Pak. J. Bot., 56(4): 1485-1490, 2024. DOI: http://dx.doi.org/10.30848/PJB2024-4(39)

PREVENTING BOLTING IN ONION (*ALLIUM CEPA* L.) BULB CROP; EFFECT OF TRANSPLANTING DATE AND SEEDLING AGE

NOOR HABIB KHAN[1*], MUHAMMAD AZIM KHAN[2], ATTAULLAH[1], ZAKRIA BACHA[1], SHAFIULLAH[1], MUHAMMAD ZAMIN[3] AND AKHTAR ALI[1]

[1]*Agricultural Research Institute, Mingora, Swat, Pakistan*
[2]*The university of Agriculture Peshawar, Pakistan*
[3]*The University of Swabi, Pakistan*
[*]*Corresponding author's email: noorhabib808@gmail.com*

Abstract

Premature bolting reduces the shelf life and marketable yield of onion bulbs. This issue is investigated in the current study. Nursery of different seedlings ages were transplanted on different dates for two seasons. Experiments were conducted in RCBD with factorial arrangements. Most of the growth and yield parameters were significantly affected by transplanting dates and seedling age. Premature bolting and unmarketable yield decreased with delay in transplanting and increased with an increase in seedling age. Two-month seedlings transplanted in mid-December gave maximum marketable yield. Transplanting 45-60 days old seedlings from 15 December to 15 January is recommended for minimum bolting percentage and highest marketable yield.

Key words: Onion (*Allium cepa* L.), Premature bolting, Seedling age, Transplanting dates, Marketable yield.

Introduction

Onion (*Allium cepa* L.) is a major vegetable cultivated in all four provinces in Pakistan. Around 2 million tons of onions were produced from an area of 148408 hectares, in 2018-19 (Fruits, vegetables and condiments statistics of Pakistan 2018-19). Lack of new, improved varieties, unavailability of quality seed at affordable prices, insect pests and diseases, weeds infestation, premature bolting and marketing of overproduce are major issues in onion cultivation.

Onion is a biennial vegetable but is mostly grown as an annual for bulb production. It has two stages of growth, a vegetative stage and a reproductive stage. In the vegetative stage, it grows and produces leaves and bulbs in the latter stage, it sends seed stalks and produces flowers and seeds. When onions are seeded/transplanted for bulbs and it initiates inflorescence development, thus, deviating from its normal life cycle, it is called bolting. Bolting makes the bulb hard, fibrous, and lightweight and it is discarded in final grading for the market. Premature bolting, therefore, reduces the marketable yield of onion bulbs (Rana & Hore, 2015; Khan *et al.*, 2019).

Most onions cultivars require a vernalizing temperature of 5-13°C at the post-juvenile stage, having 7-10 leaves for 20-120 days to initiate flowering (Khokhar, 2008; Khan *et al.*, 2021).

Bolting is a serious problem in onion bulb crops in onion-growing areas. This problem-oriented research trial was carried out with the objective of adjusting the transplanting dates of correct seedlings in such a way as to avoid bolting and achieve maximum marketable yield.

Material and Methods

Trials were conducted at ARI, Mingora, Swat, Pakistan, in 2013-14 and were repeated in 2014-15. The field was pulverized with a tractor and weeds plant debris were removed by hand. Fully decomposed FYM was mixed with soil. Soil clods were well broken with a hand hoe. Raised beds with 2×1m length and width were prepared. Seeds of commercial variety Swat-1 were sown for nursery in lines and covered with a mixture of FYM and fine sand. Swat-1 is a red skin approved onion variety with high yield and good keeping quality. The nursery was raised on different dates to prepare the required age of seedlings for each transplanting date. Plots were prepared according to the experimental design.

Bare root seedlings were transplanted manually with the help of a hand hoe in prepared experimental plots. Soon after transplanting, a pre-emergence weedicide, pendimethalin, @ 5ml / liter of water, was applied to suppress the growth of weeds. The trial field was irrigated on the following day.

45, 60 and 75-days old seedlings were transplanted on 5 different dates. All the transplanting was carried out at 15 days intervals starting from 30^{th} November. Seedlings were transplanted 10 cm apart within a row and 25 cm between rows in a plot size of 1×3 m^2 having 120 plants in 4 rows. Planting on 5 different dates and 3 seedling ages were the two factors making 15 treatment combinations that were set in RCB design with factorial arrangements in triplicate. Complete decomposed FYM @ of 15 tons per hectare was applied during land preparation. Recommended doses of nitrogen, phosphorus and potash were applied based on the soil analysis results (Table 1). Phosphorus and potash fertilizers were applied as single doses at the time of sowing while the dose of nitrogen was given in three parts.

Plant height on 20 randomly selected plants was measured from the soil surface to the longest leaf tip. Stem thickness was measured using a digital Vernier caliper. The number of plants that had bolted was counted, converted and expressed as bolting percentage. Harvesting was done at 80% of neck fall. Curing was carried out at 25.95°C with a relative humidity of 53.6% for two days. Leaves, stems and roots were clipped. Randomly selected 20 bulbs were weighed and averaged for single bulb weight. Bulbs in a unit plot were weighed as Kg $plot^{-1}$ and the value was converted for total yield ton ha^{-1}. Bolted, diseased, split and double bulbs were culled and weighed. Marketable yield was calculated by subtracting cull from total bulb yield.

Software "Statistix 8.1" was used to analyze the data. Significance between the two treatments means were worked out using the LSD test for the LSD ≤ 0.05.

Table 1. Physio-chemical properties of the soil.

