1874-0707/20 Send Orders for Reprints to reprints@benthamscience.net

The Open Biotechnology Journal

Content list available at: https://openbiotechnologyjournal.com

CrossMark

RESEARCH ARTICLE

Effect of Plant Spacing and Np Fertilizer Levels on Growth, Seed Yield and Quality of Onion (*Allium cepa* L.) at Shewa Robit, Northern Ethiopia

Getachew Amare[1,*], Wassu Mohammed[2] and Tamado Tana[2]

[1]*Department of Horticulture, College of Agriculture and Natural Resources Sciences, Debre Berhan University, Debre Berhan, Ethiopia*
[2]*Department of Plant Science, College of Agriculture and Environmental Sciences, Haramaya University, Dire Dawa, Ethiopia*

Abstract:

Background:

The shortage of quality seed is the major limiting factor of onion production in the study area. Inappropriate use of NP fertilizers and plant spacing is the major source of the problem.

Objective:

The experiment was conducted to determine optimum plant spacing and NP fertilizer for high yield and quality seed production of onion.

Methods:

The treatments were composed of plant spacing 10×20×40 cm, 20×30×50 cm, 10×40 cm, 10×50 cm, 10x30 cm and NP fertilizer levels 86.25 P_2O_5 & 85.5 N kg ha^{-1}, 115 P_2O_5 & 114 N kg ha^{-1}, 143.6 P_2O_5 & 142.5 N kg ha^{-1}, 69 P_2O_5 & 142 N kg ha^{-1} and control in a 5 x 5 factorial arrangement of RCBD with three replications.

Results:

The highest seed yield per hectare (879.4 kg) and per plot (663.6 g) was obtained from 115 P_2O_5 & 114 N kg ha^{-1} fertilizers and plant spacing 10×30cm gives the highest seed yield per plot (561.7g) and per hectare (748.9 kg). The highest germination percentage was obtained by the interaction effect of 10×30 cm and 143.6 P_2O_5 & 142.5 N kg ha^{-1}. Whereas, highest seed vigor index I and II were obtained from the interaction of 115 P_2O_5 &114 N kg ha^{-1} and 20×30×50 cm spacing.

Conclusion:

Plant spacing of 10×30 cm followed by 20×30×50 cm and 115 P_2O_5 &114 N kg ha^{-1} fertilizers could be recommended for high yield and quality onion seed production in the study area.

Keywords: Plant spacing, Seed yield, Plant growth, NP fertilizer, Seed quality, Onion (*Allium cepa* L.).

Article History	Received: September 06, 2019	Revised: November 27, 2019	Accepted: January 01, 2020

1. INTRODUCTION

Onion (*Allium cepa* L.) belongs to the family Amaryllidaceae. It is believed to have originated in Afghanistan, the area of Tajikistan and Uzbekistan, western Tien Shan and India [1]. The most recent estimations have reported that there are about 750 species in the genus *Allium*, among which onion, Japanese bunching onion, leeks and garlicare the most important edible *Allium* crops [2].

Onions are highly beneficial in nutritional terms, providing a rich source of Vitamins B_1, C and E and certain trace elements. The carbohydrate content ranges from 5% to about 11%; 100 g of edible portion provides about 36 kcal energy values [2]. Onions are also advantageous in a way that, the bulbs can be harvested and sold either 'green' to be used in salads [3], while the mature bulbs are cooked or eaten raw as a vegetable [4].

The world onion production in 2017 was about 97,862,928 tons of dry bulbs from 5,201,591 hectares of land with an average yield of 18.8 t ha^{-1}. China is the biggest onion producer

* Address correspondence to this author at the Department of Horticulture, College of Agriculture and Natural Resources Sciences, Debre Berhan University, P.O. Box: 445, Debre Berhan, Ethiopia; Tel: +251913542696; E-mail: getchamare38@gmail.com

followed by other major onion producing countries India, the USA, Iran, Egypt, Russia and Turkey [5].

The estimated total area under onion in Ethiopia was about 31,673.21 hectares, from which 293,887.5 tones were produced in 2018 with an average yield of about 9.27 t ha^{-1} [6]. This indicates the productivity of onion in Ethiopia (9.27 t ha^{-1}) is far below the world average (18.8 t ha^{-1}). The factors affecting onion production could be inappropriate spacing, poor fertilizer application and unavailability of quality seeds together with other agronomic practices [5, 6].

The seed yield and quality of onion are influenced by many factors, but cultivar, soil and climate, seedling age, bulb weight, spacing, fertilization, date of planting and seed quality are very important. Mirshekari and Mobasher [7] reported that plant spacing significantly affected onion seed production. According to Verma *et al.* [8] interaction between bulb sizes and spacing (heaviest bulb and narrow spacing) produces higher total seed yield per plant. Asaduzzaman *et al.* [9] also reported plant spacing showed a significant effect on the number of flower stalks and its length, number of umbels per plant, number of seeds per umbel and seed weight per umbel. In Ethiopia, reports show higher onion seed yield is obtained through bulb planting at 30 cm space between rows on the ridge, 20 cm between plants and 50 cm between furrows on double row spacing [10].

Fertilizer application affects the yield and quality of onion seed production [11]. Nitrogen has been found to increase the number of umbels per plant, number florets per umbel, umbel size and seed yield [12]. However, the reports regarding the role of phosphorous on seed yield are contradictory. Chakrabarti *et al.* [13] reported that phosphorous application alone or in combination with nitrogen had no effect on seed yield but Ahmed and Abdella [14] reported phosphorous alone had no effect on seed yield, however, if it is applied in combination with nitrogen, it increases the number and size of umbels and seed yield significantly.

In Ethiopia, 46 P_2O_5 kg ha^{-1} and 87 N kg ha^{-1} are used for bulb production. Whereas, the recommendation for seed production of onion is the application of 100-150 kg ha^{-1} Urea and 200-250 kg ha^{-1} of DAP which is equivalent to 114 N kg ha^{-1} and 115 P_2O_5 kg ha^{-1} [10, 15].

Bombay Red is one of the most popular onion varieties in Ethiopia. Its area coverage and production across the country are increasing from time to time and it accounts for the largest area coverage among onion varieties [14].

Despite an increase in the area of coverage, the productivity of Bombay Red onion variety in Ethiopia is much lower than the expected production level. The bottleneck problem for high production and productivity is limited availability of quality seed and lack of other associated technologies. The major problem affecting quality seed production throughout the country is that the farmers have little knowledge of the optimum amount of N and P fertilization as well proper spacing for the bulb to seed onion seed production method [10]. Farmers in North Shewa, particularly in Shewa Robit Woreda also face the problem similar to other farmers in the country. Due to this, farmers do not apply fertilizers that are recommended by FAO [10] for seed production or blanket recommendation for bulb production by the Ethiopian Institute of Agricultural research [15], instead, they apply fertilizers as they think good for high seed production. In addition, they are using high plant spacing per unit area assuming that they can produce higher onion seed. Therefore, there was a need to undertake research to identify the appropriate plant spacing and NP fertilizer combination for maximum onion seed production. Thus, this study was conducted with the following objective.

