedling age as well as its interaction effect with phosphorus did not affect this parameter. Applications of phosphorus at 46, 92 and 138 kg P_2O_5 ha^{-1}

gave similarly larger bulb diameters as compared to the plants without added phosphorus. The increment in bulb diameter due to phosphorus application might be due to the fact that phosphorus improved the carbohydrate content of the plants and it extended root growth, which ultimately increased the blub size (Jawar et al., 2016). Regarding the rates, Shaheen et al. (2007) reported that bulb diameter significantly increased with the increases of phosphorus fertilizer up to 92 kg ha^{-1}. Tibebu et al. (2014) also reported that the highest bulb diameter was obtained from 69 kg P_2O_5 ha^{-1}.

Bulb length: The main effect of seedling age ($P<0.05$) and phosphorus ($P<0.001$) significantly affected mean bulb length of onion plants; however, the interaction effect of seedling age and phosphorus fertilizer did not result significant difference ($P > 0.05$). The result indicated that, at 6 weeks of seedling age, the bulb length was significantly reduced, but no significant difference was observed with 7 weeks of seedling age. Compared with the 6 and 7 weeks of seedling age treatments, 8 weeks of seedling age produced 12 and 10% longer bulbs, respectively. The highest bulb length was observed with transplanting of 8 weeks of seedling age, while numerically the lowest bulb length was recorded in 6 weeks of seedling age (Table 1). This indicated that the 8 weeks of seedling age had maintained longer leaves and greater height which may have helped for more vegetative growth and bulb development and ultimately an increase in length of bulb. This result is in line with that of Singh and Chaure (1999) and Bahadur and Singh (2005) who observed that increase of bulb length at older seedling age as compared to treatments of the young seedling age. Similarly, Sultana (2015) reported that length of bulb increased in 50 days old seedlings, which were strong and larger in size at transplanting stage. In response to rising the rate of phosphorus from nil to 46, 92 and 138 kg P_2O_5 ha^{-1}, bulb length increased significantly. The highest bulb length was observed from 138 kg P_2O_5 ha^{-1} followed by 92 kg P_2O_5 ha^{-1}, while significantly smaller bulb length was obtained under the control treatments (Table 1). The significant increase in bulb length in response to the increment in the rate of phosphorus fertilizer may be linked to the increase in dry matter production and its partitioning to the bulb. The bulb length was higher with the application of phosphorus and this might be due to the fact that the phosphorus improved the carbohydrate content of the plants and it extended root growth, which ultimately helped in the increased length of onion bulb (Khodadadi, 2012).

Fresh bulb weight: The main effect of seedling age ($P <0.01$) and phosphorus fertilizer rate ($P <0.001$) significantly influenced the fresh bulb weight of the onion plants, but not by the interaction of the two main factors. The result revealed that, at 6 weeks of seedling age, the fresh bulb weight was significantly reduced, but no significant difference was observed with 7 weeks of seedling age (Table 2). Compared to the 6 and 7 weeks of seedling age treatments, 8 weeks of seedling age produced 6 and 9% larger bulbs, respectively. The highest fresh bulb weight was recorded from plots that were transplanted at 8 weeks of seedling age, while the least fresh bulb weight was obtained when seedlings were transplanted at 6 weeks of seedling age. It was possible that old seedling age took less time to recover from the transplanting shock in order to get established in the field (Latif et al., 2010). The result is supported by observations of Singh and Chaure (1999) and Mohanty et al. (1990) who reported that increased fresh bulb weight was obtained at old seedling age as compared to treatments of the young ones. When the rate of phosphorus was increased from 0 to 46 and 92 kg P_2O_5 ha^{-1}, there were significant increments in fresh bulb weight. When the rate of fertilizer was increased from 92 to 138 kg P_2O_5 ha^{-1}, the fresh bulb weight did not change significantly. Thus, the heaviest bulbs were produced already at 92 kg P_2O_5 ha^{-1}. The mean bulb weight of onion plants grown at the rate of 92 kg P_2O_5 ha^{-1} exceeded the fresh bulb weight of onion plants grown at the rates of 46 and 0 kg P_2O_5 ha^{-1} by about 11 and 33%, respectively (Table 2). The significant increase in fresh bulb weight in response to the increased phosphorus level might be attributed to the role phosphorus played in improving the carbohydrate content of the plants and extending root growth, which increased the diameter and length of blubs and ultimately blub size (Jawar et al., 2016). This finding is also in accordance with that of Lemma and Shimeles (2003) who reported that at 92 kg P_2O_5 ha^{-1}, there was better vegetative growth and the average bulb weight was 49 g/bulb at Melkassa. Similar results were also reported by Shaheen et al. (2007) who obtained that the highest application of phosphorus (92 kg ha^{-1}) fertilizer had a significant effect on the productivity of onion plant, hence increased average bulb weight.

