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Optimizing Seedling Age for the Production of Onion (*Allium cepa* L.) Varieties in Northeastern Ethiopia

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Abstract

Onion is commonly established in the field either by direct sowing, or by transplanting seedling from seedbed or from sets depending on the growing conditions of the specific region and grower interests. However, the optimum transplanting age in onion growing areas and Ethiopia is not well done. Field experiment was conducted at Alawuha kebele of North Wollo zone to optimize seedling age of onion varieties in 2021/2022 cropping season under irrigation. Adama Red, Bombay Red and Nafis and four seedling ages (30, 40, 50 and 60 days) were laid down in RCBD replicated three times. Phenology, growth and yield parameters were collected using standard procedures and analyzed using SAS software. Results revealed significant ($P < 0.05$) difference for plant height, leaf length, neck diameter and bulb length; while their interaction was not significant. Nafis gave significantly longer bulb (4.89 cm) than Adama Red (4.70 cm) and Bombay Red (4.45 cm). Nafis derived from 40 days old seedlings produced the highest average bulb weight (100.10 g), marketable (37.68 t ha^{-1}) and total (37.96 t ha^{-1}) bulb yield. The overall result indicated that onion establishment from 40 days old seedling may be good for yield of onion in northeastern Ethiopia.

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Keywords

Allium cepa, transplanting age, yield, varieties, pungency, bulb, cut flowers.

Introduction

Onion (*Allium cepa* L.) is an important bulb crop of tropical and subtropical parts of the world (Ghoname *et al.*, 2007). The crop is valued for its characteristic pungency and it forms essential components for flavouring dishes, sauces, soup, sandwiches and snacks (Awas *et al.*, 2010).

Growers preferred over the local shallot as of its high yield potential per unit area, accessibility of enviable cultivars for different uses, ease of propagation by seed, high domestic (bulb and seed) and export (bulb, cut flowers) markets in fresh and processed forms (Aklilu, 1997). In Ethiopia, the author further stated that the crop is produced in different parts of the country for local consumption and for export.

Due to its high profitability, ease of production, and the expansion of irrigation infrastructure in different parts of the country, the area coverage of onion is gradually increasing (Lchi *et al.*, 2020).

Onion ranks first among *Allium* species grown in Ethiopia both in area coverage (36,373.48 ha) and total production (2,738,589.86 tons) with average productivity of 7.5 t ha^{-1} during the 2019/20 cropping season (CSA, 2020). The national average yield is low as compared to the world average yield of 22.6 t ha^{-1} (FAOSTAT, 2017).

Although the development and improvement of direct sowing, Leskovau and Vavrina (1999) disputed that the most extensively adopted practice in onion production is transplanting seedlings. According to Tilaye *et al.*, (2018), transplanted onions provide an immediate and complete stand as compared to direct seeding. Addis (2020) concluded that transplanting seedling in the tropics by small-scale farmers is most efficient for the production of onion, as it allows farmers to maintain weed free plots and high soil fertility through the application of organic manure and irrigation. Tilaye *et al.*, (2018) reported that onions grown from transplants in central Ethiopia consistently produced bulb yields of 50.6 t ha^{-1}.

Small-seeded vegetables those that slow or difficult to germinate or may require special conditions, transplanting is a common practice widely used (Vavrina, 1998). Onion bulb yield is affected by age of seedlings (Chandrakar *et al.*, 2019). Choudhary *et al.*, (2016) reported that planting 8 weeks old seedlings of a local cultivar out-yielded their 10 week old counter parts. For cv. *Primavera*, plants that developed from 45 day-old seedlings performed better than plants from 65 day-old seedlings (Khodadadi, 2016).

Moreover, according to Gautam *et al.*, (2006), bulb yield is positively correlated with transplanting age. The report of Singh *et al.*, (2016) indicated that yield increased as seedling age increased when the cv. *Punjab-Naroya* used as a test crop. Significant ($P<0.05$) effects were reported with transplanting age, cultivar, and transplanting age x cultivar interaction on onion yield (Chandrakar *et al.*, 2019).

Same authors indicated that bulbs of cv. Composite 4 had the greatest diameter when four week old seedlings used. Other cultivars like Ex-Gayanawa, Ex-Dala, and D77 had the greatest bulb diameter when six week aged seedlings used as planting material. In addition, highest bulb length was also recorded when six week old seedling was used (Chandrakar *et al.*, 2019).