1.1. Objective

To determine the effect of plant spacing and NP fertilizer levels on growth, seed yield and quality of onion.

2. MATERIALS AND METHODS

The experiment was conducted at Shewa Robit Research Station of Debre Berhan Agricultural Research Center, which is located at about 225 km Northeast of Addis Ababa. It is located at 11 55’ N latitude and 37 20’ E longitudes at an altitude of 1380 meters above sea level (m.a.s.l.). The area has an average annual rainfall of 1007 mm, and annual mean minimum and maximum temperatures of 16.5 and 31°C, respectively [16]. Bombay Red onion variety was used as experimental material. The planting material was medium-sized bulbs of uniform diameter and they were sorted, which were free from insect, disease and mechanical injuries (4-5 cm). Urea fertilizer as nitrogen fertilizer and TSP (triple superphosphate) as phosphorous fertilizer were applied to the experiment.

The experiment was laid out in a Randomized Complete Block Design (RCBD) in a factorial arrangement with three replications. Five levels of nitrogen and phosphorous fertilizers combinations were 86.25 P_2O_5×85.5 N kg ha^{-1}; 143.6 P_2O_5 ×142.5 N kg ha^{-1} and 115 P_2O_5× 114 N kg ha^{-1} which were 25% below, above and FAO [16] recommendation for Central Rift Valley, respectively, 69 P_2O_5× 142 N kg ha^{-1} (farmers practice) and with zero fertilizer application as a control were used as treatments. The five spacing treatments were set as 10 × 20×40 cm double row spacing recommended for bulb production, 20 × 30 × 50 cm (spacing recommended by FAO [16] for Central Rift Valley) and single row spacing of 10 × 40 cm (spacing commonly used by farmers); 10 × 50 cm (one level above the farmers) and 10 × 30 cm (one level below farmers) respectively. The five fertilizer combinations and spacing were combined in the factorial arrangement and the experiment was laid out as a randomized complete block design with three replications. Each replication was arranged as 25 plots corresponding to the 25 treatment combinations. The plot sizes were 2.5 × 3 m = 7.5 m^2 and adjacent plots and blocks were 1 m and 1.5 m apart, respectively. Data were collected from the middle rows of each plot left one plant at both ends of rows.

The data collected were Days to 50% flowering, Days to maturity, Plant height (cm), Flower stalk diameter (cm), Number of umbels per plot, Umbel diameter (cm), Number of seeds per umbel, Seed weight per umbel (g), Seed yield per plot (kg), Seed yield per hectare (kg/ha), 1000 seeds weight (g), Germination percentage [17], Seed vigour index I (Germination (%) x Seedling length (cm) (Seedling Root length + Shoot length) and seed vigour index II (Germination (%) x Seedling dry weight (g)) and Speed of germination [18].

The collected data were subjected to analysis of variance using SAS statistical computer software version 9.1.3 program for factorial arrangement in RCBD. The analysis of variances, were performed following Duncan's Multiple Range Test [19].

The partial budget analysis was conducted for economic analysis of fertilizer application and it was carried out for combined seed yield data. The potential response of crop towards the added fertilizer and price of fertilizers during planting ultimately determined the economic feasibility of fertilizer application. The economic analysis was computed using the procedure described by CIMMYT [20]. The data were Gross average seed yield (kg ha^{-1}) (AvY), Marginal Rate of Return (MRR %), Gross Field Benefit (GFB), Net Benefit (NB) and Adjusted Yield (AjY).

2.1. Soil Analysis

Surface soil (0-30 cm depth) samples were collected by using auger from 10 spots of the experimental field before planting. These samples were composites to yield one representative sample. The samples were subjected to air drying and ground that allowed them to pass through 2.0 mm sieve before laboratory analysis. The soil samples were analyzed for texture, pH, CEC, organic matter content, total N and available P.

The soil analysis result showed that the experimental site had a soil pH of 7.9 with 0.145% total nitrogen, 1.55% and 2.68% organic carbon and organic matter content, respectively. It has 2.32 mg P per kg of soil, 48.6 cmol (+)/kg and 10.68% available phosphorus, CEC and carbon to nitrogen ratio, respectively. The soil was 8, 50 and 42% sand, silt and clay, respectively, which gave silt clay soil texture. The total nitrogen was low as it was below 0.15% as per the description given by Bruce and Rayment [21], organic matter was moderate and the level of organic carbon was high as per the description of Charman and Roper [22]. The available phosphorus was very low as it was < 5 mg P/ kg soil [23]. The CEC was very high as per Metson [24], who indicated that CEC > 40 cmol (+) /kg is high.

3. RESULTS AND DISCUSSION

3.1. Phenology and Growth of Bombay Red Onion Variety

3.1.1. Days to 50% Flowering

Days to 50% flowering was significantly (P<0.01) affected by the main effect of plant spacing. The earlier days to 50% of flowering (71.53 days) was attained in plants grown at a single row spacing of 10 × 50 cm followed by 10 × 30 cm closer spacing, with no significant difference between them. While the delayed flowering was at about 74 days in plants grown at a spacing of 10 x 40 cm (Table **1**).

The reason for early flowering on wider plant spacing might be due to less competition for light, moisture and nutrients, which consequently resulted in vigorous growth and early flowering than those which compete for essential growth factors on closer spacing. The result was in agreement with Mengistu and Yamoah [25] as they reported, when plant spacing increased from 133333 to 400000 $ha^{-1}$the days to flowering also increased from 158 to 160 days. On the other hand, it is in contrast with Gray *et al.* [26], who reported that flowering was a few days later as plant spacing increased from 10 to 80 plants/m^2. Menberu *et al.* [27] also reported that varieties planted at 25 cm intra-row spacing attained 50% flowering within a short period of time (42 days) than 40 cm spacing, indicating that densely populated plants attained 50% flowering earlier than sparsely populated plants. El-Naim [28] also confirmed that closer spacing could reduce vegetative growth and enhance flower formation.

3.1.2. Days to Maturity

Days to maturity was significantly (P<0.01) affected by the main effect plant spacing. The days to maturity was early (133.5 days) when grown at 10 × 30 cm followed by 10 × 50 cm (133.9 days) plant spacing with the non-significant difference between the two plant spacing. The maturity was delayed when grown at 10 x 40 cm single row spacing which was followed by 10 x 20 x 40 cm and 20 x 30 x 50 cm double row spacing (Table **1**).

Rumpel and Kaniszewski [29] and Brewster [30] found that delayed days to maturity was observed from sparsely populated plants, while plants grown in closer spacing or in high plant population matured early. This is because the low plant spacing per unit area had adequate space and they were not severely competing for resources for their growth and development. Accordingly, it resulted in delaying of seeds maturity. In accord with the above findings, the present study result for days to maturity showed that closer spacing 10 × 30 cm was earlier to mature but with no significant difference with wider spacing 10 × 50 cm and 20 x 30 x 50 cm double row spacing.

3.1.3. Plant Height

Significant (P<0.05) differences were observed in plant height due to the main effect of plant spacing and NP fertilizers.

