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Research Article

Influences of Seedling Age and Variety on the Growth and Bulb Yield of Onion in Northwest Ethiopia

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Onion is one of the major cash crops and helps improve the livelihoods of smallholder farmers. Although genetically and morphologically different, seedlings of all released onion varieties are transplanted at the ages ranging from 40 to 50 days, which contributes to the low level of productivity in Ethiopia. Therefore, a field experiment was conducted at the research site of Fogera National Research and Training Center during the 2019/20 irrigation season with the objective of identifying the optimum seedling age for improved onion productivity in Northwest Ethiopia. The treatments consisted of three varieties (Adama red, Bombay red, and Nasik red) and four seedling ages (30, 40, 50, and 60 days) of onion, which were laid down in 3×4 factorial arrangement using randomized complete block design with three replications. Growth and yield parameters of onion were collected based on the standard procedures and analyzed using SAS version 9.6. The results revealed that both variety and seedling age significantly ($P < 0.001$) influenced plant height, leaf number, bulb diameter, fresh bulb weight, and marketable bulb yield, while their interaction effect did not influence these parameters. Days to maturity was significantly ($P < 0.001$) affected by main as well as by the interaction effects of variety and seedling age. Younger seedling took longer time to mature, while older seedlings matured relatively early. The seedlings of Bombay red variety at 60 days age gave the earliest maturity days (105.33 days) compared to the other combinations. The highest plant height (50.18 cm), leaf number (12.00), bulb diameter (53.47 mm), bulb weight (84.39 g), and marketable bulb yield (29.97 t/ha) were recorded from Bombay red variety where the marketable yield recorded from Nasik red was statistically similar with that of Bombay red variety. Seedlings with 60 days old performed best in terms of all the tested growth and yield parameters including the highest marketability (32.03 t/ha). Accordingly, 60 days old seedlings and Bombay red and Nasik red varieties can be used to increase the productivity of onion in the study area and areas with similar agroecology.

1. Introduction

Onion (*Allium cepa* L.) belongs to the family Alliaceae and is one of the most important bulb vegetable crops worldwide [1]. It was originated from Central Asia [2] and cultivated in many African countries including Ethiopia [3]. The crop is very important for seasoning and flavoring of foods. In Ethiopia, onion is especially indispensable input for the preparation of daily stews, the so-called "*Wot,*" as well as vegetable foods [4]. It also helps neutralize acid substance produced during the course of digestion of meat, cheese, and other food [5]. About 104,554,458 tons of onion with the productivity of 19.1 $t \cdot ha^{-1}$ was produced worldwide. China, India, and the USA are the top three largest producers of onion. From Africa, Egypt is the largest producer of the crop with the production volume and productivity of 3,155,649 ha and 35.5 $t \cdot ha^{-1}$, respectively [6].

According to CSA [7] data, about 346,048.1 tons of bulbs with the productivity of 8.9 $t \cdot ha^{-1}$ are produced in Ethiopia. Amhara region is the major producer of onion in the country where it contributes about 50% (172,911.2 tons) of the national onion production with a productivity of 12.3 $t \cdot ha^{-1}$. Central Gondar, East Gojjam, South Wollo, and South Gondar zones are the major production areas in the region [8].

Onion is the major source of incomes for majority of the smallholder farmers in Ethiopia in general and in Amhara region in particular. It plays a significant role in improving

the livelihoods of smallholder farmers. Moreover, the crop is a source of foreign exchange earning of the country as it is exported to the regional markets including Djibouti, Somalia, and South Sudan [9].

Although significant social and economic importance of the crop, its productivity in the country as well as in Amhara region is very low compared to the world average and countries such as Kenya (17.9 $t \cdot ha^{-1}$) and Egypt (35.5 $t \cdot ha^{-1}$) as indicated in FAOSTAT [6]. The low level of production and productivity is associated with various constraints including inappropriate agronomic practices, low yielding cultivars, weak extension system, diseases and pests, and fluctuation of climatic conditions [10, 11].