Gebremedhn *et al.*, (2018) concluded that seedling age affects bulb yield and yield components, with varietal variation that must be take into consideration. Maurya *et al.*, (1997) reported that as transplanting age increased, fresh bulb yield of onion decreased. On the other hand, seedlings with young age recovered from transplanting shock more rapidly than older ones (Seetohul and Hanoomanjee, 1999).

Although earlier works on transplanting age of onion in the temperate climate, most work has been devoted to container size in controlled environments with no work done under field conditions similar to that adopted by small-scale farmers in warmer regions. Therefore, the objective of this study was to investigate the effect of different onion seedling ages on growth and yield of onion varieties and recommend optimum seedling age to growers.

Materials and Methods

The experiment was conducted from October 2021 to February 2022 under irrigation at Alawuha, Gubalafto district of eastern Amhara region. The site is located at 11°53' 53″ to 11° 53' 57″ N latitude and 38° 51' 44″to 39° 47' 23″E longitude with an altitude of 1510 m above sea level (m.a.s.l). It is situated at about 533 km north of Addis Ababa and 373 km east of Bahir Dar, respectively. The study area is characterized as sub-tropical with an extended dry period of eight to ten month. The average annual rainfall is bimodal and erratic in nature that varies widely from 800-1050 mm; with an average temperature of 21.25°C and mean maximum temperature of 22.5°C in May and minimum temperature of 12.40°C in October. It has clay loam soil textural class (Alebachew *et al.*, 2019). Onion (*Allium cepa* L.), tomato (*Solanum lycopersicum* L.), Teff (*Eragrostis tef*), maize (*Zea mays* L.) and sorghum (*Sorghum bicolor*) are major crops grown in the study area (GDoARD, 2019).

Adana Red, Bombay Red and Nafis varieties of onion were used as an experimental material. Adana Red and Bombay Red were released by Melkasa Agricultural Research Center in 1980; while Nafis in 2010. All varieties have the characteristic of medium-red bulb color, erect leaf arrangement and flat globe bulb shape with maturity date of 120 days (EARO, 2004; MoARD, 2011). Seeds were obtained from Melkasa Agricultural Research Center. The recommended dose of 100 kg N ha^{-1} in the form of Urea ($CO([NH_2]_2)$ (46% N) and 200 kg NPSB rha^{-1} were applied (EthioSIS, 2016).

The experiment consisted of a factorial combination of four seedling ages (30, 40, 50 and 60 day old seedling) and three varieties (Adana Red, Bombay Red and Nafis). The experimental plot was laid out as a randomized complete block design (RCBD) in factorial arrangements with three replications. Each experimental plot was 3 m wide and 2 m long (3x2) with 1.0 m and 1.0 m spacing between plots and blocks, respectively. Each plot accommodated 15 rows with 20 plants per row with the spacing of 20 cm and 10 cm between rows and plants, respectively, as recommended by EARO (2004).

To have fine seedbed for good root development, the experimental field was plowed three times using a pair of oxen and the seedbeds with 5 m long and 1 m wide were leveled manually for each variety. Rows with 10 cm was lined and seeded with onion seed, covered lightly with soil. Urea, at the rate of 100 g Urea/5 $m^2$and was applied and mulched with grass until seedlings emerged. Until seedlings transplanted to the main field, agronomic practices required for seedlings were carried out (EARO, 2004).

The experimental area was prepared using draft animals and human labor; pulverize large size clods to make the land to fine tilth, and the field was then marked out into blocks and experimental units. After a day before removing irrigation, healthy, vigorous, and good for looking seedlings were selected for transplanting. The selected seedlings were transplanted late in the afternoon in order to reduce the risk of desiccation and poor establishments.

The field plants were undertaken based on predetermined treatments on 40 cm ridges x 20 cm row spacing x 10 cm plant spacing. A recommended dose of 200 kg NPSB ha^{-1} was applied uniformly to all plots during transplanting. About 100 kg N $ha^{-1}$was applied in two splits, one-half at transplanting, and the remaining half side-dressed at the active stage of vegetative growth 45 days after transplanting, according to the transplant age of seedlings (EARO, 2004). Other cultural practices like weeding, irrigation intervals, cultivation and plant protection methods were done uniformly for all experimental plots as recommended by EARO (2004).