The tallest plants (87.3 cm) were found in double row spacing of 10 x 20 x 40 cm and single row spacing of 10 x 50 cm with no significant difference in between. On the other hand, the shortest plants (77.18 cm) were recorded from 20 x 30 x 50 cm double row spacing and narrower spacing of 10 × 40 cm (Table **1**). This might be due to the preference of the onion crop for wider double row and single row spacing which give a small number of plants per unit area. The taller plant height observed in plants grown under single row spacing of 10 x 50 cm might be due to less competition to light, moisture and nutrients as they grow far apart.

The current result was in accord with the reports of Law-Ogbomo [31] and Jilani *et al*. [32] who reported that the onion bulbs planted on wider spacing of 30 × 20 cm produced the tallest plant, which was much higher than the shortest plants produced from the closest spacing of 25 × 15 cm. The authors described the closer spacing resulted in competition among plants for nutrient and light thus resulting in short plants, while, the plants grown in wider spacing produced more green leaf and extra food which promoted the plant height.

Table 1. The main effect of plant spacing and NP fertilizers rates on phenology and growth of Bombay Red onion variety grown at Shewa Robit.

Spacing (cm)	Days to 50% Flowering	Days to Maturity	Plant Height (cm)	Flower Stalk Diameter (cm)	Number of Umbel Per Plot
10 x 20 x 40	72.07bc	134.9ab	87.13a	1.449bc	1562a
20 x 30 x 50	72.53b	134.5abc	77.18c	1.549a	505c
10 x 40	73.53a	135.2a	79.31bc	1.421c	1213b
10 x 50	71.53c	133.9bc	86.31ab	1.497ab	1050b
10 x 30	72.33bc	133.5c	85.49ab	1.308d	1472a
LSD 5%	0.914	0.947	11.8	0.0742	170.6
Fertilizer rate (P_2O_5 and N kg ha^{-1})					
0 x 0	73.00a	135.07a	76.01b	1.334c	1118a
86.25 x 85.5	72.33a	134.53a	82.59ab	1.435b	1189a
115 x 114	71.87a	133.80a	87.65a	1.559a	1218a
143.6 x 142.5	72.07a	133.93a	84.63a	1.439b	1153a
69 x 142	72.73a	134.67a	84.53a	1.457b	1122a
LSD 5%	Ns	ns	7.17	0.0742	ns
CV (%)	1.7	1.0	11.8	7.0	20.0

LSD (5%) = Least Significant Difference at *P*=0.05, CV (%) = Coefficient of Variation ns= non-significant. Means in columns with the same letter(s) in each treatment are not significantly different.

The NP fertilizer rate of 115 P_2O_5 and 114 N kg ha^{-1} gave the highest plant height of 87.65 cm followed by 143.6 P_2O_5 and 142.5 N kg ha^{-1}. Increasing fertilizer from zero to 115 P_2O_5 and 114 N kg ha^{-1} resulted in the increased height of the plant. Whereas, further increase in fertilizers above those described levels decreases the height of the plants (Table **1**). Gupta and Sharma [33] and Ali *et al.* [34] reported that an increase in nitrogen fertilization from the control increases the height of the plant up to the certain stage at which the growth ceases or become decreased due to the toxicity of the fertilizer which is similar to results of the present study. The increase in growth with a rise in nitrogen up to a certain optimum level might be due to the availability of more nutrients, which help the maximum vegetative growth of onion plant and the effect of N contributing to the higher rates of vegetative growth and stem elongation.

3.1.4. Flower Stalk Diameter

Flower stalk diameter was significantly (P<0.01) influenced by the main effect of plant spacing and NP fertilizers (Table **1**). The highest flower stalk diameter was recorded by 20 x 30 x 50 cm double row spacing followed by plants grown at 10 x 50 cm, which were statistically apart. Plants grown at plant spacing of 10 x 30 cm had small (1.30 cm) flower stalk diameter. The highest flower stalk diameter (1.56 cm) was recorded from NP fertilizers 115 P_2O_5 and 114 N kg ha^{-1} and the lowest (1.334 cm) was from control (Table **1**). This result was in agreement with the report by Gusmao *et al*. [35] and Mozumder *et al*. [36] as they reported that wider spacing showed higher flower stalk diameter than closer spacing. This might be due to the fact that plants grown in wider spacing or low plant populations had adequate space and they might not severely compete for resources that were important for their growth and development and consequently resulted in high flower stalk diameter.

3.2. Seed Yield and Yield Components

3.2.1. Number of Umbles Per Plot

The number of umbels per plot was significantly (P<0.01) affected by the main effect of plant spacing. Plant spacing of 10 x 20 x 40 cm double row and 10 × 30 cm had 1562 and 1472 umbels per plot, respectively, which were the highest in the experiment. On the other hand, the smallest number of umbels per plot (505) was recorded for the plants grown at a spacing of 20 × 30 × 50 cm double row spacing (Table **1**).

The result agreed with the works of Asaduzzaman *et al.* [12], Rumpel and Kaniszewski [29] and Abedin *et al.* [37] who reported that as the plant spacing decreased the number of umbels per plot also increased dramatically.

3.2.2. Umbel Diameter

Umbel diameter was significantly (P<0.01) influenced by the main effect of plant spacing and significantly (P<0.05) affected by NP fertilizers (Table **2**).

The highest umbel diameter (6.366 cm) was obtained when plants were grown at 20 × 30 × 50 cm double row spacing which was followed by 10 x 20 x 40 cm double row spacing. Accordingly, the larger umbel diameter (6.267 cm) was obtained with the NP application rates of 115 P_2O_5 and 114 N kg ha$^{-1,}$ which were followed by 143.6 P_2O_5 and 142.5 N kg ha^{-1}. The diameter of the umbel was small when plants were grown at 10 × 30 cm spacing and zero fertilizer application (Table **2**).

These results were in accord with the work done by Firoz *et al.* [38] and Khan *et al*. [39] who found significantly large umbels from sparsely populated plants than densely populated. This might be due to a higher supply of food materials to the umbel by the plants grown at wider spacing with decreased competition for moisture, light and nutrients. According to Ali *et al.* [40], phosphorous and nitrogen fertilization showed a significant effect on umbel diameter. This was in agreement with the result of this study where NP fertilizers showed significant effect on umbel diameter. This might be due to the fact that flower setting and seed formation are highly controlled by phosphorous and the application of nitrogen increased the vegetative growth, produced good quality foliage and promotes carbohydrate synthesis thereby produces larger umbel diameters [41].

3.2.3. Number of Seeds Per Umbel

The number of seeds per umbel was significantly (P<0.01) affected by the main effect of plant spacing and NP fertilizers (Table **2**). The highest number of seeds per umbel (910.2) was recorded for plants that were grown at 20 × 30 × 50 cm double row spacing followed by 10 × 50 cm spacing. Whereas, the small number of seeds per umbel was recorded from plants grown in plots with 10 x 20 x 40 cm double row spacing. The highest number of seeds per umbel (914.6) was recorded from plants that received 115 P_2O_5 and 114 N kg ha^{-1} followed by 143.6 P_2O_5 and 142.5 N kg ha^{-1}, which were statistically apart with the former. While the lowest number of seeds per umbel was from control with no significant difference from plants that received 86.25 P_2O_5 and 85.5 N kg ha^{-1} (Table **2**).