Total biomass yield: The analysis of variance revealed that the main effect of phosphorus fertilizer application significantly ($P<0.05$) influenced the total biomass yield of onion, compared to the control treatment. On the other hand, neither the main effect of seedling age nor its interaction with phosphorus influenced the total biomass yield of the crop. Increasing the rate of phosphorus from 0 to 46 kg P_2O_5 ha^{-1} significantly increased the total biomass yield (Table 2). However, further application beyond 46 kg P_2O_5 ha^{-1} did not significantly increase the biomass yield. The total biomass yield of onion plants grown at a rate of 46 kg P_2O_5 ha^{-1} exceeded the total biomass yield of onion plants grown at rates of 0 kg P_2O_5 ha^{-1} by about 12%. The highest total biomass yield was obtained from the highest phosphorus rate (138 kg ha^{-1}) though not significantly different from those obtained at 46 and 92 kg P_2O_5 ha^{-1}, whereas the lowest total biomass

Table 2. Main effects of seedling age and phosphorus fertilizer rates on fresh bulb weight, total biomass yield, bulb dry weight and unmarketable and under sized bulb yield of onion grown at Alage.

Treatment	Fresh bulb weight (g)	Total biomass yield (t ha^{-1})	unmarketable bulb yield (t ha^{-1})	Bulb dry matter fraction (%)	Neck thickness (cm)
Seedling age					
6	81.28^b	47.32	1.88	10.98^b	1.03
7	79.19^b	48.69	2.08	11.89^a	1.03
8	86.27^a	52.64	2.03	12.36^a	1.02
LSD(0.05)	3.62	-	-	0.9	-
Significance level	**	NS	NS	*	NS
P_2O_5 (kg ha^{-1})					
0	66.84^c	43.69^b	2.66^a	10.68^b	0.97
46	80.42^b	49.05^{ab}	2.08^{ab}	10.91^b	1.03
92	88.89^a	52.61^a	1.80^{bc}	12.33^a	1.02
138	92.83^a	52.86^a	1.45^c	13.05^a	1.08
LSD(0.05)	4.18	7.21	0.57	1.04	-
Significance level	***	*	**	**	NS
CV (%)	6.13	17.51	34.75	10.64	10.55

Means followed by the same letters within a column are not significantly different at ($P < 0.05$).

yield was obtained under the control treatment. This result is in line with that of Shaheen et al. (2007) who reported that application of phosphorus had a major effect on the productivity of onion plant, hence increased total biomass yield. This result is in disagreement with that of Abdissa (2008) who reported that phosphorus has shown non-significant effect on total dry biomass yield of onion; thus, absence of response to phosphorus in the previous study might be due to sufficient amount of available P which was found in the soil of the experimental site.

Unmarketable bulb yield: The analysis of variance indicated that phosphorus application rate had significant ($P<0.01$) effect on unmarketable bulb yield of onion. However, neither the main effect of seedling age nor its interaction with phosphorus affected unmarketable bulb yield. The result of the study indicated that increasing the rates of application of phosphorus decreased the unmarketable bulb yield per hectare. Among all phosphorus rates the highest unmarketable bulb yield was recorded in the unfertilized plots, whereas the lowest was recorded at 138 kg ha^{-1} phosphorus rate though this was statistically at par with 92 kg ha^{-1} (Table 2). High unmarketable yield observed in low rates of phosphorus application have been associated with early bulb formation, severe stunting, and fewer large sized bulbs than those under high phosphorus rates. This result is contrary with that of Tibebu et al. (2014) who stated that phosphorus had no significant effect on unmarketable yield of onion that might be due to adequate amount of available P which was found in the soil of the experimental site.