Both the growth and yield parameters were collected from plants in the net plot area (5.32 m^2). The collected parameters were plant height, leaf number per plant, leaf length, bulb diameter, neck diameter, average bulb fresh weight, above ground dry biomass from ten randomly selected plants; whereas, days to maturity, marketable, unmarketable and total bulb yields were recorded per plot base. Plants grown in the central four rows were selected for data collection, leaving aside plants in the border rows and those at the end of each row in order to remove the border effect. Plant height was measured using a scale ruler from the ground level to the tip of the terminal leaves of ten randomly selected plants at the time of maturity and average value was used for further statistical analysis. Leaf number was counted from ten randomly selected plants at maturity. Leaf length was measured at physiological maturity from the sheath to tip of the leaf of ten plants using a ruler and the average value was used.

Above ground dry biomass was determined by weighing the whole above ground plant parts from ten plants; separated, chopped and dried in an oven at 65°C until constant weight was attained. Days to maturity was taken at physiological maturity starting from seedling transplanting to a day at which more than 70% of the plants in a plot showed yellowing of leaves. Average bulb weight was measured using a sensitive balance (R21E6-max-6000, power input 220-240 VOHAUS Corporation; USA); hence, the average value was used for further analysis. Bulb diameter was taken by measuring the wider portion of matured bulbs at harvest using a digital caliper (DECA.300, England).

Neck diameter was measured using digital caliper. Marketable bulb yield, which referred to as the weight of healthy and marketable bulbs that ranges from 20 to 160 g (Morsy *et al.*, 2012), was taken from net plot area at harvest. Total bulb yield was measured from the total harvest of the net plot as a sum weight of marketable and unmarketable bulb yields that were measured in kg per plot and eventually converted into t ha^{-1}. Harvest index was expressed as the ratio of total bulb fresh weight to the total biomass fresh weight at harvest maturity and expressed in percentage. Harvest index was calculated as total fresh bulb weight divided by total fresh biomass weight and multiplied by one hundred. The collected data were subjected to the analysis of variance (ANOVA) by using SAS (Statistical Analysis System) version 9.2. The least significant difference (LSD) test at 5% probability was used for mean separation of the treatments. Pearson's correlation was carried out to see the association among parameters (Gomez and Gomez, 1984).

Results and Discussion

Plant height (cm)

Main effects of both seedling age and varieties significantly ($P < 0.01$) affected onion plant height. The tallest plant (60.71 cm) was obtained from plants grown using 40 day old seedlings; while the shortest values

(42.46 cm) were recorded from plants grown using 30 day old seedlings (Table 1). Plant height was decreased as seedling age increased after 40 days old. This may be due to the fact that old seedlings may not have recovered from transplanting shock more rapidly compared to young ones. The tallest plants produced may be attributed to the fact that the younger transplants had more time for vegetative growth. This result is in line with Bijarniya *et al.,* (2015) who found the tallest plant due to planting 8 weeks old seedlings that may attribute for greater stored food as compared to 6 weeks old seedlings. Varieties had significant (P<0.01) effects on plant height. The tallest plant was obtained from Nafis, followed by Adama Red (Table 1). The difference in plant height among the onion varieties could be due to the difference in their genetics make up. The result is in line with the findings of several other researchers (Tegbew, 2011; Yemane *et al.,* 2014; Tibebu *et al.,* 2014).

Leaf length (cm)

Leaf length was significantly (P<0.01) affected by the main effects of seedling age and varieties; there was no interaction effect of two factors on this parameter. The longest leaf was observed when seedlings transplanted at 40 days of age; while the shortest leaf length was obtained using 30 days old seedlings (Table 1). Delayed transplanting past the optimum time in which they are making active growth adversely affects growth after transplanting. In this regard, Singh and Chaure (1999) reported that longer leaves were recorded at old seedling age as compared to treatments of the young ones. On the other hand, Nafis gave significantly longer leaf length than the other varieties. In line with the result, Yemane *et al.,* (2014) reported that longer leaf length was recorded from Adama Red than Melkam and Bombay Red. Tibebu *et al.,* (2014) found longer leaf length from Nafis than Adama Red and Bomby Red.