This result was in line with Ali *et al.* [40], who found that the highest number of seeds per umbel (95.28) was obtained from 150 N kg ha^{-1} and the lowest from the control. Abu-Sarra [42] also reported that the highest number of seeds per umbel was recorded from optimum fertilization and the lowest from lower nitrogen levels. This might be due to the role of nitrogen in the reduction of flower abortion and the effect of phosphorus on flower and seed production. Asaduzzaman *et al.* [9] also reported that as plant spacing increased the number of seeds per umbel also increased significantly which was in agreement with the current study result. This might be due to the role of wider spacing for a better supply of nutrients, light and moisture which might give excellent growth and development of a large number of seeds per umbel.

3.2.4. Seed Weight Per Umbel

Seed weight per umbel was significantly (P<0.05) affected by the main effect of NP fertilizer application and plant spacing. The highest seed weight per umbel was recorded from plants grown at spacing of 20 x 30 x 50 cm double row spacing, 143.6 P_2O_5 and 142.5 N kg ha^{-1} and 115 P_2O_5 and 114 N kg ha^{-1} fertilizers application with the non-significant difference among them. The lowest seed weight per umbel was recorded from the plants that were grown under zero NP fertilizer application (Table **2**).

High seed weight per umbel under high NP fertilizers might be due to the role of nitrogen in the buildup of carbohydrate and different metabolites and the role of phosphorous in seed formation and development [43]. Small seed weight per umbel under the highest plant spacing could be due to the effect of competition for moisture, light and nutrients.

The result was in agreement with the study by Ali *et al.* [34] who reported that seed weight per umbel was significantly different due to the effect of nitrogen and phosphorus dose. In accord with this study, Begum *et al*. [44] and Tesfu and Yamoah [45] also reported that the highest seed weight per umbel was recorded from wider spacing than narrower spacing.

3.2.5. Seed Yield Per Plot and Per Hectare

Highly significant (P<0.01) differences were exhibited for seed yield per plot and per hectare due to the main effects of NP fertilizers and plant spacing. The highest seed yield per plot and per hectare was obtained from the plants that were grown at 20 x 30 x 50 cm double row spacing and 10× 30 cm single row spacing with the non-significant difference between the two plant spacings. The lowest seed yields per plot and per hectare were recorded from plant spacing of 10 x 20 x 40 cm double row spacing. On the other hand, the highest seed yields per plot and per hectare were obtained from the rate of fertilizer 115 P_2O_5 and 114 N kg ha^{-1} followed by 143.6 P_2O_5 & 142.5 N kg ha^{-1}. The lowest seed yield per plot and per hectare was recorded from control or plants which did not receive fertilizer (Table **2**).

This indicated that the plots with very high and low plant spacing were efficient in giving higher seed yield per plot and hectare. This might be due to less competition for growth essentialities under low plant spacing; therefore, it can favor vigorous growth and highest yield. Whereas, when the plant spacing is closer, the total seed yield per plot and per hectare will be higher; since low seed yield per plant is compensated by higher plant spacing per unit area. The current study result was in accord with the studies by Jilani *et al*. [32] and Ali *et al.* [34], who reported significantly higher seed yield per plot from plants grown under closer spacing, increased fertilizer applications and from plants grown under wider spacing with optimum fertilizer application.

3.3. Seed Quality Parameters

3.3.1. Thousand Seeds Weight

The main effect of NP fertilizer levels significantly (P<0.05) affected 1000 seeds weight. The highest 1000 seeds weight was obtained from plants that received NP fertilizers of 143.6 P_2O_5 and 142.5 N kg ha^{-1} followed by 115 P_2O_5 and 114 N kg ha^{-1}. Plants that did not receive fertilizer (control) produced the lowest 1000 seeds weight (Table **2**). In this experiment, only the control treatments produced seeds slightly lower than the world average for 1000 seed weight (3.6 g) [46], while all other treatments produced more than the average seed weight for the onion. Generally, as both N and P_2O_5 rates increased the seed weight was also increased. This might be due to the fact that nitrogen and phosphorous are basic components of starch and carbohydrate of the seeds of plants. These elements are actively involved as a building block of the seed materials thereby increased the weight of the seed of the onion [41].

In agreement with the present study, Ozer [47] and Ozden [48] reported that higher rates of fertilizer application produced heavyweight seeds. On the other hand, the current study results were in contrast to Ali *et al.* [34] and Ali *et al.* [40] who reported that nitrogen and phosphorous fertilizers did not have a significant effect on 1000 seeds weight.

Table 2. The main effect of plant spacing and NP fertilizer rates on seed yield and yield components of Bombay Red onion variety grown at Shewa Robit.

Spacing (cm)	Umbel Diameter(cm)	Number of Seeds Per Umbel	Seed Weight Per Umbel(g)	Seed Yield Per Plot(g)	Seed Yield Per Hectare (kg)	1000 Seed Weight (gm)
10 x 20 x 40	6.144ab	753.7b	2.811c	383.8b	511.7c	3.654a
20 x 30 x 50	6.366a	910.2a	3.516a	545.3a	727.1ab	3.694a
10 x 40	5.656cd	824.7ab	3.243abc	505.9ab	674.1ab	3.609a
10 x 50	5.975bc	904.1a	3.333ab	463.2ab	612.3bc	3.689a
10 x 30	5.533d	795.3b	2.954bc	561.7a	748.9a	3.685a
LSD (5%)	0.3745	93.1	0.4756	98.6	130.8	ns
Fertilizer rate (P_2O_5 and N kg ha^{-1})						
0 x 0	5.734b	820.1bc	2.899b	281.3d	375.0c	3.529b
86.25 x 85.5	5.809b	756.1c	2.984b	374.8cd	499.8c	3.697ab
115 x 114	6.267a	914.6a	3.293ab	663.6a	879.4a	3.634ab
143.6 x 142.5	6.045ab	895.0ab	3.636a	640.7ab	853.8a	3.873a
69 x 142	5.818b	802.2bc	3.046b	499.5bc	666.1b	3.598ab
LSD (5%)	0.3745	93.1	0.4756	98.6	130.8	0.2021
CV (%)	8.6	15.1	20.4	27.3	27.2	3.529b

LSD (5%) = Least Significant Difference at P=0.05, CV (%) = Coefficient of Variation ns= non-significant. Means in columns with the same letter(s) in each treatment are not significantly different.

3.3.2. Germination Percentage

Germination percentage was significantly (P<0.01) affected by the interaction effect of NP fertilizers and plant spacing. Plant spacing of 10 × 30 cm and 143.6 P_2O_5 and 142.5 N kg ha^{-1} fertilizers gave the highest germination percentage of seeds (97%) followed by the same spacing with 142 N and 69 P_2O_5kg ha^{-1} (96.67%) with no significant difference between the two means. The lowest germination percentage (82.0) was obtained when 20 × 30 × 50 cm double row spacing was interacted with the control fertilizer application (Table **3**).

