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# Effect of planting time on growth, yield components, seed yield and quality of onion (*Allium cepa* L.) at Tehuledere district, northeastern Ethiopia

Maria Tesfaye[1], Derbew Belew[2], Yigzaw Dessalegn[3] and Getachew Shumye[4*]

## Abstract

**Background:** Onion (*Allium cepa* L.) is member of the family Alliaceae and the most widely grown herbaceous biennial vegetable crop. Quality planting material is one of the major inputs to successful vegetable production. However, it is one of the major constraints in Ethiopia. Northeastern Ethiopia has suitable agro-climatic condition for onion seed production. However, onion seed production packages, including its appropriate planting time, are not yet determined. Evidences on effects of the different planting time on quality and yield level are not well explored. Therefore, this experiment was conducted at Jari small-scale irrigation scheme from September 2015 to April 2016 to determine an appropriate planting time for a better plant growth, yield components, seed yield and quality of Adama red onion variety.

**Methods:** The experiment was laid out in randomized complete block design with three replications. Treatments were nine planting dates: September 1st, September 16th, October 1st, October 16th, October 31st, November 15th, November 30th, December 15th and December 30th. Data were collected on growth, yield components, seed yield and quality parameters and analyzed using SAS version 9.2 statistical software.

**Results:** Analysis of variance revealed that plant height, number of leaves per plant, number of scapes per plant, scape diameter, scape height, days to 50% flowering and maturity, umbel diameter, number of seeds per umbel, 1000-seed weight, seed yield and germination percentage were significantly influenced by planting time. The highest seed yield (1032.7 kg/ha) and the highest germination percentage (94.3%) were recorded from bulbs planted early (September 1st). On the other hand, the lowest seed yield (29.7 kg/ha) and germination percentage (15.3%) recorded from bulb planted late (December). The correlation values explain the apparent association of the planting time parameters with each other and clearly indicated the magnitude and directions of the association and relationships.

**Conclusion:** The September 1st is recommended as appropriate planting time for onion seed production at Jari, northeastern Ethiopia.

**Keywords:** Onion, Planting date, Seed yield, Seed quality

## Background

Onion (*Allium cepa* L.) is one of the most important vegetable crops grown in Ethiopia. It ranks first among *Allium* species grown in Ethiopia both in area coverage and total production [1]. Its area coverage was 24,357.7 ha, and total annual production was 219,735.3 tons with average productivity of 9 t/ha during 2013/14 cropping season [1]. The area coverage of onion is steadily increasing mainly due to its high profitability, ease of production, and the expansion of irrigation infrastructure in different parts of the country [2]. Likewise, the

*Correspondence: aytenew2001@gmail.com
[4] Department of Plant Science, College of Agriculture, Wollo University, P.O. Box 1145, Dessie, Ethiopia
Full list of author information is available at the end of the article

demand for quality onion seed is steadily increasing over time [3]. However, seed supply is inadequate, its price is increasing, and onion seed available in the market is poor in quality [2]. Onion seeds lose viability within a year, and hence, they are poor in maintaining quality. Owing to these challenges, onion seed production gradually started by smallholder farmers in different parts of the country.

Onion seed production is influenced by many factors, among which varieties, bulb size, soil, climate, spacing, fertilizer application and date of planting are important. Cool weather with ample moisture supply is required for flower stalk initiation. Then, drier conditions with good sunshine are required for pollination, seed maturity, harvesting and processing [2]. High temperature during flowering results in flower abortion and subsequently results in lower seed yield. On the other hand, very low temperature, foggy weather and rainfall during flowering time affect the movement of honey bees and the pollination process. Rainfall during harvesting time adversely affects the quality of onion seed. Therefore, selection of appropriate planting date to align the time of maturity during dry season is crucial for onion seed production in a given locality.