Leaf number

Leaf number per plant was significantly (P<0.05) influenced by the interaction of seedling age and varieties. Nafis produced maximum number of leaves when grown from 40 days old seedlings although statistically at par with Adama Red grown from the same aged seedlings (Table 2). The seedling at the age of 40 days revealed better establishment in the field, which might have helped the plants to produce more height with greater surface area for yielding a larger number of leaf primordia and young leaves during the growing season. The positive and significant correlation between plant height and number of leaves (r =0.90**, data not shown) confirms the speculation of the result. Contrary to the current finding, Tilaye *et al.,* (2018) reported that seedling age influenced number of leaves.

Shoot dry weight (g)

Shoot dry weight was significantly (P<0.01) affected by the interaction of varieties and seedling age. Maximum shoot dry weight (10.6 g) was recorded from Nafis, when grown at seedling age of 40 days old followed by Adama Red grown at the same seedling age (Table 2). The stimulatory effect of seedlings at 40 days old might be credited to the appropriate weather condition during vegetative growth, which contributed to good foliage growth and formation of sufficient canopy; and thus, able to make best photosynthesis, hence increasing dry matter accumulation. The positive and significant correlation of shoot dry weight with plant height (r = 0.89**), leaf length (r = 0.87**) and number of leaves (r = 0.90**) confirmed the speculation. The result is in line with Herison *et al.,* (1993) who reported that increase in photosynthetic area of the plant (plant height and number of leaves) in turn increased the amount of assimilates that could contribute to accumulation of dry matter.

Days to maturity

Days to maturity were significantly (P < 0.01) affected by the interaction effect of variety and seedling age. Maximum mean days required to mature (127.67) was recorded from Adama Red, when grown using seedlings at the age of 30 days; while the minimum value (90.33) was recorded from Nafis, when grown using seedlings aged at 60 days (Table 2). The results indicated that onion grown using old seedlings could be able to easily mature earlier than young seedlings. This might be because old seedlings, considering their age starting from nursery and going quickly to bulb formation, have a greater advantage; rather than investing resources in increasing plant height and leaf number. In line with the result, Choudhary *et al.,* (2016) reported that transplant ages of 35-days-old seedlings took significantly longer days to crop maturity as compared to 65-days-old seedlings.

Bulb diameter (cm)

Bulb neck diameter was significantly (P < 0.01) influenced by seedling age and varieties but not affected by their interaction. Bulbs produced from seedling age of

40 days age increased the bulb neck diameter by 58.4, 35.4, 15% as compared to seedling age of 30, 60, and 50 days old, respectively (Table 3). Thicker neck could be due to improved plant growth with respect to plant height, number of leaves per plant and leaf area per plant. All of this could be attributed to increased rate of photosynthesis and assimilation in plant tissues. The positive and significant correlation of bulb neck diameter (data not shown) with plant height (r = 0.88**), leaf length (r = 0.83**) and number of leaves (r = 0.90**) confirms the hypothesis. The result is in agreement with Gautam *et al.,* (2006) who reported that neck thickness is one of the important parameters, which is highly significantly influenced by seedling age. Khodadadi (2016) reported 72% bulb neck diameter increment when onion was grown from seedling at the age of 75 days old, rather than 45 day-old seedlings.

Maximum bulb neck diameter was recorded from Nafis followed by Adama Red (Table 3). Genetic difference among varieties could be the source of variation among varieties for bulb neck thickness. Similar to the result, Bijarniya *et al.,* (2015) reported Adama Red had significantly thicker bulb neck than Bombay Red by about 15%. Ansari (2007) evaluated the performance of Nasik Red, Hybrid Rosy, Local White and local Red, and reported that Nasik Red recorded thicker bulb neck than the other four varieties. Yemane *et al.,* (2014) reported significantly higher bulb neck diameter (1.77 cm) for Melkam as compared to Adama Red (1.57 cm). Gessesew *et al.,* (2015) obtained significantly higher bulb thickness from Adama Red and Melkam than Bombay Red.