Among those problems, the use of inappropriate seedling ages is the main production challenge in the study area. Although genetically and morphological different, all onion varieties released by Agricultural Research Centers are transplanted at the ages ranging from 40 to 50 days in Ethiopia [12]. On the other hand, seedling ages of vegetables including onion influence the growth and development of the crop as indicated by Anbes et al. [13]. In the field trial conducted by Muhammad et al. [14], onion seedlings transplanted at 40 days after sowing produced the highest plant height, leaf number, leaf length, size and weight of bulbs, and bulb yield as compared to seedlings with the age of 50 and 60 days. Similarly, Vaishnava [15] reported that the seedlings' age of 30 days produced the highest bulb yield. Increasing the seedling age from 30 to 60 days however reduced the bulb yield. According to MoANR [12], on the other hand, late and early transplanting of seedlings significantly influences the survival and growth performance of onion. In this regard, the present study was initiated to identify the optimum seedling age that ensures the optimum growth and bulb yield of onion.

2. Materials and Methods

2.1. Description of the Study Area. The experiment was conducted in Fogera district at the research site of Fogera National Research and Training Center during the irrigation season of 2019/20. The center is found in Woreta town of Fogera district, Amhara National Regional State in the northwestern part of Ethiopia. The experimental site is located at 11° 58′ North latitude and 37° 41′ East longitude with an elevation of 1,810 meter above the sea level (Figure 1). Based on the ten years' meteorological data (2007–2017), the mean annual rainfall of the district was 1,300 mm, while the minimum, maximum, and average air temperatures were 11.5, 27.9, and 18.3°C, respectively. The average metrological data of Fogera district during the study site are presented in Figure 2, where the maximum temperatures ranged from 24.2°C (September) to 28.6°C (February), while the minimum temperatures ranged from 12.2°C in December to 15.1°C in February. During the study period, the rainfall and relative humidity continuously decreased where the month of September recorded the highest rainfall (119 mm) and relative humidity (79%) as indicated in Figure 2.

The main physical and chemical properties of soil of the experimental site are presented in Table 1 as described by Alemniew et al. [16] and Getahun and Habtie [17]. The experimental site represents the major onion production areas in Amhara region where tomatoes, cabbages, pepper, and other vegetables are also growing [18].

2.2. Experimental Treatments' Design and Procedures. The experiment comprised three onion varieties, namely, Adama red, Bombay red, and Nasik red and four seedling ages (30, 40, 50, and 60 days after sowing). Seeds of the onion varieties were obtained from Melkassa Agricultural Research Center. Treatments were factorially combined (3 × 4) and laid out in randomized complete block design (RCBD) with three replications.

Seeds of the onion varieties were sown on well-prepared seedbeds on 10-day intervals (18th September, 2019 (60 days), 28th September, 2019 (50 days), 08th October, 2019 (40 days), and 18th October, 2019 (30 days)). All important cultural practices for seedling production such as watering, application of fertilizers, and weed, disease, and insect pest control activities were undertaken uniformly for all age groups of seedlings as described by MoANR [12].

The experimental field was plowed and leveled by a tractor, while ridges and plots were made manually before seedling transplanting. Large clods were broken down in order to bring the land to a fine tilth. Hardened, healthy, and uniform seedlings were transplanted on the well-prepared experimental field on the same date where onion seedlings were 30, 40, 50, and 60 days old after sowing. Planting of onion seedlings was conducted using ridge planting system in double row (Figure 3) with the recommended spacing 40 cm between water furrow, 20 cm between rows, and 10 cm between plants within row [13]. A plot consisted of four double rows and two single rows at each side of the plot where one row contained 15 onion plants. The gross and net plot areas were 1.5 m × 3.2 m (4.8 m^2) and 1.2 m × 2.4 m (2.88 m^2), respectively. The blocks were separated by a distance of 1.0 m (Figure 4), whereas the space between each plot within a block was 0.5 m.