The effect of planting time on onion seed production and its significant effects on both productivity and quality was studied and reported by several researchers in different parts of the world. The effect of different planting dates on onion seed production in Bangladesh was done, and October 30th was recommended as the best planting date [4]. Similarly, November 15th identified as the best planting date for onion seed production on Borga region of Bangladesh with a total rain fall of 351 mm [5] and Giza region of Egypt with mean minimum and maximum temperature of 15.60 and 29.8 °C, respectively [6]. In Iran, the best planting dates for onion seed production was from September 22nd to October 6th and from October 21st to November 5th for onion varieties Texas Early Grano 502 and Germez Iranshah, respectively, with mean minimum and maximum temperature of 21.48 and 9.09 °C, respectively [7].

Although Ethiopia has very diverse agro-ecology, studies on the effect of planting time on onion seed production are limited. Studies in Central Ethiopia showed that onion seed production is best if mother bulbs are planted in September and October which helped to align the time of flowering on the months of January and February, during cooler and drier months [2]. However, in Kobo October 25th was recommended as the best planting time for onion seed production with mean annual rainfall of 668 mm and mean minimum and maximum temperature of 15 and 31 °C, respectively [8]. These findings depict the importance of identifying appropriate planting date for onion seed production in each locality and variety. Therefore, the present study was conducted to identify the appropriate planting time for onion seed production and associated selected quality indicators in Tehuledere district, northeastern Ethiopia.

## Methods

### Description of the study area

The experiment was conducted at Jari small-scale irrigation scheme, Tehuledere district in northeastern Ethiopia during the period of September 2015 to April 2016. Geographically the experimental site is located at 11°14′N latitude and 39°40′E longitude and at an elevation of 1700 m above sea level (masl). The soil of the experimental site is sandy loam in texture, and its mean annual rainfall is 1204.6 mm [9]. The mean maximum and minimum temperature during the growing season was 28.0 and 6.0 °C, respectively. Monthly temperature and rainfall data of the trial site during the experiment period are given in Table 1.

### Experimental materials and design

The experiment was conducted under irrigation from September 2015 to April 2016. Onion cultivar 'Adama Red' was used as experimental material for this study. Recommended bulb size with a bulb diameter ranging from 4.1 to 5 cm and free from insect, disease and mechanical injury was selected and used for the study. Treatments of the experiment were nine planting dates such as September 1st, September 16th, October 1st, October 16th, October 31st, November 15th, November 30th, December 15th and December 30th.

The experiment was laid out using randomized complete block design (RCBD) with three replications. The size of each experimental plot was 2.1 m wide and 3 m long. Each plot had six rows. The spacing between irrigation furrows, planting rows and plants within a row was 50, 30 and 20, respectively. A spacing of 1 and 1.3 m was maintained between plots and blocks. Oxen plowing

**Table 1 Monthly temperature (°C) and rain fall (mm) at Jari northeastern Ethiopia during the trial period. *Source*: Kombolcha Meteorological Directorate (2016)**

| Months | Temperature | | | Rain fall |
|---|---|---|---|---|
| | Maximum | Minimum | Mean | |
| September | 28.4 | 8.4 | 18.4 | 66.43 |
| October | 27.2 | 5.2 | 16.2 | 20.8 |
| November | 25.8 | 2.6 | 14.2 | 75.2 |
| December | 25.8 | 3.4 | 14.6 | 22.4 |
| January | 27.4 | 7.2 | 17.3 | 39.2 |
| February | 31.0 | 7.6 | 19.3 | 29 |
| March | 31.2 | 6.8 | 19.0 | 98.3 |
| April | 28.8 | 11.6 | 20.2 | 97.6 |

method and manual harrowing were used for land preparation and fine seedbed preparation, respectively. About one third of the growing portion of mother bulbs was cut for easy and quick sprouting of growing buds. The lower portion with disk-like stem and roots was dusted with ash to prevent decay due to fungal infection and used for planting. Mother bulbs were planted by hand. The recommended fertilizer rates of urea 100 and 200 kg/ha DAP [2] were applied. DAP was applied at the time of planting, and urea was applied in two split doses of equal amounts, at planting and 45 days after planting. The field was irrigated 3 days after planting to facilitate for easy germination of bulbs. Then, it was irrigated every 7 days until full flowering and then at every 10-day interval followed by 10–15-day interval near maturity [2]. Weeding was done from 15 days after planting up to harvesting within 7–14-day interval at each growing phases.