Bulb length (cm)

The analysis of variance revealed that there was a significant (P<0.01) between varieties and seedling age in their bulb length. The results indicated that among seedlings at an age of 40 days old, the bulb length was significantly higher followed by 50 days old seedling age. Compared with the 30, 50 and 60 days old seedling age, 40 days old seedling age produced 45, 8 and 16% longer bulbs (Table 3). This indicated that the 40 days of seedling age had attained longer leaves and greater height, which may have helped for more vegetative growth and bulb development and ultimately an increase in bulb length. The positive and significant correlation (data not shown) of bulb length with plant height (r = 0.87**), leaf length (r = 0.89**), leaf number (r = 0.88**), neck diameter (r = 0.89**) and average bulb weight (r = 0.84**) confirmed the hypothesis. A similar finding was published by Sultana (2015) who reported that length of bulb increased in 50 days old seedlings, which were stronger and larger in size at transplanting stage. Furthermore, Singh and Chaure (1999) observed that there is an increase of bulb length at younger seedling age compared to treatments using older seedling age.

Bulb length (cm)

In this experiment, all of the tested varieties showed a significant difference on the length of fresh bulb. The length of bulb varied from 4.45 cm for Bombey Red to 4.89 cm for Nafis, with an average of 4.68 cm (Table 3). Increment in leaf number and length, that might increase assimilate production and allocation to the bulbs, could have increased the bulb length of onion. Different varieties have different morphological characteristics (Khodadadi, 2016). This might be attributed to reduced limitations of growth factors that allows better foliage growth, and ensures for the bulbs to have more assimilates available for storage, thus resulting in higher bulb length.

Bulb diameter (cm)

Bulb diameter was significant (P < 0.05) influenced by the interaction of seedling age and varieties. Nafis and Adama Red significantly produced higher bulb diameter when grown using 40 day old seedling (Table 4). Several researchers reported large bulbs (greater than 5cm diameter) from young seedling than those with old transplant ages (Choudhary *et al.,* 2016; Singh *et al.,* 2016); and therefore contributed to stronger photosynthetic efficiency and vigorous vegetative growth. Bulb diameter was positively and significantly correlated (data not shown) with plant height (r = 0.91**), leaf length (r = 0.91**) and leaf number (r = 0.93**); and confirmed the hypothesis of the study.

Average bulb weight (g)

Average bulb weight was significantly (P<0.01) influenced by the interaction effect of seedling age and varieties. As Table 4 illustrates, the highest average bulb weight was recorded from Nafis grown using 40 days old seedling; while the lowest value was obtained from Bombay Red grown using 30 days old seedling. Increment of average bulb weight of the three varieties could be accredited to the increase in plant height, number of leaves produced and leaf length in response to the growth stage of the young seedlings.

Table.1 Main effects of seedling age and varieties on the growth of onion

Treatments	Growth parameters	
Seedling age	**Plant height (cm)**	**Leaf length (cm)**
30	42.46^{d}	32.79^{d}
40	60.71^{a}	49.49^{a}
50	53.35^{b}	44.39^{b}
60	46.25^{c}	39.73^{c}
LSD (*P*< 0.05)	2.81	2.22
Significance Level	**	**
Varieties		
Adama red	52.31^{b}	41.77^{b}
Bomby red	45.01^{c}	36.70^{c}
Nafis	54.76^{a}	46.31^{a}
LSD (P< 0.05)	2.43	1.93
F-test	**	**
CV (%)	5.67	5.47

Means in columns with the same letter are not significantly different from each other at P ≤ 0.05.

Table.2 Interaction effects of seedling age and varieties on growth and phenology of onion

Treatments		Growth parameters		
Transplanting time (age)	Varieties	Leaf number	Shoot dry weight (g)	Days to maturity
	Adama red	8.06^{g}	4.31^{g}	127^{a}
30	Bombay red	7.63^{g}	3.51^{h}	119^{c}
	Nafis	10.67^{de}	5.25^{f}	99.33^{g}
	Adama red	14.53^{a}	7.96^{b}	122.66^{b}
40	Bombay red	11.7^{cd}	6.77^{c}	116^{d}
	Nafis	15.3^{a}	10.60^{a}	96.3^{h}
	Adama red	12.26^{bc}	5.93^{e}	114.33^{d}
50	Bombay red	11.56^{cd}	5.46^{f}	111.33^{e}
	Nafis	12.87^{b}	6.56^{cd}	93.33^{i}
	Adama red	9.93^{ef}	5.18^{f}	110.67^{e}
60	Bombay red	9.2^{f}	4.66^{g}	106.33^{f}
	Nafis	11.3^{cd}	6.17^{de}	90.33^{j}
LSD (P< 0.05)		1.12	0.45	2.25
F-test		*	**	**
CV (%)		6.13	4.27	1.12

Means in columns with the same letter are not significantly different from each other at P ≤ 0.05.