The whole dose of recommended blended NPSB fertilizers (242 kg/ha) was applied during transplanting, while urea at the rate of 79 kg/ha was applied as band in two splits where the first half was applied after seedling establishment (on the 15th day of planting), while the remaining half was applied 20 days after the first application. Experimental plants were irrigated uniformly using the furrow irrigation method at 4-5 days of interval until their establishment (four weeks) and at 5–7 days of intervals until maturity [12]. The irrigation water was sourced from pods collected from rainfall. The irrigation interval was arranged based on the recommendation of MoANR [12], which was determined based on the environmental conditions, soil types, the type of crop, and its developmental stages. Other management activities including cultivation, weeding, disease, and insect pest management were conducted uniformly for all experimental plants as described by Ketema et al. [19].

2.3. Data Collection and Analysis. Growth- and yield-related parameters of onion were collected following their standard procedures. Physiological maturity and stand count were

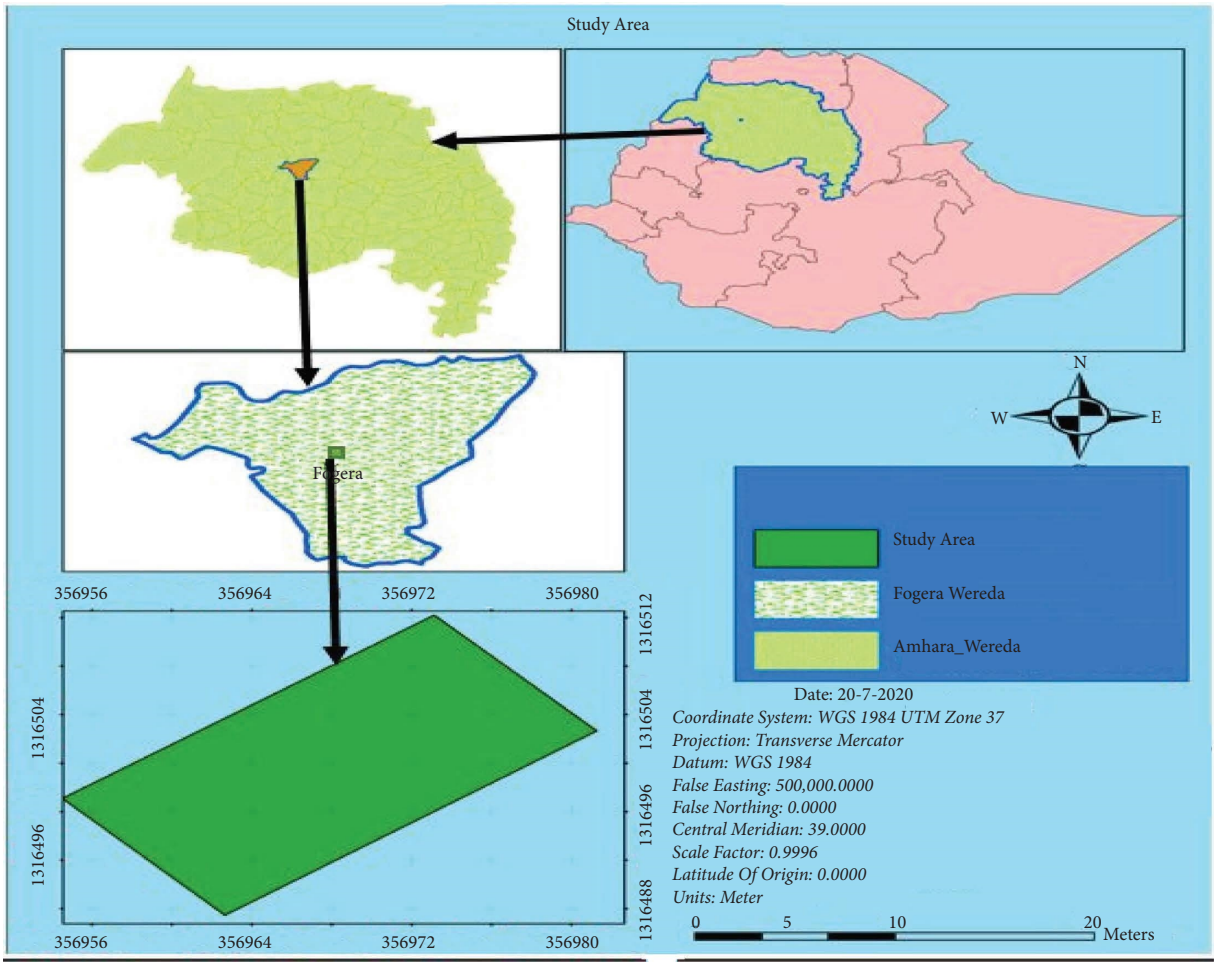

Figure 1: Map of the study area.