### Data collection and analysis

The central four rows of each plot and ten plants from each plot were used for data collection. Data were collected for different plant characters such as plant height (cm), number of leaves per plant, number of scapes per plant, scape height (cm), scape diameter (at the base), umbel diameter, number of seeds per umbel, seed yield per plant (g) and thousand seed weight (g). On the other hand, data on days 50% flowering and maturity and seed yield per hectare (kg) were collected on net plot size basis. Seed germination (%) test was conducted at Dessie seed laboratory, and seed germination percentage was calculated [10]. Data collected on various parameters were subjected to analysis of variance (ANOVA) using SAS version 9.2 software [11]. Differences among treatment means were compared using the least significant difference test (LSD) at 5% probability level.

## Results

### Growth and phonological parameters

Both plant height and number of leaves per plant were significantly ($p \leq 0.01$) affected by planting date (Table 2). Plant height ranged from 61.8 to 82.6 cm with an average of 74.1 cm. The maximum plant height (82.6 cm) was recorded from bulbs planted on September 1st, and the lowest plant height (61.8 cm) was recorded from bulbs planted on December 30th (Table 2). Number of leaves per plant ranged from 15.4 to 54.4 with an average of 31.6. The maximum number of leaves per plant (54.4) was recorded from plants planted in September, while the minimum number of leaves per plant (15.4) was recorded from bulbs planted in December.

Planting time highly significantly ($p \leq 0.01$) influenced scape number per plant, scape height and scape diameter (Table 2). The number of scapes per plant ranged from 2.7 to 6.3 with an average of 4.4. The height and diameter of scapes ranged from 49.9 to 72.5 cm and from 0.58 to 1.48 cm, respectively. The maximum number of scapes per plant, scape height and scape diameter was recorded from bulbs planted early such as on September 1st. On the other hand, bulb planted late such as on December 15th and 30th had short and minimum number of scapes per plant with small scapes diameter.

### Seed yield and quality parameters

Planting time was significantly influenced onion seed yield and seed yield-related parameters such as umbel diameter, number of seeds per umbel, 1000-seed weight, seed yield per plant and seed yield per hectare (Table 3). Bulb planted in September and October had significantly higher umbel diameter, number of seeds per umbel, 1000-seed weight, seed yield per plant and seed yield per hectare compared to those planted in November and December.

**Table 2 Effect of planting time on growth and phonological parameters of onion at Jari northeastern Ethiopia**

| Planting time | Plant height (cm) | No. of leaves/plant | No. of scape/plant | Scape diameter (cm) | Scape height (cm) | Days to 50% flowering | Days to 50% maturity |
|---|---|---|---|---|---|---|---|
| Sept 1st | 82.6$^{a}$ | 46.7$^{a}$ | 6.3$^{a}$ | 1.48$^{a}$ | 72.5$^{a}$ | 79.3$^{abc}$ | 130.2$^{b}$ |
| Sept 16th | 80.9$^{a}$ | 54.4$^{a}$ | 5.0$^{bc}$ | 1.25$^{b}$ | 70.4$^{a}$ | 80.7$^{ab}$ | 132.8$^{a}$ |
| Oct 1st | 80.1$^{ab}$ | 46.5$^{a}$ | 4.7 $^{cd}$ | 0.88$^{e}$ | 69.8$^{a}$ | 77.3 $^{cd}$ | 129.0$^{b}$ |
| Oct 16th | 77.7$^{ab}$ | 25.3$^{b}$ | 5.9$^{ab}$ | 0.99$^{d}$ | 64.7$^{a}$ | 58.7$^{e}$ | 129.6$^{b}$ |
| Oct 31st | 72.5$^{abcd}$ | 27.3$^{b}$ | 4.0$^{de}$ | 1.12$^{c}$ | 69.5$^{a}$ | 68.0$^{d}$ | 124.0$^{d}$ |
| Nov 15th | 69.5$^{bcd}$ | 31.9$^{b}$ | 3.5$^{ef}$ | 0.72$^{f}$ | 64.7$^{a}$ | 60.7$^{e}$ | 126.7$^{c}$ |
| Nov 30th | 76.2$^{abc}$ | 14.6$^{c}$ | 4.8 $^{cd}$ | 0.72$^{f}$ | 55.3$^{b}$ | 81.0$^{ab}$ | 120.3$^{e}$ |
| Dec 15th | 65.3 $^{cd}$ | 15.4$^{c}$ | 2.7$^{f}$ | 0.61 $^{g}$ | 53.4$^{b}$ | 73.2 $^{cd}$ | 120.0$^{e}$ |
| Dec 30th | 61.8$^{d}$ | 22.5$^{bc}$ | 2.7$^{f}$ | 0.58 $^{g}$ | 49.9$^{b}$ | 84.3$^{a}$ | 110.1$^{f}$ |
| Mean | 74.1 | 31.6 | 4.4 | 0.93 | 63.4 | 73.7 | 124.8 |
| LSD (5%) | 11.4 | 9.8 | 0.96 | 0.09 | 9.2 | 6.7 | 2.1 |
| CV (%) | 8.9 | 17.9 | 12.63 | 5.96 | 8.4 | 5.2 | 0.95 |