Total bulb yield: The main effect of seedling age as well as that of phosphorus significantly ($P < 0.001$) influenced the total bulb yield of onion. Additionally, the interaction effect of seedling age and phosphorus application rate significantly ($P < 0.05$) influenced the total bulb yield of the onion. At 6 weeks of seedling age, total bulb yield was significantly improved at 92 kg $ha^{-1}P_2O_5$ rate. Further increasing phosphorus up to 138 kg ha^{-1} showed a decline in the total bulb yield by 29%, however, no significant difference was showed among the two phosphorus rates except those unfertilized plots and 92 kg P_2O_5 ha^{-1}, which were at par. Under 7 weeks of seedling age, the highest and lowest total bulb yields were recorded at 92 kg ha^{-1} phosphorus and control treatments, respectively. However, no significant difference was recorded among 46 and 138 kg P_2O_5 ha^{-1} treatments. In the 8 weeks of seedling age, P application rate at 92 and 138 kg ha^{-1} improved total bulb yield by about 36 and 42%, respectively compared to that of untreated treatment. However, the two phosphorus rate (92 and 138 kg ha^{-1}) had no significant difference at the same seedling age of 8 weeks (Table 3). Generally, increased application rate of phosphorus produced higher total bulb yields with optimum seedling age (8 weeks seedling age). The high total bulb yield produced due to phosphorus application and old seedling age might be because of increase in photosynthetic area of the plant (plant height and number of leaves) which in turn increased the amount of assimilate that could be partitioned to the storage organs (increased bulb

Table 1. Interaction effects of seedling age and phosphorus rates on total bulb yield (t ha^{-1}) of onion grown at Alage.

Seedling age (weeks)	Total bulb yield (t ha^{-1})				Harvest Index (%)			
	P_2O_5(kg ha^{-1})				P_2O_5(kg ha^{-1})			
	0	46	92	138	0	46	92	138
6	24.27[f]	35.48[de]	45.24[ab]	35.01[de]	77.55[c]	87.67[ab]	90.07[a]	89.7[a]
7	31.83[e]	39.11[cd]	43.43[bc]	39.52[cd]	83.83[b]	91.03[a]	90.1[a]	91[a]
8	35.47[de]	39.54[cd]	48.49[a]	50.6[a]	89[a]	90.2[a]	89.15[a]	91.75[a]
LSD(0.05)	4.43				3.00			
Significance level	*				*			
CV (%)	9.66				3.5			

Means followed by the same letters within a column or row are not significantly different at (P<0.05).

diameter and average bulb weight). This may lead to improved carbohydrate content of the plants and extended root growth, which consequently increased the total bulb yield. In harmony to this result, Verma et al. (1971) reported that transplanted onion at 8 weeks old gave the highest yield of bulb.

Harvest index: The analysis of variance showed that means of harvest index was significantly ($P < 0.05$) affected by the interaction effect of seedling age and phosphorus rate. Moreover, harvest index was significantly influenced by the main effects of seedling age ($P < 0.01$) and phosphorus application ($P < 0.001$). Generally, increased rate of phosphorus produced higher harvest index with increased age of seedling (Table 3). The highest harvest index was recorded under the 8 weeks of seedling age combined with application of 138 kg P_2O_5 ha^{-1}, while the lowest value was obtained from transplanting of 6 weeks of seedling age with the control treatment. At 6 week seedling age, harvest index was significantly improved at 92 P_2O_5kg ha^{-1} rate, further increasing of phosphorus up to 138 kg ha^{-1} at this seedling age showed a decline in the harvest index. However, statically no significant difference was observed among the two phosphorus rate except those untreated plots and 46 kg ha^{-1} which were at par. Under 7 week seedling age, the highest and lowest harvest indices were recorded at 46 kg ha^{-1} phosphorus and control plots, respectively. However, no significant difference was recorded among 46, 92 and 138 kg P_2O_5 ha^{-1} P rates. In the 8 weeks of seedling age, no significant difference was recorded among 0, 46, 92 and 138 kg P_2O_5 ha^{-1} treatments. Over all, differences among the three seedling age levels become progressively narrower with increasing rates of P application. The high harvest index produced due to P application and higher seedling age might be because of increased photosynthetic area of the plant (height of plants and number of leaves) which increased the amount of assimilate that could be partitioned to the storage organs (increased bulb length and average bulb weight) which consequently increased the harvest index.