Table.3 Main effects of seedling age and varieties on yield components of onion

Treatments	Yield parameters	
Transplanting time	**Neck diameter (cm)**	**Bulb length (cm)**
30	1.59^{d}	3.70^{d}
40	2.52^{a}	5.38^{a}
50	2.19^{b}	5.00^{b}
60	1.86^{c}	4.66^{c}
LSD (P< 0.05)	0.14	0.13
Significance Level	**	**
Varieties		
Adama red	2.06^{b}	4.70^{b}
Bombay red	1.85^{c}	4.45^{c}
Nafis	2.22^{a}	4.89^{a}
LSD (*P*< 0.05)	0.12	0.12
F-test	**	**
CV (%)	6.89	2.93

Means in columns with the same letter are not significantly different from each other at $P \leq 0.05$.

Table.4 Interaction effects of seedling age and varieties on yield components of onion

Treatments		Yield parameters		
Transplanting time (age)	**Varieties**	**Bulb diameter (cm)**	**Average bulb weight (g)**	**Harvest index (%)**
	Adama red	4.39^{f}	43.14^{g}	68.9^{abc}
30	Bombay red	4.19^{f}	35.08^{h}	70.87^{a}
	Nafis	5.06^{e}	52.51^{f}	67.46^{bcd}
	Adama red	7.04^{a}	79.59^{b}	66.39^{d}
40	Bombay red	6.4^{b}	67.68^{c}	67.00^{cd}
	Nafis	7.05^{a}	106.10^{a}	63.92^{e}
	Adama red	6.23^{b}	59.37^{e}	68.22^{bcd}
50	Bombay red	5.72^{cd}	54.63^{f}	67.7^{bcd}
	Nafis	6.43^{b}	65.61^{cd}	69.47^{ab}
	Adama red	5.57^{d}	51.89^{f}	67.26^{cd}
60	Bombay red	5.21^{e}	46.61^{g}	66.9^{cd}
	Nafis	5.92^{c}	61.72^{de}	67.08^{bcd}
LSD (P< 0.05)		0.22	4.57	2.19
F-test		*	**	*
CV (%)		1.94	4.28	1.96

Means in columns with the same letter are not significantly different from each other at $P \leq 0.05$.

Table.5 Interaction effects of seedling age and varieties on the yield of onion

Treatments		Yield parameters	
Transplanting time (Age)	**Varieties**	**Marketable bulb yield (t ha^{-1})**	**Total bulb yield (t ha^{-1})**
	Adama Red	11.77^{gh}	12.37^{gh}
30	Bombay Red	10.93^{h}	11.68^{h}
	Nafis	13.49^{fgh}	13.98^{fgh}
	Adama Red	31.27^{b}	31.68^{b}
40	Bombay Red	27.7^{c}	28.07^{c}
	Nafis	37.68^{a}	37.97^{a}
	Adama Red	25.64^{c}	26.08^{c}
50	Bombay Red	21.93^{d}	22.45^{d}
	Nafis	27.57^{c}	28.00^{c}
	Adama Red	14.75^{e}	15.21^{ef}
60	Bombay Red	14.38^{efg}	14.93^{efg}
	Nafis	16.62^{e}	17.13^{e}
LSD (*P*< 0.05)		2.76	2.74
F-test		**	**
CV (%)		7.9	7.69

Means in columns with the same letter are not significantly different from each other at P ≤ 0.05.

Similarly, Pearson's correlation analysis also indicated that average bulb weight was positively and significantly (P< 0.01) correlated with plant height (r = 0.89**), leaf length (r = 0.87**), above ground biomass (r = 0.99**) and leaf number (r = 0.90**) of onion. The current result is in agreement with Kanton *et al.*, (2015) who obtained that the heaviest (57.2 g) onion bulbs were derived from 40-day-old transplants, and the lightest (26.1 g) from plants developed from 70-day-old transplants.