Means followed by the same letter within a column are not significantly different at 5% probability level

**Table 3 Effect of planting dates on onion seed yield and quality parameters at Jari northeastern Ethiopia**

| Planting time | Umbel diameter (cm) | No. of seed/umbel | 1000-seed weight (g) | Seed yield/plant (g) | Seed yield kg/ha | Germination percentage |
|---|---|---|---|---|---|---|
| Sept 1st | 5.8$^{a}$ | 533.3$^{a}$ | 3.6$^{a}$ | 10.0$^{a}$ | 1032.7$^{a}$ | 94.3$^{a}$ |
| Sept 16th | 5.3$^{ab}$ | 395.2$^{b}$ | 3.6$^{a}$ | 5.5$^{b}$ | 652.3$^{b}$ | 71.0$^{b}$ |
| Oct 1st | 5.2$^{ab}$ | 351.9$^{b}$ | 2.9$^{b}$ | 4.9$^{bc}$ | 691.5$^{b}$ | 50.3$^{c}$ |
| Oct 16th | 4.7$^{bc}$ | 218.4$^{c}$ | 2.9$^{b}$ | 4.4$^{c}$ | 552.5$^{c}$ | 50.7$^{c}$ |
| Oct 31st | 4.4$^{bc}$ | 107.5$^{d}$ | 2.4 $^{cd}$ | 0.8$^{e}$ | 102.2$^{e}$ | 25.0$^{e}$ |
| Nov 15th | 5.0$^{abc}$ | 60.2$^{e}$ | 2.2$^{d}$ | 0.4$^{e}$ | 37.4$^{e}$ | 18.0$^{f}$ |
| Nov 30th | 4.8$^{bc}$ | 153.0$^{d}$ | 2.7$^{bc}$ | 2.1$^{d}$ | 280.8$^{d}$ | 39.0$^{d}$ |
| Dec 15th | 4.3$^{c}$ | 59.4$^{e}$ | 2.4 $^{cd}$ | 0.5$^{e}$ | 57.4$^{e}$ | 15.3$^{f}$ |
| Dec 30th | 3.3$^{d}$ | 47.4$^{e}$ | 2.3 $^{cd}$ | 0.3$^{e}$ | 29.7$^{e}$ | 21.7$^{e}$ |
| Mean | 4.8 | 214.0 | 2.8 | 3.2 | 381.8 | 42.8 |
| LSD (5%) | 0.9 | 45.88 | 0.4 | 0.6 | 73.7 | 6.1 |
| CV (%) | 10.9 | 12.38 | 8.9 | 10.9 | 11.2 | 8.3 |

Means followed by the same letter within a column are not significantly different at 5% probability level

Planting time significantly influenced the umbel diameter, which was ranged from 3.3 to 5.8 cm with a mean of 4.8 cm. The highest umbel diameter (5.8 cm) was recorded from bulbs planted on September 1st but was not significantly different from those planted on September 16th, October 1st and November 15th. On the other hand, the smallest umbel diameter (3.3 cm) was recorded from bulbs planted on December 30th.