According to the reports by Asaduzzaman *et al.* [9], inter and intra row spacing had a tremendous effect on seed germination percentage in which the highest germination was mostly recorded from wider spacing than closer spacing. Ali *et al.* [40] and Ahmed [49] reported that phosphorus and nitrogen fertilization had a significant effect on seed germination percentage in which mostly higher germination percentage was recorded from high fertilizer application.

Unlike the reports of those researchers and similar to the report by Gray *et al*. [50], the result of this study showed that closer spacing with high phosphorus and nitrogen application gave higher seed germination percentage than wider spacing and high NP fertilizer applications. The reason behind this could be the interaction of closer plant spacing and higher fertilization increased the proportion of seed from primary umbels, thus improving seed quality. This is because the embryos of seeds from primary umbels are larger than seeds derived from subsequent umbels and due to the active involvement of the minerals in the development of the embryo and in buildup and activation of seed germination hormones.

Seed germination percentage of 90-94% is considered as the highest and 70% as a minimum germination requirement for most onion cultivars under the Ethiopian condition [51]. In this study, 48% treatments (12 out of 25) produced seeds with >90% germination which could be categorized as highest germination percentage and none of the treatments produced seeds with <80% germination indicating all the treatment combinations produced seeds either with highest or above the minimum germination requirement of onion seeds in the country.

3.3.3. Speed of Germination

The main effect of NP fertilizers and its interaction with plant spacing had a highly significant (P<0.01) effect on the speed of germination (Table **4**).

The fastest rate of germination (30.20 seed germination per day) was recorded by the interaction of 142 N and 69 P_2O_5 kg ha^{-1} fertilizers combination with 10 × 40 cm plant spacing followed by plants in plots without fertilizer application and 20 x 30 x 50 cm double row spacing (Table **4**). Those fast rates of germination might be due to the small-sized seeds produced from those treatments and the ability of those small seeds to germinate early. This result was in agreement with Ndor *et al.* [52] and Cuocolo and Barbieri [53] as they explained that the earlier germination of the small seeds could be that, the seeds required less moisture and nutrients to germinate and small seeds also have small surface area and can imbibe enough moisture at a short time and commenced the process of germination.

3.3.4. Seed Vigour Index

The interaction effect of plant spacing and NP fertilizers showed a highly significant (P<0.01) effect on seed vigour index I and II (Table **5**).

3.3.4.1. Seed Vigour Index I

The highest seedling vigour index I (947.2) was obtained from the interaction of 20 x 30 x 50 cm double row plant spacing with 115 P_2O_5 and 114 N kg ha^{-1} followed by 10 × 50 cm and 143 P_2O_5 and 142 N kg ha^{-1}. On the other hand, the lowest (102.3) seedling vigour index I was recorded for seeds that did not receive fertilizer and grown at 20 x 30 x 50 cm double row spacing (Table **5**).

According to Singh and Singh [54] and Ashenafi *et al.* [55], the highest seed vigour index I was recorded from plants that were grown in wider spacing and optimum fertilization. This could be due to the fact that in large seed size there is more food reserve in the cotyledon of the seed to sustain the seedling growth and make seedlings to be vigorous than the smaller seed sizes whose food reserve could be exhausted very soon. The result of this study agreed with the above reports as the highest seedling vigour index I was observed from the interaction of wider spacing of 20 x 30 x 50 cm double row spacing and 10 × 50 cm in combination with the optimum and highest rate of fertilizers combinations.

3.3.4.2. Vigour Index II

The highest vigour index II (46.73) was recorded from the interaction of 20 x 30 x 50 cm double row spacing and 115 P_2O_5 and 114 N kg ha^{-1} fertilizers. Whereas, the lowest vigour index II (9.2) was obtained from the interaction of 10 x 20 x 40 cm double row spacing and without fertilizer application (control) (Table **6**). This report was in agreement with Ashenafi *et al.* [55] and Singh and Sachan [56], who reported that wider spacing with optimum fertilizer application produced large-sized seeds and gave high seed vigor index II. The result of this study agreed with the above reports as the highest seedling vigour index II was observed from the interaction of wider spacing 20 x 30 x 50 cm double row spacing and 115 P_2O_5 and 114 N kg ha^{-1} NP fertilizers. Whereas, the lowest was observed from the interaction of control and closer 10 x 20 x 40 cm double row spacing and control.

3.4. Partial Budget Analysis

The partial budget analysis was performed using CIMMYT [20] description and guidelines for economic analysis of fertilizer application. As the rate of NP fertilizer application increased, each additional kilogram of the fertilizer had an effect on seed yield. To estimate the total costs, the mean current prices of Urea and TSP were collected at the time of planting and the market price of onion seed was taken at harvest.

The result of the economic analysis showed that the highest net benefit 358, 120.8 birr ha^{-1}, highest rate of marginal returns 3587% and highest benefit-cost ratio 5.34 were obtained from the plant spacing 10 × 30 cm and 115 P_2O_5 & 114 N kg ha^{-1} NP fertilizers. It was followed by 20 × 30 × 50 cm double row spacing and 115 P_2O_5 & 114 N kg ha^{-1} NP fertilizers which had 329,615.20 birr hs^{-1} net benefit, 3463.9% rate of marginal return and 4.885 benefit-cost ratio. The result revealed that the use of those plant spacing and fertilizer applications was cost-effective as compared to the others (Table **7**). The cost of onion seed was exceptionally high 400 birr per kg from normal market which was 260 birr per kg when the produce was collected and this was one reason for high net benefit recorded in this study.

Table 3. Interaction effect of plant spacing and NP fertilizer rates on seed germination percentage of Bombay Red onion variety grown at Shewa Robit.

Spacing (cm)	Fertilizer Rates (P_2O_5 and N kg ha^{-1})				
	0 & 0	86.25 & 85.5	115 & 114	143.6 & 142.5	69 & 142
10 x 20 x 40	85.00jk	84.00kl	95.00abc	91.00fg	80.00m
20 x 30 x 50	82.00l	88.00hi	91.00fg	93.00cdef	86.00 ijk
10 x 40	82.33l	88.00hi	94.33bcd	92.33def	95.33ab
10 x 50	85.33jk	85.00jk	95.00abc	89.00gh	94.00 bcde
10 x 30	92.00ef	82.67l	86.67ij	97.00a	96.67a
LSD (5%) =	2.13				
CV (%) =	1.5				

LSD (5%) = Least Significant Difference at *P*=0.05, CV (%) = Coefficient of Variation ns= non-significant. Means in rows and columns with the same letter(s) in each treatment are not significantly different.

Table 4. Interaction effect of plant spacing and NP fertilizer rate on the speed of germination of Bombay Red onion variety grown at Shewa Robit.