Harvest index

The analysis of variance showed that means of harvest index was significantly (P < 0.05) affected by the interaction effect of seedling age and varieties of onion. Highest harvest index of 70.87% was obtained from Bombay Red derived from 30 days old seedling age; although it was statistically at par with Adama Red derived from the same aged seedlings (Table 4). The findings are consistent with the reports of Chandrakar *et al.*, (2019) who indicated that 40 days old seedlings produced maximum harvest index than 70 day old seedling age. In a rice experiment, Sarwa *et al.*, (20011) showed that the highest harvest index (25.47%) was recorded with transplanting younger seedlings (10 days) and the lowest value (20.37%) was found when transplanting was done with older seedlings (40 days). The response of varieties to seedling age could be attributed to differences in their genetic makeup.

In line with the present result, Yemane *et al.*, (2014) reported that the highest harvest index 83% was recorded for Bombay Red followed by Melkam (81%), Adama Red (77%) and the lowest harvest index was for Nafis. The highest harvest index recorded from onion grown with very small seedling age might be due to the shorter leaf, plant height and small leaf diameter that could reduce the aboveground biomass; which in turn reduced vegetative biomass as compared to the relative higher weight of economic yield of the crop, which ultimately resulted in higher harvest index. The production of low harvest index could be due to the production of more vegetative growth which diverted assimilates away from bulbs.

Marketable yield (t ha^{-1})

The analysis of variance revealed that the interaction effect of seedling age and varieties significantly (P<0.01) influenced marketable bulb yield. Nafis derived from 40 days old seedling produced maximum marketable bulb yield followed by Adama Red derived from the same seedling age (Table 5). The increment in marketable bulb yield could be due to the utilization of young seedlings as planting materials, which attributed to the increment in vegetative growth and increased production of assimilate leading to increment in bulb diameter and average bulb weight, as also reported by Choudhary *et al.*, (2016).

Furthermore, correlation analysis indicated that marketable bulb yield was significantly ($p < 0.05$) and positively correlated with plant height (r = 0.91**), leaf length (r = 0.85**), leaf number (r = 0.90**), shoot fresh weight (r = 0.89**), shoot dry weight (r = 0.90**), average bulb weight (r = 0.90**), bulb length (r = 0.88**) and bulb diameter (r = 0.92**) of onion. Bhonde *et al.*, (2001) reported that onion seedlings transplanted after 8 weeks resulted in maximum marketable bulb yield of 20.5 t ha^{-1}, which is statistically higher than 10 and 6 weeks old seedlings; and they suggested 8 weeks old seedling as an optimum age for the commencement of bulb.

Total bulb yield (t ha^{-1})

Total bulb yield of onion had significantly ($P < 0.01$) affected by the interaction of seedling age and varieties. Yield of Nafis derived from 40 days old seedling was nearly tripled compared to the yield obtained from Bombay Red derived from 30 days old seedlings (Table 5). The performance of yield contributing growth factors with young aged seedlings might contribute to the production of high bulb yield. Furthermore, correlation analysis indicated that total bulb yield was significantly and positively correlated with plant height (r = 0.91**), leaf length (r = 0.85**), leaf number (r = 0.92**), average bulb length (r = 0.88**), neck diameter (r = 0.89**), average bulb weight (r = 0.89), and average bulb diameter (r = 0.92**). Several reports worldwide agree with this result (Singh *et al.*, 2016; Tilaye *et al.*, 2020; Chandrakar *et al.*, 2019).

On the other hand, in Ghana, plants developed from 20 to 40 day old transplants gave significantly optimum bulb yields (Kanton *et al.*, 2003). Vachhani and Patel (1989) conducted field trials with the cultivar Pusa Red and reported that the yield increased with seedling age from 25.77 t ha^{-1} with 4 week old seedlings to 46.23 t ha^{-1} with 7 week old seedlings, but then decreased gradually to 32.53 t ha^{-1} with 10 week old seedlings.

The findings of the experiment revealed that seedling age and varieties as well as their interactions significantly affected phenology, growth, yield and yield attributes of onion. Variety Nafis derived from 40 days old seedling gave the highest marketable bulb yield (37.68 t ha^{-1}) and total bulb yield (37.97 t ha^{-1}). Hence, use of 40 days old seedling can be used as an alternative option for onion production in the study area.

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