Planting time significantly influenced ($p \leq 0.01$) number of seeds per umbel which ranged from 47.4 to 533.3 seeds per umbel with an average of 214.0. In the earlier studies, number of seeds per umbel (256.6–515.3) and (93.0–299.9) were reported in Ethiopia (Kobo area) and Bangladesh, respectively [5, 8]. However, in the present study, the highest number of seeds per umbel (533.3) was recorded from September 1st planting date. On the other hand, the minimum number of seeds per umbel (47.4) was recorded from December 30th planting date, but it was statistically on par with December 15th and November 15th plantings dates.

Planting time significantly influenced ($p \leq 0.01$) thousand seed weight (Table 3). Similarly, the significant effect of planting dates on thousand seed weight was reported in other studies [6, 8]. Thousand seed weight ranged from 2.2 to 3.6 g with an average of 2.8 g. The maximum thousand seed weight (3.6 g) was recorded from early planting time such as September 1st and September 16th. On the other hand, the minimum thousand seed weight (2.2 g) was recorded from bulbs planted on November 15th and it was statistically on par with those planted on December 15th, December 30th and October 31st.

Seed yield per plant was significantly influenced by planting time (Table 3). The average seed yield per plant ranged from 0.3 to 10.0 g with an average of 3.2 g. The highest seed yield per plant (10.0 g) was obtained from bulbs planted on September 1st. On the other hand, the lowest seed yield per plant (0.25 g) was recorded from bulbs planted on December 30th but not significantly different from those planted on December 15th, November 15th and October 31st.

Planting dates significantly influenced seed yield per hectare and ranged from 29.7 to 1032.7 kg/ha with an average of 381.8 kg/ha (Table 3). The maximum seed yield (1032.7 kg/ha) was obtained from September 1st planting. On the other hand, the least seed yield (29.7 kg/ha) was recorded from December 30th planting, but the seed yield was on par with December 15th, October 31st and November 15th plantings. Therefore, early planting dates are suitable for higher onion seed yield at Jari irrigation scheme.

The germination percentage of onion seeds produced significantly influenced by planting time (Table 3). The percentage of germination ranged from 15.3 to 94.3% with overall average of 42.8%. The highest germination percentage was recorded from seeds harvested from bulbs planted on September 1st. On the other hand, low germination percentage was recorded from seeds harvested from those planted on December 15th, but there was no significant difference with those planted on November 15th.

### Correlation analysis among planting time and different parameters

Correlation coefficient ($r$) values computed to determine the relationships between and within the planting time and parameter are depicted in Table 4. The correlation values explain the apparent association of the planting time parameters with each other and clearly indicated

the magnitude and directions of the association and relationships.

Plant height ($r=-0.915$), number of leaves/plant ($r=-0.858$), number of scape/plant ($r=-0.834$), diameter of scape ($r=-0.905$), scape height ($r=-0.929$), days to 50% maturity ($r=-0.901$), umbel diameter ($r=-0.861$), number of seed/umbel ($r=-0.916$), thousand seed weight ($r=-0.855$), seed yield/plant ($r=-0.881$), seed yield/hectare ($r=-0.895$) and germination percentage ($r=-0.876$) were negatively but strongly correlated with planting time (Table 4).