Quality parameters

Bulb dry matter fraction

The main effect of seedling age ($P < 0.05$) and phosphorus ($P < 0.001$) significantly affected mean bulb dry matter fraction of onion plants, however, the interaction effect did not show significant differences ($P > 0.05$). This study indicated that, significant differences were observed among the seedling age levels, in such a way that the 8 weeks of seedling age gave the highest onion bulb dry matter fraction, while the lowest bulb dry matter fraction was obtained under 6 weeks of seedling age. However, no statically significant difference was observed between 7 and 8 weeks of seedling age (Table 2). The dry matter fraction for different age of seedlings varied possibly due to variation of growth patterns and photosynthesis at growing phases. The results of the present study are in agreement with Latif et al. (2010), Sultana (2015) and Bhonde et al. (2001) who reported that dry matter content of onion bulb was significantly influenced by the age of seedling. This might be due to the fact that the optimum age of seedlings planted had better growth, which resulted in higher production of dry matter content of bulb (Sultana, 2015). This result is also consistent with the findings of Muhammad et al. (2016) who reported that the seedling transplanted at 60 days have high dry matter percentage as compared to the seedling transplant in early stage and it might be attributed to the fact that as the bulb size decreased quantity of water content also decreased resulting in high percentage of dry matter. Increasing the rate of phosphorus from nil to 46 kg P_2O_5 ha^{-1} not significantly increased the bulb dry matter fraction of onion. But, increasing the rate of phosphorus further from 46 to 92 kg ha^{-1} increased the dry matter fraction of onion plants. And also the mean dry matter fraction of plants did not show significant difference as further increase in phosphorus

Table 4. Interaction effects of seedling age and phosphorus rates on marketable bulb yield (t ha^{-1}) of onion grown at Alage.

Seedling age (weeks)	P_2O_5(kg ha^{-1})			
	0	46	92	138
6	21.63^{g}	33.25^{def}	43.22^{ab}	33.17^{def}
7	28.09^{f}	36.07^{cde}	40.79^{bc}	37.51^{cd}
8	32.08^{ef}	36.78^{cde}	45.84^{a}	48.33^{a}
LSD(0.05)		4.43		
Significance level		*		
CV (%)		10.26		

Means followed by the same letters within a column or row are not significantly different at (P<0.05).

rate from 92 to 138 kg ha^{-1}. Thus, the mean dry matter fraction of onion treated with phosphorus at the rate of 92 kg ha^{-1} exceeded the bulb dry matter of onion plants treated with nil and 46 kg P_2O_5 ha^{-1} by about 15 and 13%, respectively. Similar observations were reported by Woldetsadik (2003) who stated that on a clay soil in a sub-humid tropical environment of Ethiopia in shallot (*Allium ascalonicum*) crop, increased application of P slightly increased bulb dry matter content of onion. Similarly, Tibebu et al. (2014) reported that the rate of P application increased dry matter content of onion.

Neck thickness

Seedling age and phosphorus fertilization and their interaction did not significantly ($p > 0.05$) affect the formation of neck thickness of onion (Table 2). This could be due to the minimal direct effect of fertilization in the formation of thick-necked bulbs. Brewester (1987) reported that neck-thickness is a physiological event that is influenced by seasons, sites and cultivars, not by fertility.