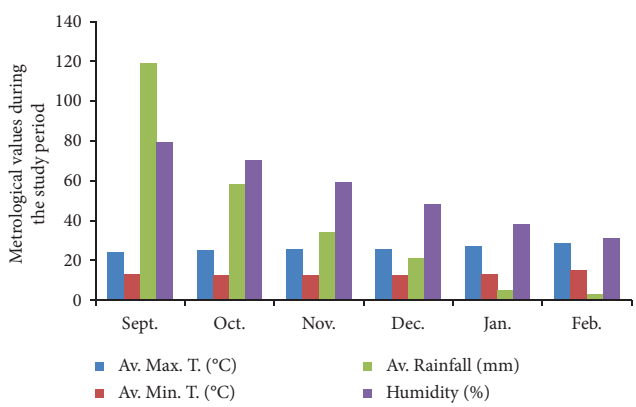

Figure 2: Average monthly metrological data of Fogera district during the study period.

collected on plot basis. Plant height and number of leaves per plant were collected from ten randomly taken plants grown in the net plot area as described by Kumbhkar et al. [20]. Similarly, diameter and fresh weight of bulbs were collected from ten randomly taken bulbs that were harvested from the net plot area. Marketable bulb yield was collected from the net plot area and expressed at hectare basis as described by Desalegn and Aklilu [21].

The collected data were subjected to analysis of variance (ANOVA) using Statistical Analysis Software (SAS) version 9.4. Whenever the ANOVA was significant, mean separation was carried out using the least significant difference (LSD) at $P < 0.05$.

3. Results and Discussion

3.1. Phenological and Growth Parameters of Onion as Influenced by Variety and Seedling Age of Onion

3.1.1. Days to Maturity. Onion variety, seedling age and their interaction have been significantly ($p < 0.01$) affected days to maturity of onion. Bombay red variety matured earlier compared to other varieties. Similarly, onion plants from the 60 days old seedlings matured earlier. Based on the interaction effect, planting of Bombay red variety using 60 days old seedlings recorded the earliest maturity (105.33 days), while planting Adama red variety using 30 days old seedlings matured about 40 days later (146.33 days) (Table 2).

Differences in days to maturity of onion varieties observed in the present study are obviously associated with the inherent genetic variation of the varieties. Variation in days to maturity was also observed in onion varieties grown in

Table 1: Selected physical and chemical properties of the soil of the experimental site.

Soil properties	Units	Soil depth (0–20 cm)
Soil texture		
Sand	%	9
Silt	%	19
Clay	%	72
Textural class		Heavy clay
Chemical properties		
pH (H_2O) 1 : 2.5 g soil	—	6.08
Electrical conductivity	ds m^{-1}	0.048
Total nitrogen	%	0.11
Organic carbon	%	1.33
Organic matter	%	2.29
Available phosphorus	ppm	3.58
Available potassium	ppm	240.59
CEC	meq per 100 g soil	61.05

Figure 3: Vegetative growth of onion at the early stage of development.

Figure 4: Vegetative growth of onion at the midgrowth cycle.

Ethiopia [22], which is in line with the results of the present study. Early maturity related to 60 days old seedlings of onion observed in the present study could be associated with less transplanting shock and lag time and thus continuation of photosynthesis activities after transplanting and accumulation of assimilates in the bulbs that hasten maturity [23].

3.1.2. Stand Count. Stand count at harvest was significantly influenced by onion variety ($p < 0.01$) and seedling age ($p < 0.001$), while their interaction did not influence this parameter. Bombay red recorded the highest stand count (89.78%), which was statistically similar with that of Nasik red, while the lowest percentage of stand count (86.11%) was recorded from Adama red variety (Table 3). These

Table 2: Interaction effect of seedling age and variety on days to maturity of onion.