## Discussion

### Growth and phonological parameters

Bulb planted in September showed vigorous vegetative growth (plant height and number of leaves) compared to those planted in December. The increase in plant height could mainly be due to early planting which might have provided plants with relatively cooler period compared to the latter eight plantings. The cooler period stimulates cytokine and gibberellins' accumulation, modifying the hormonal balance and leading the plant to increase the plant development and responsible for elongation of flower stalk [12]. The taller plant height provides more photosynthetic capacity to the plant than shorter height with more number of leaves compared to those planted in November. This could be attributed to the increase in the vegetative growth of the onion plant through the effect of planting time, and the cooler time was important for the synthesis of different growth component of onion stem and seed. This good foliage indicates higher growth, development and productivity of plant. Similarly, in other study, in Kobo area, the significant effect of planting dates was recorded, where bulb planted in October had maximum plant height compared to those planted in November [8]. Likewise, the significant effect of planting dates on plant height and number of leaves per plant was also reported [7]. In this study, bulbs planted in September were longer and with more number of leaves compared to those planted in November. On the other hand, other study indicated that bulb planted in November was longer and with more number of leaves per plant compared to those planted in October [5]. This could be attributed to climatic variation among the study sites.

The maximum number of scapes per plant, scape height and scape diameter was recorded from bulbs planted early such as on September 1st. These showed that early planting resulted in vigorous plants. In agreement with this, the maximum number of scapes per plant, scape length and scape diameter was recorded from early planting dates [6, 8].

Concerning flowering date, the bulb planted in December 30th took maximum number of days for flowering but no significant difference with bulb planted in September and November 30th. This might be attributed to the coincidence of growth stage of the crop and occurrence of cold weather to induce bolting. Similarly, other report indicated that planting time had marked influence on the number of days required for 50% flowering [8]. In

**Table 4 Correlation analysis of planting time among growth, yield components, seed yield and quality of onion at Jari northeastern Ethiopia**

| | PT | PTH | NL | NS | DS | SH | FL | DM | UD | NSU | TSW | SYPP | SYPH | GP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PT | 1 | −0.915* | −0.858* | −0.834* | −0.905* | −0.929* | 0.034 | −0.901* | −0.861* | −0.916* | −0.855* | −0.881* | −0.895* | −0.876* |
| PTH | | 1 | 0.684* | 0.920* | 0.786* | 0.798* | 0.039 | 0.850* | 0.875* | 0.879* | 0.846* | 0.845* | 0.890* | 0.860* |
| NL | | | 1 | 0.506 | 0.718* | 0.808* | 0.188 | 0.724* | 0.686* | 0.816* | 0.746* | 0.716* | 0.735* | 0.731* |
| NS | | | | 1 | 0.782* | 0.679* | −0.072 | 0.738* | 0.754* | 0.816* | 0.804* | 0.863* | 0.877* | 0.871* |
| DS | | | | | 1 | 0.848* | 0.035 | 0.730* | 0.708* | 0.835* | 0.821* | 0.828* | 0.788* | 0.854* |
| SH | | | | | | 1 | −0.234 | 0.887* | 0.794* | 0.726* | 0.621 | 0.669* | 0.685* | 0.656 |
| FL | | | | | | | 1 | −0.339 | −0.074 | 0.306 | 0.337 | 0.226 | 0.217 | 0.293 |
| DM | | | | | | | | 1 | 0.885* | 0.714* | 0.688* | 0.676* | 0.710* | 0.663 |
| UD | | | | | | | | | 1 | 0.803* | 0.730* | 0.776* | 0.781* | 0.754* |
| NSU | | | | | | | | | | 1 | 0.948** | 0.976** | 0.980** | 0.973** |
| TSW | | | | | | | | | | | 1 | 0.925* | 0.923* | 0.966** |
| SYPP | | | | | | | | | | | | 1 | 0.986** | 0.981** |
| SYPH | | | | | | | | | | | | | 1 | 0.966** |
| GP | | | | | | | | | | | | | | 1 |

*PT* planting time, *PH* plant height, *NL* number of leaves/plant, *NS* number of scape/plant, *DS* diameter of scape, *SH* scape height, *FL* days to 50% flowering, *DM* days to 50% maturity, *UD* umbel diameter, *NSU* number of seed/umbel, *TSW* thousand seed weight, *SYPP* seed yield/plant, *SYPH* seed yield per hectare, *GP* germination percentage

*, **Significant at 5 and 1% probability levels, respectively. The decimal numbers without any asterisk are nonsignificant ($p > 0.05$)

the present study, the bulb planted in September 16th took maximum number of days to mature although bulbs planted in December 30th required minimum number of days to reach maturity. This indicates that bulb planted in relatively hot season mature early condition matured early compared to those which were planted in relatively cold season [4].