Marketable bulb yield

Marketable bulb yield of onion was significantly affected ($P < 0.001$) by the seedling age and phosphorus rate. Similarly, significant interaction effect of seedling age and phosphorus was observed on the marketable bulb yield of onion ($P<0.05$).

Under 6 weeks of seedling age, marketable bulb yield increased by about 100% at 92 kg ha^{-1} phosphorus compared to lowest yield recorded from untreated plots (Table 4). Further increase of phosphorus to 138 kg ha^{-1} did not significantly show variation, rather it showed a drop by about 30% and leveled off with yields from control plots and those fertilized at 46 kg ha^{-1} phosphorus. At 7 weeks of seedling age, the highest marketable bulb yield was produced at 92 kg ha^{-1} P rate while the lowest marketable bulb yield was obtained from control treatments. Significant differences were recorded among yields at 46, 92 and 138 kg ha^{-1} P rate under the 7 weeks age. At 8 weeks of seedling age, the control plot had notably reduced yield of marketable bulb as compared to the three phosphorus rates. The highest marketable bulb yield was recorded at 8 weeks of seedling age combined with 138 kg ha^{-1} phosphorus rate; though statically at par to that obtained from 92 kg P_2O_5 ha^{-1} under similar seedling age (Table 4).

From the present result it can be deduced that old seedling age and higher phosphorus rate help to increase the vegetative growth of the plant which has improved assimilate availability for storage and led to an increased average bulb weight that gave an advantage to increase the marketable bulb yield.

Partial budget analysis

The partial budget analysis revealed that the highest net benefit of Birr 152829 was recorded from the combination of 138 kg P_2O_5 ha^{-1} and 8 weeks of seedling age with marginal rate of 1481%. This was followed by net benefit of Birr 145372.3 from the phosphorus rate of 92 kg P_2O_5 ha^{-1} and 8 weeks of seedling age with the marginal rate of return of 5657%. This means that for every Birr 1.00 invested in 92 kg P_2O_5 ha^{-1} and 8 weeks of seedling age, producers can expect to recover the Birr 1.00 and obtain an additional 56.57 Birr. Whereas, the lowest net benefit (Birr 69200 ha^{-1}) was recorded from control treatments (0 kg P_2O_5 ha^{-1}) combined with 6 weeks of seedling age (Table 5).

The minimum acceptable marginal rate of return (MRR %) should be between 50 and 100% (CIMMYT, 1988). Thus, the current study indicated that marginal rate of return is higher than 100% (Table 6). Hence, the most economically attractive yield of the onion crop in the study area was that the combinations of 92 kg P_2O_5 ha^{-1} application and 8 weeks of seedling age with low cost of production and higher benefits. The yield from the combination of 138 kg P_2O_5 ha^{-1} with 8 week old seedlings still meets the 100% marginal rate of return

Table 5. Partial budget analysis for phosphorus rate and seedling age experiments of onion at Alage.

Treatments		Average yield ($t\ ha^{-1}$)	Adjusted yield ($t\ ha^{-1}$)	Gross benefit (Birr ha^{-1})	Total cost that vary (Birr ha^{-1})	Net benefit (Birr ha^{-1})
Seedling age (weeks)	P rate (kg ha^{-1})					
6	46	33.25	26.6	106400	803.7	105596.3^{D}
7	46	36.07	28.86	115440	803.7	114636.3^{D}
8	46	36.78	29.42	117680	803.7	116876.3
6	92	43.22	34.58	138320	1307.4	137012.3^{D}
7	92	40.79	32.63	130520	1307.4	129212.3^{D}
8	92	45.84	36.67	146680	1307.4	145372.6
6	138	33.17	26.54	106160	1811	104349^{D}
7	138	37.51	30	120000	1811	118189^{D}
8	138	48.33	38.66	154640	1811	152829
6	0	21.63	17.3	69200	-	69200^{D}
7	0	28.09	22.47	89880	-	89880^{D}
8	0	32.08	25.66	102640	-	102640^{D}

Table 6. Marginal analysis, seedling age and phosphorus rates experiment in Alage.