Seedling ages	Adama red	Bombay red	Nasik red
30	146.33[a]	136.33[bc]	140.00[ab]
40	137.00[b]	121.00[ef]	133.33[bcd]
50	137.00[b]	115.00[f]	132.00[bcd]
60	128.33[cde]	105.33[g]	127.67[de]
P-value		**	
CV (%)		3.79	
SE		0.14	

Here, ** = significant at $p < 0.01$; CV = coefficient of variation; SE = standard error; means sharing the same letters are not different at $P = < 0.05$.

Table 3: Effect of variety and seedling age on growth parameters of onion.

Varieties	Stand count (%)	Plant height (cm)	Number of leaves per plant
Adama red	86.11[b]	47.80[b]	8.86[c]
Bombay red	89.78[a]	50.18[a]	12.00[a]
Nasik red	89.53[a]	49.72[ba]	10.03[b]
P value	**	**	***
Seedling ages			
30	85.63[c]	44.73[c]	9.26[c]
40	86.41[c]	48.26[b]	9.77[c]
50	89.08[b]	52.61[ba]	10.54[b]
60	92.78[a]	53.70[a]	11.63[a]
P value	***	***	***
CV (%)		4.75	5.76
SE ± 1		0.06	0.59

Here, * = significant at $p < 0.05$; ** = significant at $p < 0.01$; *** = significant at $p < 0.001$; CV = coefficient of variation; SE = standard error; means in the same column sharing the same letters are not significantly different at $P = < 0.05$.

differences among varieties might be associated with the environmental requirement of the onion varieties that could be influenced by the inherent genetic makeup.

In the case of seedling age, older seedlings (60 days) recorded the highest percentage of stand count at harvest (92.78%), while the youngest seedlings (30 days) showed the lowest (85.63%) stand count percentage, which was statistically similar with stand count recorded from 40 days old seedlings. The use of 60 days old seedlings enhances the stand count of onion population at harvest, which could be positively influenced with the availability of more stored foods that facilitate easy establishment during transplanting. The results are in line with the findings of Choudhary et al. [24] who reported that 70 days old seedlings recorded the highest stand count at harvest compared to those seedlings with 55 and 40 days ages.

3.1.3. Plant Height. The analysis of variance revealed that plant height was significantly affected by the main effects of variety ($p < 0.01$) and seedling age ($p < 0.001$). However, the interaction effect of variety and seedling age did not influence this parameter. Bombay red variety produced the longest plant height (50.18 cm), while Adama red produced the shortest plant height (47.8 cm). Plant height difference among varieties was also observed by other researchers, which could obviously associate with differences in genetic makeup and environmental needs of the varieties [22, 25].

Plant height was increased as age of seedlings increased. Seedlings planted at the age of 60 days recorded highest plant height (53.70 cm). On the other hand, younger seedlings (30 days) produced the shortest onion plants (Table 3). The significantly higher plant height under transplanting of 60 days old seedlings may be owing to the fact that optimum age of seedlings performed active growth which might have contributed to more vigorous growth and development of onion plants including pseudo-stem. The results are in line with the findings of other researchers where older seedlings recorded longer plants compared to young onion seedlings [26, 27].

3.1.4. Number of Leaves per Plant. The number of leaves per plant was influenced by variety and seedling age ($p < 0.001$) of onion. However, the interaction effect of the two factors did not influence this parameter. The highest leaf number per plant (12) was recorded by variety Bombay red, while variety Adama red recorded the lowest leaf number per plant (8.86). On the other hand, seedlings transplanted at 60 days age recorded the highest number of leaves per plant (11.63) and youngest seedlings (30 days old) recorded the lowest number of leaves (Table 3).

Genetic makeup of a given variety and environmental conditions influence the number of onion leaves, which is also observed in the present study. Similar to the present results, different scholars observed variations in the number of leaves among onion varieties [22, 25, 28]. The increase in the number of leaves in older seedlings (60 days) could be due to the increase in photosynthesis activities and accumulation of relatively higher stored food which may have contributed to the growth and development of new leaves. The results are in agreement with the findings of other researchers who observed more number of leaves under older onion seedlings compared to the younger ones [27, 28].