Spacing (cm)	Fertilizer Rates (P_2O_5 and N kg ha^{-1})				
	0 x 0	86.25 x 85.5	115 x 114	143.6 x 142.5	69 x 142
10 x 20 x 40	28.65 cdef	26.75 ghijk	29.67abc	26.25efghij	24.57m
20 x 30 x 50	30.03 ab	27.56 efgh	25.07lm	28.68 bcdef	27.00 ghij
10 x 40	28.57cdef	27.35fghi	28.00 defg	26.03 ijkl	30.20a
10 x 50	27.71 efg	26.31hijkl	29.06 abcd	25.86 jklm	29.17 abcd
10 x 30	29.31abcd	25.49 klm	25.72 jklm	28.55 cdef	28.83 bcde
LSD (5%) = 0.6033					
CV (%) = 3.0					

LSD (5%) = Least Significant Difference at *P*=0.05, CV (%) = Coefficient of Variation in percent, ns= non-significant. Means in rows and columns with the same letter(s) in each treatment are not significantly different.

Table 5. Interaction effect of plant spacing and NP fertilizer rates on seed vigour index I of Bombay Red onion variety grown at Shewa Robit.

Spacing (cm)	Fertilizer Rate (P_2O_5 and N kg ha^{-1})				
	0 & 0	86.25 & 85.5	115 &114	143.6 & 142.5	69 & 142
10 x 20 x 40	726.4m	869.0f	817.0h	813.9h	780.1j
20 x 30 x 50	102.3r	572.0q	947.2a	637.0n	624.4o
10 x 40	744.0l	817.4h	883.3e	597.7p	110.1r
10 x 50	826.0g	833.0g	880.0e	935.0b	920.0c
10 x 30	794.7i	791.0i	895.0d	570.0q	770.7k
LSD (5%) =	3.622				
CV (%) =	0.7				

LSD (5%) = Least Significant Difference at *P*=0.05, CV (%) = Coefficient of Variation in percent, ns= non-significant. Means in rows and columns with the same letter(s) in each treatment and trait are not significantly different.

Table 6. Interaction effect of plant spacing and NP fertilizer rates on seed vigour index II of Bombay Red onion variety grown at Shewa Robit.

Spacing(cm)	Fertilizer Rates (P_2O_5 and N kg ha^{-1})				
	0 & 0	86.25 & 85.5	115 & 114	143.6 & 142.5	69 & 142
10 x 20 x 40	9.2t	18.75 n	22.49 efg	20.76 kl	22.28 fgh
20 x 30 x 50	22.04 hi	22.58 ef	46.73 a	16.02 q	18.37º
10 x 40	16.03q	20.49l	31.15 b	17.07p	20.83 k
10 x 50	19.26m	21.84i	24.11d	21.25j	22.17 ghi
10 x 30	13.2r	16.97p	22.66e	26.67c	10. 20s
LSD (5%)= 1.636					
CV (%)= 1.0					

LSD (5%) = Least Significant Difference at *P*=0.05, CV (%) = Coefficient of Variation in percent, ns= non-significant. Means in rows and columns with the same letter(s) in each treatment are not significantly different.

Table 7. Economic analysis due to the application of NP fertilizer levels and plant spacing on marketable seed yield of Bombay Red onion grown at Shewa Robit.

N and P_2O_5 Rate (kg ha^{-1})	Spacing (cm)	Average Seed Yield (kg ha^{-1})	Adjusted Seed Yield (kg ha^{-1})	Gross Field Benefit (ETB ha^{-1})	Total Cost (ETB ha^{-1})	Net Benefit (ETB ha$^{-1)}$	Marginal Return	Marginal Rate of Return (%)	Benefit Cost Ratio
0 × 0	10 ×20×40	267	240.3	96120	60000	36120	0.602	60.2	0.602
85.5 × 86.25	10 ×20×40	459	413.1	165240	65578	99662	11.39	1139	1.52
114 × 115	10 ×20×40	662.	595.8	238320	67464.8	170855.2	18.04	1804	2.53
142.5 × 143.75	10 ×20×40	560.	504	201600	69330.2	132269.8	10.30	1030	1.907
142 × 69	10 ×20×40	611.	549.9	219960	67039.2	152920.8	16.59	1659	2.28
0 × 0	20×30×50	364.	327.6	131040	60000	71040	1.184	118.4	1.184
85.5 × 86.25	20×30×50	518.	466.2	186480	65578	120902	8.939	893.9	2.015
114 × 115	20×30×50	1103.	992.7	397080	67464.8	329615.2	34.639	3463.9	4.885
142.5 × 143.75	20×30×50	804.	723.6	289400	69330.2	220069.8	15.972	159.72	3.174
142 × 69	20×30×50	847.	762.3	304920	67039.2	237880.8	23.701	2370.1	3.548
0 × 0	10×40	435.	391.5	156600	60000	96600	1.61	161	1.61
85.5 × 86.25	10×40	479.	431.1	172440	65578	106862	1.839	183.9	1.629
114 × 115	10×40	837.	753.3	301320	67464.8	233855.2	18.386	1838.6	3.466
142.5 × 143.75	10×40	713	641.7	256680	69330.2	187349.8	9.726	972.6	2.70
142 × 69	10×40	906.	815.4	326160	67039.2	259120.8	23.08	2308	3.865
0 × 0	10×50	350	315	126000	60000	66000	1.1	110	1.1
85.5 × 86.25	10×50	504.	453.6	181400	65578	115822	8.931	893.1	1.766
114 × 115	10×50	614	552.6	221040	67464.8	153575.2	11.73	1173	2.276

(Table 7) contd.....

N and P_2O_5 Rate (kg ha^{-1})	Spacing (cm)	Average Seed Yield (kg ha^{-1})	Adjusted Seed Yield (kg ha^{-1})	Gross Field Benefit (ETB ha^{-1})	Total Cost (ETB ha^{-1})	Net Benefit (ETB ha$^{-1)}$	Marginal Return	Marginal Rate of Return (%)	Benefit Cost Ratio
142.5 × 143.75	10×50	627.	564.3	225720	69330.2	156389.8	9.68	968	2.255
142 × 69	10×50	967.	870.3	348120	67039.2	281080.8	30.55	3055	4.19
0 × 0	10×30	460.	414	165600	60000	105600	1.16	116	1.16
85.5 × 86.25	10×30	539.	485.1	194040	65578	128462	4.098	409.8	1.958
114 × 115	10×30	1181.	1062.9	425160	67039.2	358120.8	35.87	3587	5.34
142.5 × 143.75	10×30	627.	564.3	225600	69330.2	156269.8	5.43	543	2.253
142 × 69	10×30	938.	844.2	337680	67464.8	270215.2	22.0	2200	4.005

During experimental period the price of urea and DAP fertilizer was 14 and 16.16 ETB kg^{-1} and selling price of onion seed was 400 ETB kg^{-1}.