Treatments		Total cost that vary (Birr ha^{-1})	Marginal cost (Birr ha^{-1})	Net benefit (Birr ha^{-1})	Marginal net benefit (Birr ha^{-1})	Marginal rate of return (%)
Seedling age	P rate (kg ha^{-1})					
8	46	803.7	-	116876.3	-	-
8	92	1307.4	503.7	145372.6	28496	5657
8	138	1811	503.6	152829	7456.4	1481

threshold value. However, this treatment will not be a viable option because the yield from this combination was statistically at par with that obtained from 92 kg P_2O_5 ha^{-1} and 8 weeks old age.

Conclusions

The analysis of variance showed that plant height, leaf length, days to maturity, bulb length, fresh bulb weight, and bulb dry matter fraction were significantly influenced by the main effect of seedling age and phosphorus fertilizer rates. However, leaf number per plant, bulb diameter, total biomass yield and unmarketable bulb yield were significantly affected only by the main effects of different rates of phosphorus fertilizer. Seedling age and P fertilizer rate as well as their interaction did not significantly affect the formation of neck thickness of onion. From this study, significantly taller plant height, leaf number per plant, leaf length and early bulb maturity was obtained at the seedling age of 8 weeks and 92 kg ha^{-1}phosphorus rate. However, bulb length, fresh bulb weight, total biomass yield and bulb dry matter fraction were recorded in the treatments of 8 weeks of seedling age and 138 kg ha^{-1} phosphorus rate. However, the result of this study showed that at 92 and 138 kg P_2O_5 ha^{-1} rate there was no significant variation in each parameter. Therefore, the study showed that, the highest yield of marketable and total bulb yield of Bombay Red onion variety were produced at treatment combination of 8 weeks of seedling age with 138 kg ha^{-1} P rate, but no significant difference was observed in these parameters at 92 kg P_2O_5 ha^{-1} combinations with same seedling age. However, the combination of 8 weeks of seedling age fertilized with 92 kg ha^{-1} P rate also gave statistically comparable yield to the highest value. Therefore, from the present study it can be concluded that, the most economically attractive yield of the onion crop in the study area was obtained by the combinations of 92 kg P_2O_5 ha^{-1} applications and 8 weeks of seedling age with low cost of production and higher benefits.

Since this experiment is a one-year study in a single environment, further research over locations and years is warranted to confirm the present results.

CONFLICT OF INTERESTS

The authors have not declared any conflicts of interests.

REFERENCES

Abdissa Y (2008). Effects of nitrogen and phosphorus rates on growth, yield, quality and storability of onion (*Allium cepa* L.) on vertisols of