#### Seed yield and quality parameters

Bulb planted in September had significantly higher umbel diameter but not significant different with planted in October 1st and November 15th. In the same way, September 1st had significantly different with other planting time for number of seeds per umbel, seed yield per plant and seed yield per hectare compared to other planting dates.

Similarly, umbel diameter was recorded with a range of 3.0–6.9 cm in Bangladesh [5] and from 4.8 to 6.0 cm in kobo, Ethiopia [8]. The highest umbel diameter recorded from bulb planted in October compared to in November [8] and in November compared to those planted in December and January [6]. This shows that early planting increases umbel diameter compared to late planting. On the other hand, in Bangladesh the maximum umbel diameter was recorded from onion bulbs planted in November compared to those planted in October [5]. This difference might be attributed to the climatic variability among the study sites.

The number of seeds per umbel ranged from 47.4 to 533.3 with the highest number of seeds per umbel (533.3) was recorded from September 1st planting date. The variation in number of seeds per umbel might be due to flower abortion, indicating the time when high temperature caused such even, lack of efficient pollinators of all the flowers in the umbel, shortage of nutrition which caused high competition and death of the weak florets in the umbel [8]. So, selection of appropriate time in a given location is crucial in onion seed production.

Thousand seed weight ranged from 2.2 to 3.6 g with the maximum thousand seed weight (3.6 g) was recorded from early planting times (September 1st and September 16th), the minimum thousand seed weight (2.2 g) was recorded from onion bulbs planted on November 15th, and it was statistically on par with those planted on December 15th, December 30th and October 31st. This might be attributed to climatic condition prevailing during the seed filling stage. Therefore, early planting results in well-filled seeds compared to late plantings. In addition, the seed filling period of late planting dates was significantly shorter than early planting time. However, in Bangladesh, heavy 1000-seed weights from bulbs planted in November compared to those planted in October [5].

The average seed yield per plant ranged from 0.3 to 10.0 g with the highest seed yield per plant (10.0 g) was obtained from bulbs planted on September 1st. Similarly, the effects of planting dates on seed yield per plant were significant [4–6]. Therefore, early planting time resulted in higher seed yield per plant. Cool temperature for flower development in early planting time and subsequent favorable temperature could have increased the final seed yield per plant on early planting dates. High atmospheric temperature causes early maturity of bulbs before attaining sufficient growth of plant, thereby resulting in low seed yield in onion. The difference in seed yield per plant might be due to the number of scapes per plant, number of seed per umbel and cool temperature for flower development in early planting, and subsequent favorable temperature could have increased the final seed yield per plant. Similarly, in Kobo area, higher seed yield per plant was recorded from bulb planted in October compared to those planted in November [8].

The maximum seed yield per hectare (1032.7 kg/ha) was obtained from September 1st planting, while the least seed yield (29.7 kg/ha) was recorded from December 30th planting which is not significantly different with December 15th, October 31st and November 15th plantings. Similarly, in Bangladesh higher seed yield was recorded from bulbs planted in October compared to those planted in November [4]. In late planting, it might be resulted in reduced cycle and less yield, because the plants received stimulus for bulb development before reaching full vegetative development. Therefore, early planting times are suitable for higher onion seed yield at Jari irrigation scheme.

In the same way, the germination percentages were ranged from 44 to 84% and from 77.1 to 97.6% in Bangladesh and Ethiopia (Kobo area), respectively [5, 8]. The highest germination percentage was recorded from seeds harvested from bulbs planted on September 1st. On the other hand, low germination percentage was recorded from seeds harvested from those planted on December 15th, but there was no significant difference with those planted on November 15th. The reason for increasing the percentage of seed germination in early planting may be due to the highest seed size and seed weight. Therefore, early planting is suitable to produce high-quality onion seed at Jari irrigation scheme. Similarly, early planting date is recommended to produce high-quality seed at Kobo area [8].