CONCLUSION

The results of this research indicated that the application of NP fertilizers significantly (*P*<0.01) affected flower stalk diameter, seed yield per plot, seed yield per hectare and the number of seeds per umbel. It significantly (*P*<0.05) affected plant height, umbel diameter, seed weight per umbel and 1000 seeds weight. The highest seed yield per hectare (879.4 kg) and per plot (663.6 g) was obtained from 114 N and 115 P_2O_5 kg ha^{-1} fertilizer levels. On the other hand, the highest 1000 seeds weight (3.87 g) was also recorded from 143.6 P_2O_5 and 142.5 N kg ha^{-1}. The plant spacing significantly (*P*<0.01) affected days to 50% flowering, flower stalk diameter, umbel diameter, number of umbels per plot, number of seed per umbel, seed yield per plot, seed yield per hectare and significantly (*P*<0.05) affected plant height, number of umbels per plot and seed weight per umbel. The highest seed yield per plot (561.7 g) and per hectare (748.9 kg) was recorded from plant spacing of 10 × 30 cm. Whereas, the highest number of seeds per umbel (910.2) was obtained from 20 × 30 × 50 cm double row spacing and 114 N and 115 P_2O_5 kg ha^{-1} fertilizer levels (914.6). On the other hand, the highest seed weight per umbel (3.516 g) was obtained from 20 × 30 × 50 cm double row spacing and 143.6 P_2O_5 and 142.5 N kg ha^{-1} (3.636 g). The interaction effect of NP fertilizers and plant spacing only affected germination percentage, speed of germination, seed vigor index I and II in which highest germination percentage was obtained from the interaction of 10 × 30 cm and 143.6 P_2O_5 and 142.5 N kg ha^{-1} whereas the highest seed vigor indexes I and II were obtained from 115 P_2O_5 and 114 N kg ha^{-1} and 20 × 30 at 50 cm double row spacing.

On the basis of one growing season research results, it is possible to conclude that the better crop phenology and growth parameters were obtained from 10 × 40 cm and 115 P_2O_5 and 114 kg N ha^{-1} fertilizers. The highest seed yield and yield components and seed quality attributes were obtained from plant spacing 20 x 30 x 50 cm double row spacing and 115 P_2O_5 and 114 N kg ha^{-1}combination followed by plant spacing 10 x 50 cm and 143.6 P_2O_5 and 142.5 N kg ha^{-1}.

According to the partial budget analysis of the marginal rate of return, net benefit and benefit-cost ratio, plant spacing 10 × 30 cm with 115 P_2O_5 and 114 N kg ha^{-1}fertilization was the most profitable which was followed by 20 × 30 × 50 cm double row spacing and 115 P_2O_5 and 114 N kg ha^{-1} fertilization. Thus, based on partial budget analysis and response of Bombay Red onion variety to plant spacing and NP fertilizers combination for the studied characters, it is suggested that 10 × 30 cm with 115 P_2O_5 and 114 N kg ha^{-1} followed by 20 x 30 x 50 cm double row spacing and 115 P_2O_5 and 114 N kg ha^{-1} fertilizer application were better than all the other treatments and can be recommended for Bombay Red onion variety for high yield and quality seed production in the study area.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Ethiopian Ministry of Education, Debre Berhan University, Madawalabu University and Debre Berhan Agricultural Research Center are acknowledged for their supports.

REFERENCES

[1] Malik YS, Nehra BK. Effect of stickling, planting dates and spacing on seed yield of radish (*Raphanus sativus* L.) cv. Pusa chetki. Vegetable Science 1999; 26(2): 149-51.
[2] Ranbinowitch HD. and L Currah, 2001, Allium Crop Science: Recent Advances CABI publishing, CAB International, Wallingford, UK. 2002.
[3] De Lannoy G. 2001.Vegetable Crops in Tropical Africa 395-511 In: Raemaeks R H (Editor) Crop Production in Tropical Africa 1540 pp Directorate General for International Cooperation (DGIC) Belgium.
[4] Straub RW, Emmett B. Pests of Monocotyledon Crops.Vegetable Crop Pests. U. K.: Macmillan Press 1992; pp. 213-62.

[5] FAO (Food and Agriculture Organization). Production year book. Food and Agriculture 2017.

[6] CSA (Central Statistical Authority). Report on Area and Production of Private Peasant Holdings Statistical Bulletin, Vol 1 Addis Ababa, Ethiopia 14. 2018.

[7] Mirshekari B, Mobasher M. Effect of sowing date, plant density and onion size on seed yield of Azashahr Red onion variety in Tabriz. J Agric Sci Islamic Azad Univ 2006; 12(2): 397-405.

[8] Verma TS, Chand R, Thakur PC, Lalkhanpal KD, Singh A. Effect of bulb size and plant spacing on yield of onion. Ind J Hill Farming 1994; 7(1): 102-4.

[9] Asaduzzaman MD, Mahmudul Hasan MD, Mainul Hasan MD, Moniruzzaman MD. Quality seed production of onion (*Allium Cepa* L.): An integrated approach of bulb size and plant spacing. J Agric Res (Lahore) 2012; 50(1): 119-28.

[10] FAO-CDMDP. The FAO-CDMDP Onion seed production techniques. Ethiopia: Asella: A manual for extension agents and seed producers 2010.

[11] Nandpuri KS, Madan SPA, Singh A, Singh S. Effect of various doses of nitrogen and Phosphorus on Onion seed production. Pp. 92. In: Currah, L. and F. J. Proctor, (eds), 1990. Onion in tropical regions National Resources Institute Bulletin. No. 35, UK.

[12] Nehra BK, Pandita ML, Kirti S, Sing K. Cultural and nutritional studies in relation to seed production in onion (*Allium cepa* L.). Haryana J Hortic Sci 1988; 17: 106-10.

[13] Chakrabarti AK, Choudhurry B, Singh C. Effect of nitrogen and phosphorous on seed production of onion (*Allium cepa* L.). Seed Res J 1980; 8: 1-4.

[14] Ahmed IH, Abdella AA. Nitrogen and phosphorus fertilization in relation to seed production in onion *Allium cepa* L. ISHS. Acta Hortic 2006; (143): VIII. African Symposium on Horticultural Crops.

[15] EIAR (Ethiopian Agricultural Research Organization). 2012. Directory of Released Crop Varieties and their Recommended Cultural Practices. Addis Ababa, 26.

[16] BoA (Bureau of Agriculture). Kewet Woreda Agriculture Development Office, Annual report (2000)..

[17] ISTA. 2008. International Seed Testing Association. International rules for seed testing..

[18] Abdul-Baki AA, Anderson JD. Vigour determination in soybean by multiple criteria. Crop Sci 1973; 13: 630-3. [http://dx.doi.org/10.2135/cropsci1973.0011183X001300060013x]

[19] Duncan DB. Multiple range and multiple F tests. Biometrics 1955; 11: 1-42. [http://dx.doi.org/10.2307/3001478]

[20] CIMMYT. Maize production regions in developing countries CIMMYT Maize program report. Mexico: CIMMYT ElBatan 1988; p. 138.

[21] Bruce RC, Rayment GE. Analytical methods and interpretations used by the Agricultural Chemistry Branch for Soil and Land Use Surveys. Queensland Department of Primary Industries. Bulletin QB8 (2004), Indooroopilly, Queensland, 1982..

[22] Charman PEV, Roper MM. Soil organic matter. Soils their properties and management. 3rd ed. Melbourne: Oxford University Press 2007; pp. 276-85.