Shewa Robit. M.Sc Thesis presented to Haramaya University, Ethiopia.
Agerie A, Afework B (2013). Habitat preferences, seasonal abundance and diets of rodents in Alage, Southern Ethiopia. African Journal of ecology 52:284-291.
Ahn PM (1993). Tropical soils and fertilizer use. Long man group, UK.
Ali MK, Alam MN, Islam MS, Islam MK, Baree MA (2008). Effects of cow dung at different levels of phosphorus on growth, yield and quality seed production of onion. Research Journal of Agriculture and Biological Sciences 4(1):86-93.
Aliyu U, Magaji MD, Singh A, Mohammed SG (2007). Growth and yield of onion (*Allium cepa* L.) as influenced by nitrogen and phosphorus levels. International Journal of Agricultural Research 2:937-944.
Anisuzzaman M, Ashrafuzzaman M, Ismail MR, Uddin MK, Rahim MA (2009). Planting time and mulching effect on onion development and seed production. African Journal of Biotechnology 8(3):412-416.
Bahadur MM, Ashrafuzzaman M, Chowdhury MF,Mazumder DN (2002). Response of chickpea (*Cicer arietinum*) varieties to different levels of phosphorus. Crop Research Hisar 23(2):293-299.
Bahadur A, Singh R (2005). Influence of seedling age on bulb production of Rabi onion. Annals of Agricultural Research 26 (1):147-148.
Bhonde SR, Chougule AB, Singh NB (2001). Studies on the effect of age of seedlings and date of harvesting on yield and quality of onion during late kharif season. N.H.R.D.F., News-Letter 21(1):27-30.
Bijarniya NK, Jat ML, Patel BK, Bana ML (2015). Effect of age of seedling and dates of transplanting on growth, yield andquality of onion (*Allium cepa* L.) in Rabiat Sardarkrushinagar Dantiwada Agricultural University, North Gujasrat. Journal of Rural and Agricultural Research 15(2):38-42.
Brady NC, Weil RR (2002). The nature and properties of soils.13th (ed.), Pearson Education Asia. Delhi, India P 960.
Brewester JL (1987). The effect of temperature on the rate of sprout growth and development within stored onion bulbs. Annual Applied Biology 111:463-465.
Brewster JL (1994). Onions and other vegetable alliums. CAB International, Wallingford, UK. 236 p.
International Maize and wheat improvement center (CIMMYT) (1988). From agronomic data to farmer recommendations: An economics training manual. Completely revised edition. Mexico. D.F. pp. 19-33.
Central Statistical Agency (CSA) (2013). Agricultural sample survey volume I statistical Bulletin 532 May 2013, Addis Ababa, Ethiopia.
Decoteau (2000). Vegetable crops. The Pennsylvania State University. P 325.
Deepika C (2013). Studies on effect of seedling age and transplant density on growth, yield and quality of Rabi onion, at Chhattisgarh plains. http://krishikosh.egranth.ac.in/bitstream/1/88108/1/DEEPIKA%20CHANDRAVANSHI%20.pdf
Dewis J, Freitas P (1975). Physical and chemical methods of soil and tissue analysis. FAO, Rome.
Ethiopia Agricultural Research Organization (EARO) (2004). Directory of released crop varieties and their recommended cultural practices.
Fageria NK (2003). Plant tissue test for determination of optimum concentration and uptake of nitrogen at different growth stages in lowland rice. Commune. Soil Science Plant Analysis 34:259-270.
Food and Agriculture Organization (FAO) (1998). Developing seed security strategies and programs for food security in developing countries. In Proceeding of the International Work Shop on Seed Security for Food Security, 30 November to December 1997.
Food and Agriculture Organization (FAO) (2011).Crop production. Available at: http:/www.faostat.fao.org
Fatma A, Rizk AM, Shaheen EH, Abd El-Samad, Omaima MS (2012). Effect of different nitrogen plus phosphorus and sulphur fertilizer levels on growth,yield and quality of onion (*Allium cepa* L.) Dokki, Egypt. Journal of Applied Sciences Research 8(7):3353-3361.
Fekadu M, Dandena G (2006). Review of the status of vegetable crops production and marketing in Ethiopia. Uganda Journals of Agricultural Sciences 12(2):26-30.
Getachew A (2014). Effect of plant spacing and NP fertilizer levels on growth, seed yield and seed quality of onion (*Allium cepa*L.) at Shewa Robit, M.Sc Thesis presented to Haramaya University, Northern Ethiopia P 29.
Griffiths G, Trueman L, Crowther T, Thomas B, Smith B (2002). Onions a global benefit to health. Phytotherapy Research 16:603-615.