#### Correlation analysis among planting time and different parameters

With increase in time of planting (from September 1st to December 30th), there was increase in temperature. Onion requires ample moisture with cool environment. So the increase in temperature influences flower stalks development, flowering and seed maturation.

Plant height ($r=-0.915$) and number of leaves/plant ($r=-0.858$) were negatively but strongly correlated with planting time (Table 4). Both plant height and number of leaves/plant could mainly important for photosynthesis and pollination. This implied that the cooler time was important for the synthesis of different growth components of onion stem and seed. This good foliage indicates higher growth, development and productivity of plant.

Umbel diameter ($r=-0.861$), number of seed/umbel ($r=-0.916$), thousand seed weight ($r=-0.855$), seed yield/hectare ($r=-0.895$) and germination percentage ($r=-0.876$) were negatively but strongly correlated (Table 4). For that reason, it is possible to say that umbel size of the onion plant is one of the major characters highly demanded for flower and seed production and positive relation with seed yield. The result indicated that the above-mentioned parameters can be increased by early planting in which the plant can accumulate high seed yield and quality due to the extended vegetative growth of the plant. Similarly, parameters can be increased by extending crop cycle by early planting [13].

The tallest scape height was associated with the highest yields and the greatest number of seeds per plant. The taller scape height might have provided more photo-assimilates to the plant causing the weight of each seed to be greater than the weight of seed from plants with short scape. The highest seed yield (1032.7 kg/ha) as well as the highest germination percentage (94.3%) was recorded from onion planted on September 1st. On the other hand, the lowest seed yield (29.7 kg/ha) and germination percentage (15.3%) recorded from onion planted in December. It was evident that plants sown in September 1st exhibited superior performance both in growth, yield and quality characters. This may be because there was enough time for the early planted onion plants to complete both their growth and developmental stages, which in turn enhanced the production and partitioning of photo-assimilates, thus leading to an increase in growth and yield characters. Plants sown late (December 30th) had no adequate time to complete their life cycle fully.

## Conclusion

The finding showed significant differences among the different planting dates with regard to growth, yield and quality parameters, viz. number of leaves/plant, number of scape/plant, scape diameter, days to 50% flowering, days to maturity, number of seed per umbel, thousand seed weight and seed yield/plant. The highest seed yield/plant, seed yield per hectare and germination percentage were obtained from early planting date, while significantly the lowest values were recorded from late planting. Therefore, based on the finding of the current study, early planting (September 1st) can be used for high yield and better quality of onion seed. Several growth, yield component and quality parameters were negatively but strongly correlated with planting time of bulbs. Hence, September 1st was identified and recommended as the optimum planting time for seed production of "Adama red" at Jari irrigation scheme, Tehuledere district of northeastern Ethiopia.

#### Authors' contributions

MT initiated the research, wrote the research proposal, conducted the research, did data entry and analysis and wrote the manuscript. DB and YD involved in methodology, writing, reviewing and editing of research proposal and manuscript; and GS did data entry and analysis and writing the manuscript. All authors read and approved the final manuscript.

#### Author details

[1] Department of Plant Science, College of Agriculture, Mekdela Amba University, P.O. Box 32, Tuluawlia, Ethiopia. [2] College of Agriculture and Veterinary Medicine, Jimma University, P.O. Box 378, Jimma, Ethiopia. [3] International Livestock Research Institute, P.O. Box 527, Bahir Dar, Ethiopia. [4] Department of Plant Science, College of Agriculture, Wollo University, P.O. Box 1145, Dessie, Ethiopia.

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#### Competing interests

The authors declare that they have no competing interests.

#### Availability of data and materials

Collected and analyzed data during the current study are available upon on reasonable request from the corresponding author.

#### Consent for publication

Not applicable.

#### Ethics approval and consent to participate

Not applicable since the study involved onion plants.

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