3.2. Bulb Yield Parameters of Onion as Influenced by Variety and Seedling Age of Onion

3.2.1. Bulb Diameter. The analysis of variance revealed that bulb diameter was significantly affected by the main effects of variety ($p < 0.01$) and seedling age ($p < 0.001$). However, the interaction effect of variety and seedling age did not influence this parameter. Bombay red variety produced bulbs with significantly wider diameter (53.47 mm) compared to Nasik red (50.81 mm) and Adama red (50.75 mm) varieties, while the bulb diameter of Adama red and Nasik red varieties was statistically similar (Table 4). In terms of seedling age, the highest bulb diameter (55.28 mm) was observed from onion plants where the seedlings were 60 days old, whereas the lowest bulb diameter (46.43 mm) was

Table 4: Effect of variety and seedling age on yield parameters of onion.

Varieties	Bulb diameter (mm)	Fresh bulb weight (g)
Adama red	50.75[b]	72.62[c]
Bombay red	53.47[a]	84.39[a]
Nasik red	50.81[b]	79.29[b]
P value	**	***
Seedling Age		
30	46.43[c]	70.37[c]
40	52.27[b]	75.82[b]
50	52.74[b]	79.96[b]
60	55.28[a]	88.92[a]
P value	***	***
CV (%)	4.78	6.20
SE	0.07	0.15

Here, ** is significant at $P < 0.01$ and *** is significant at the $P < 0.001$ probability level. Means in the same column sharing the same letters are not significantly different at $P = < 0.05$.

recorded from plants sourced from 30 days old seedlings. Seedlings that had 40 and 50 days age produced bulbs that were statically similar in bulb diameter (Table 4).

Bulb diameter is an important indicator for yielding capacity of a given variety of onion, which is among others influenced by genetic makeup of the variety and the growing environmental conditions. In this regard, other researchers also observed variations in bulb diameter among different onion varieties [28]. The fact is that optimum aged onion seedlings (60 days) can develop more root and shoot and synthesize much more photosynthetic assimilates so that they could produce onion bulbs with relatively higher diameter and fresh weight. The results of the present study are in line with others [27].

3.2.2. Fresh Bulb Weight. Bulb weight is an important trait that is directly related to the quality and yield of onion. In the present study, it was observed that the variety and seedling age significantly ($p < 0.001$) influenced fresh bulb weight of onion. However, the interaction effect of variety and seedling age did not influence this parameter. Bombay red produced the heaviest (84.39 g) bulbs, while Adama red recorded the smallest ones (72.62 g). On the other hand, as seedling age increased, the fresh bulb weight also increased where 60 days old seedlings produced the heaviest bulbs (88.92 g) and young aged seedling (30 days) produced the smallest (70.37 g) bulbs (Table 4).

The heaviest and widest bulb recorded by Bombay red in the present study has obviously showed high yielding capacity of the variety in the study area. In this regard, different scholars have been also reported that Bombay red variety produced bulbs with the highest fresh weight compared to Adama red and Nasik red varieties [29]. Bulb weight is also affected by the genetic potential of the variety and the suitability of the growing environment where varieties differ in their performance as indicated in the present study and studies of other scholars [28, 30]. Transplanting onion seedlings at 60 days also recorded the highest bulb weight, which could be associated with less transplanting shock and thus the development of more roots, shoots, and photosynthetic assimilates which led to the development of relatively bigger bulbs with larger diameter and fresh weight. The results of the present study are in line with others [27] who reported that older seedlings produced relatively heavier bulbs compared to the younger onion seedlings [26, 27].

3.2.3. Marketable Bulb Yield. Variety and seedling age in their main effect significantly ($p < 0.001$) affected the bulb yield of onion, while their interaction effect did not influence this parameter. Bombay red (29.97 $t \cdot ha^{-1}$) and Nasik red (29.10 $t \cdot ha^{-1}$) varieties recorded the highest bulb yields, while Adama red variety (25.55 t/ha) recorded the lowest bulb yield. In terms of seedling age, seedlings transplanted at 60 days old recorded the highest bulb yield (32.13 $t \cdot ha^{-1}$) and youngest seedlings recorded the lowest (23.04 $t \cdot ha^{-1}$) bulb yield (Figure 5).