Jackson MC (1975). Soil chemical analysis. Prentice Hall, Inc. Englewood Cliffs, NJ.
Jawar A, Abdurrab, Haji M, Muhammad A, Anwar R, Abdul S, bid K, Junaid K, Abbas J, Hamid K (2016). Effect of sowing dates and phosphorus levels on growth and bulb production of onion. Pure and Applied Biology 5(3):406-417.
Jilani MS, Ahmed P, Waseem K, Kiran M (2010). Effect of plant spacing on growth and yield of two varieties of onion (*Allium cepa* L.). Pakistan Journal of Science 62(1):37-41.
Khodadadi M (2012). The effects of planting date and mother bulb size on quantitative and qualitative seed traits of onion red variety. International Journal of Agriculture of Crop Production 2(4):324-327.
Kumbhkar BR, Patel NM, More SG (2016). Effect of age of seedlings on growth, yield and quality of onion (*Allium cepa* L.) in rabi under North Gujarat condition. Green Farming 7(3):758-759.
Latif MA, Choudhury MSH, Rahim MA, Hasan MK, Pal BK (2010). Effects of spacing and age of seedling on the growth and yield of summer onion. Journal of Agroforestry and Environment 3(2):129-133.
Lemma D, Shimeles A (2003). Research experiences in onion production. Research report No. 55, EARO, Addis Abeba, Ethiopia. 52 p.
Leskovau DI, Vavrina CS (1999). Onion growth and yield are influenced by transplant tray cell size and age. Scientia Horticulture 80:133-143.
Ministry of Agriculture and Rural Development (MOARD) (2006). Crop variety register. Crop development department, Issue No.9, June 2006, Addis Ababa, Ethiopia.
Mohanty BK, Barik T, Dora DK (1990). Effect of time of transplanting and age of seedling of onion (*Allium cepa* L.). Indian Agriculturist 34(2):111-113.
Muhammad T, Amjad M, HayatS,Husain A, SaeedA (2016). Influence of nursery sowing dates, seedling age and nitrogen levels on bulb quality and marketable yield of onion (*Allium cepa* L.) at Faisalabad, Pakistan. Pure and Applied Biology pp. 226-230.
Muhammad T, Amjad M, Ali M, Hanif M, Hussein MAM, Haseeb A, Noor A (2017). Seedling age and nitrogen level enhance vegetative growth and yield of onion (*Allium cepa* L.) at Faisalabad, Pakistan. International Journal of Agriculture and Environment Research 3(2):232-239.
Olsen SR, Cole CV, Watanable FS, Dean LA (1954). Estimation of phosphorus in soils by extraction with sodium bicarbonate. USDA, circular 939:1-19.
Rai MM (1981). Principle of soil science. MacMillan India Limited Calcutta pp.179-182.
Ray N, Yadav DS (2005). Advance vegetable production. Research co book center, India.
Sirinka Agricultural Research Center (SARC) (2008). List of varieties hand out. Sirinka, Ethiopia.
SAS (Statistical Software) Institute Inc. (2008). SAS/STAT. 9.2. User's guide. Cary, NC: SAS Institute Inc. USA.
Shaheen AM, MonaM, AbdelM, Aisha AM, Fatma AR (2007). Natural and chemical phosphorus fertilizers as affected onion plant growth, bulb yield and its some physical and chemical properties. Australia journal of basic and applied science, Insect Publication 1(4):519-524.
Singh J, Chaure NK (1999). Effect of seedling age and nitrogen levels on growth and yield of onion (*Allium cepa* L.). Advances in Horticultural and Forestry 6:73-77.
Sultana MST (2015). Effect of age of seedlings and number of plants per hill on the growth and yield of onion. M.Sc. Thesis, Dept. Hort., BAU, Dhaka pp. 45-46.
Tibebu S, Melese T, Abrham S, Samuel U (2014). The effect of variety, nitrogen and phosphorous fertilization on growth and bulb yield of onion (*Allium cepa* L.) at Wolaita, Southern Ethiopia. Journal of Biology, Agriculture and Healthcare 4:90-92.
Vachhani MU, Patel ZG (1993). Growth and yield of onion (*Allium cepa* L.) as affected by levels of nitrogen, phosphorous and potash under growth Gujarat condition. Progressive Horticulture 25(3):32-41.
Verma JP, Rathore SVS, Yadav BS (1971). Performance of bulb crop of onion as affected by sowing date and age of transplants. Progressive Horticulture 3(2):29-33.

Walkley A, Black CA (1954). An examination of different methods for determining soil organic matter and the proposed modification by the chromic acid titration method. Soil Science 37:29-38.

Woldetsadik K (2003). Shallot (*Allium ascalonicum* L.) Responses to plant nutritents and soil moisture in a sub-humid tropical climate. Doctoral dissertation, Swedish University of Agricultural Sciences, Alnarp pp. 1-28.