[23] Holford ICR, Cullis BR. Effects of phosphate buffer capacity on yield response curvature and fertilizer requirements of wheat in relation to soil phosphate tests. Aust J Soil Res 1985; 23: 417-27. [http://dx.doi.org/10.1071/SR9850417]

[24] Metson AJ. 1961.Methods of chemical analysis for soil survey samplesSoil Bureau Bulletin No 12, New Zealand Department of Scientific and Industrial Research, pp 168-175 (Government Printer: Wellington, New Zealand)

[25] Mengistu and Yamoah. Effect of sowing date and planting density on seed production of carrot (*Daucus carota* var. *sativa*) in Ethiopia. Afr J Plant Sci 2010; 4(8): 270-9.

[26] Gray D, Steckel JRA, Chrimes JR, Davies ACW. Density and harvest date effects on leek seed yields and quality. Seed Sci Technol 1991; 19: 331-40. b

[27] Kitila M, Belew D, Mohammed A, Getachew Y. Effect of intra-row spacing and variety on fruit yield and quality of fresh market tomato (*Lycopersicon esculentum* Mill.) under Jimma condition, Ethiopia. Ethiopia J Appl Sci Technol 2012; 3(1): 32-42.

[28] ElNaim AM. 2003. Effect of different irrigation water quantities and cultivars on growth and yield of sesame (*Sesamum indicum* L.). Ph.D. Thesis, faculty of Agriculture, University of Khartoum.75p.

[29] Rumpel J, Kaniszewski S, Dysko J. Effect of drip irrigation and fertilization timing and rate on yield of onion. J Veg Crop Prod 2003; 9: 65-73. [http://dx.doi.org/10.1300/J068v09n02_08]

[30] Brewester JL. Onions and other vegetable Alliums. Wallingford, UK: CAB International 2008. [http://dx.doi.org/10.1079/9781845933999.0000]

[31] Law-Ogbomo and R.K.A. Egharevba. Effects of planting density and npk fertilizer application on yield and yield components of tomato (*Lycospersicon esculentum* Mill) in forest location. World J Agric Sci 2009; 5(2): 152-8.

[32] Jilani MS, Ahmed P, Waseem K, Kiran M. Effect of plant spacing on growth and yield of two varities of onion (*Allium Cepa* L.) under the agro- climatic condition of d. i. khan. Pak J Sci 2010; 62(1): 2010.

[33] Gupta RP, Sharma VP. 2000.Effect of different spacing and levels of nitrogen for production of export quality onion bulbs planted on raised bed News Letter National Horticultural Research and Development Foundation 20:1-4, 13-16

[34] Ali MK, Alam MN, Islam MS, Islam MK, Baree MA. Effect of cow dung at different level of phosphorus on growth, yield and quality seed production of onion. J Agric Biol Sci 2008; 4(1): 86-93.

[35] de Gusmao SAL. de., M.T.A. de Gusmao, J.G. de Padua and L.T. Braz. 2008. Behavior of the wild coriander (*Eryngium foetidum* L.) in subtropical conditions, Latin-American Symposium on the Production of Medicinal, Aromatic and Condiments Plants, ISHS Acta Horticulturae, I: 569.

[36] Mozumder , *et al.* 2012, Effect of Row and Plant Spacing on Seed Production of *Eryngium Foetidum*. Int J Hortic 2012; 2(4): 13-20. [http://dx.doi.org/10.5376/ijh.2012.02.0004]

[37] Abedin MJ, Rahim MA, Islam KS. Effect of planting date and bulb size on the yield and quality of onion seed. Bangladesh J Seed Sci Tech 1999; 3(1&2): 25-8.

[38] Firoz ZA, Alam MS, Uddin MS, Khatun SA. Effect of sowing time and spacing on lettuce seed production in hilly region. Bangladesh J Agric Res 2009; 34(3): 531-6. [http://dx.doi.org/10.3329/bjar.v34i3.3980]

[39] Khan H, Iqbal M, Ghaffoor A, Waseem K. Effect of various plants spacing and different nitrogen levels on the growth and yield of onion. J Biol Sci 2002; 2: 545-7. [http://dx.doi.org/10.3923/jbs.2002.545.547]

[40] Ali MK, Alam MN, Islam MS, Islam MK, Baree MA. Effect of nitrogen and potassium level on yield and quality seed production of onion. J Appl Sci Res 2007; 3(12): 1889-99.

[41] Brady NC, Weil RR. The nature and properties of soils. 13th ed. Delhi, India: Pearson Education Asia 2002.

[42] Abu-Sarra A F. 1999. Effect of cultivar, bulb size and nitrogen nutrition on onion seed yield Agricultural Research Corporation, Rahad Research Station Annual Reports 1998/99

[43] Marschner H. Mineral nutrition of higher plants. 2nd ed. New York: Academic Press 1995.

[44] Begum A. 1995.Effects of planting time, irrigation, set size and spacing on the seed production of some onion cultivars Department of Horticulture, BAU, Mymensingh 80.

[45] Tesfu Mangistu and C. Yamoah. 2010. Effect of sowing date and planting density on seed production of carrot (*Daucus carota var.* sativa) in Ethiopia. African Journal of Plant Science 4:8.270-279

[46] FAO. Production year book. Rome: Food and Agriculture Organization of the United Nation 2012.

[47] Özer H. Sowing date and nitrogen rate effects on growth, yield and yield components of two summer rapeseed cultivars. Eur J Agron 2003; 19: 453-63. [http://dx.doi.org/10.1016/S1161-0301(02)00136-3]

[48] Ozden O. 2009. Effects of source and rate of nitrogen fertilizer on yield, yield components and quality of winter rapeseed (*Brassica Napus* L.). Chil J Agric Res 2010; 70(1): 132-41.

[49] Ahmed AA. 1982 The influence of mineral nutrition on seed yield and quality of onion pp 267 In: George A T 1999 Vegetable seed production 2nd edition CABI Publishing.

[50] Gray D. Are the plant densities currently used for carrot seed production too low. Acta Hortic 1981; (111): 159-65. [http://dx.doi.org/10.17660/ActaHortic.1981.111.22]

[51] Lemma Dessalegne and Shimeles Aklilu. Research Experiences in Onion production Research Report No 55 Ethiopia Agricultural Research Organization, Addis Ababa, Ethiopia. 2003.

[52] Ndor E, Dauda NS, Chammang HB. Effect of germination media and seed size on germination and seedling vigour of fluted pumpkin (Telferia occidentalis) Hook. F Int J Agric Sci ISSN: 2167-0447 vol.2 (3), pp. 113-115

[53] Cuocolo L, Barbieri G. Effects of nitrogen fertilization and plant

density on seed yield of onion (*Allium cepa* L.). Rivista di Agronomia 1988; 22195202
[54] Singh NP, Singh RA. 2002 Scientific crop production, X press Graphics, Delih- 28, 1st ed, India.
[55] Woldeselassie A, Teshome H, Simon T. Influence of bulb treatment and spacing patterns on yield and quality of onion (*Allium cepa* Var. Cepa) seed at humbo larena, southern ethiopia. . J Biol Agric Healthcare 2014; 4(13): 2014.
[56] Singh SR, Sachan BP. Evaluation of different bulb size, spacing and varieties for higher seed yield and attributing traits on onion (*Allium cepa* L.). Crop Res Hissar 1999; 17(3): 351-5.