Onion varieties differ in their yielding capacity where Bombay red and Nasik red varieties perform best in their marketable bulb yield, which could be attributed to their genetic makeup and suitability of the growing environment. Differences in bulb yield among onion varieties were also reported by other researchers, which is in agreement with the results of the present study [31]. The increased bulb yield under the 60 days old seedling is due to the fact that optimum aged seedlings appeared to develop more root and shoot and to synthesize much more photosynthetic activities. Such activities in turn help increase the vegetative growth and assimilate accumulation in bulbs that led to an increased average diameter and weight of bulbs and marketable bulb yield. Similar results have also been reported by Gurjar et al. [26] and Fatematuzzohora and Karim [27].

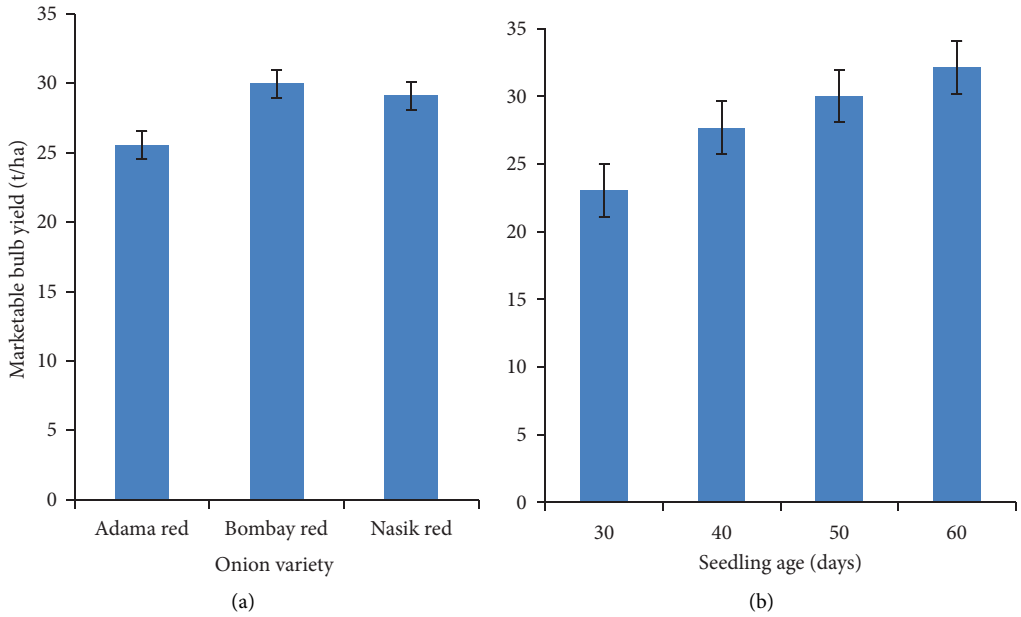

Figure 5: Effect of variety (a) and seedling age (b) on bulb yield of onion.

4. Conclusion

Variety and seedling ages influenced most of the growth and yield parameters of the onion. From the tested onion varieties, Bombay red performed best in all the tested parameters including bulb yield, which was statistically similar with the bulb yield produced from Nasik red variety. Onion seedlings at the age of 60 days were also superior in most of the tested growth and yield parameters of onion including stand count at harvest, plant height, number of leaves, diameter and weight of bulbs, and bulb yield. Therefore, seedlings of 60 days old and Bombay red and Nasik red varieties can be used to improve the productivity of onion in the study area and areas with similar agroecology.

Data Availability

The data used to support the findings of this study are available upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Eshetie Aragie carried out the field work and drafted the manuscript. Melkamu Alemayehu and Alemu Abate performed the statistical analysis and contributed to the write-up of the manuscript. All authors read and approved the final manuscript.

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