Soil analysis	2013-14	2014-15
Soil texture	**Silt loam**	**Silt loam**
pH	6.4	6.0
OM %	1.59	1.31
Lime %	2.4	2.6
N %	0.057	0.035
P mg Kg^{-1}	41.0	27.51
K mg Kg^{-1}	54.0	50.0
Cu mg Kg^{-1}	5.48	4.02
Fe mg Kg^{-1}	32.62	34.62
Zn mg Kg^{-1}	6.22	4.90
Mn mg Kg^{-1}	11.25	14.75

Results and Discussion

Plant height and number of leaves at the bolting stage: Transplanting date and seedling age significantly affected plant height and number of leaves $plant^{-1}$ (Table 2). Early transplanting (30^{th} November) gave maximum plant height (58.80 cm) and maximum number of leaves (8.29) whereas almost two months late transplanting on 30 January resulted in a minimum plant height of 53.77 cm and 6.29 leaves $plant^{-1}$. Seedling age also influenced plant height and the number of leaves per plant. Plants derived from 75 days old seedlings produced a maximum plant height of 57.91 cm and more leaves 8.08 compared to those derived from 60- and 45-days old seedlings.

Similar results were reported by (Bijarniya *et al.*, 2015) that maximum plant height and maximum number of leaves from 8 weeks old transplant at 45, 75 and 90 days after transplanting. On the contrary, (Kanton *et al.*, 2003) studied a significant effect of seedling age on plant height and reported the tallest plants from 40 days old transplants. (Khokhar *et al.*, 2007) stated that the number of leaves determines the critical plant size at which bolting occurs at low temperatures and reported that 7-10 leaf stage is a sensitive plant size for bolting. If transplantation is carried out earlier, plants will be triggered for bolting rather than bulbs formation. Cramer (2003) observed that earlier planted onions produced bigger plants with more leaves compared to later seeding onions. Thus, early transplanting coupled with aged seedlings complete the juvenile phase early and become receptive to a cold stimulus that induces bolting.

Days to harvesting: The transplanting date significantly affected days to harvesting, while the seedling age effect was found to be non-significant ($p<0.05$). Maximum days to maturity of 180.89 were observed on 30^{th} November transplanting, whereas minimum days 152.72 to maturity was taken by 30 January transplanting (Table 2).

Though the effect of the age of seedlings on maturity was not significant, nevertheless, more days to physiological maturity were taken by younger seedlings compared to older seedlings. The combined means of two years showed a maximum of 167.93 days to maturity when 45 days old seedlings were transplanted while a minimum of 165.73 days to maturity when 75 days old seedlings were transplanted. Bulbs start to mature at the fulfillment of the required minimum day length and temperature of the specific cultivar. Hence the same cultivar sown on different dates or having varying seedling ages will start to mature more or less at the same time. Thus, late transplanting takes fewer days to maturity than early transplanting. The results are in line with the findings of (Sawant *et al.*, 2002 and Khan *et al.*, 2019) that maturity occurred earlier in early transplanting but took more days, while maturity in late transplanting occurred late but took fewer days to maturity. The findings of (Bijarniya *et al.*, 2015) that older seedlings take fewer days to maturity than younger seedlings also support our results.

Bolting percentage: Transplanting date and seedling age significantly affected bolting percentage, while the year effect was non-significant (Table 2). A maximum bolting percentage of 33.63 was recorded on 30^{th} November transplanting and decreased with delay in transplanting and diminished with late transplanting on 30 January. Thus, bolting decreased from 33.63 % to 0% when transplanting was delayed from 30 November to 30 January. The flower is induced in onion by low temperature after the juvenile stage of development. (Khokhar *et al.*, 2007a) observed a direct relationship between leaves and plant height at which bolting initiates and concluded that 7-10 leaf stage is sensitive to bolting at low temperature. When seedlings are transplanted early in the season, seedlings will achieve enough growth to complete the vegetative phase before the fall of temperature. And when cold temperatures occur, it induces bolting instead of making bulbs (Khan *et al.*, 2021). Sowing should be adjusted to prevent plants from receiving a cold spell at sensitive plant size that causes bolting instead of bulb formation. It is not possible to exactly define transplantation date so that the bolting can be reduced and yield is improved at the same time because environment and cultivar genetic make-up have interactive effect (Cramer, 2003). Temperature later in the season, particularly in March-April when plants have enough leaf numbers to respond to a cold stimulus, varies year after year. In some years, the climate is cool and favors bolting or vice versa (Khan, 2017). In our study, though the year effect is not significant, the 2013-14 season is a little colder than the 2014-15 (Fig. 3) and thus has more bolting numbers. (Boyhan *et al.*, 2009) also reported more bolting occurrences in 2003-04 season compared to 2004-05 season. Similarly, the highest bolting percentage was noted in older seedlings compared to younger seedlings. The highest bolting percentage, 30.81, was observed in 75 days old transplanting followed by 9.86 in 60 days old transplanting. The lowest bolting percentage, 4.60 was noted 45 days old transplanting. Transplant size may be an important factor in onion performance. Commonly, large seedlings have higher yields but more bolting occurrence (Boyhan *et al.*, 2009). This may be due to the fact that large seedlings are more stressed and grown enough to enter the reproductive stage early, as reflected in the study of Boyhan *et al.*, (2009) and happened in the current study too. Dong *et al*., (2013) stated that Onion seedlings must be grown to a certain age before they sense the cold temperature and start the vernalization process. Gao *et al*., (2011) found that older seedlings needed less accumulation of low temperatures for bolting. Kanton *et al*., (2003) reported that older (30 or 40 days) seedlings take fewer days to mature than younger transplant (20 days) seedlings. Jahromi and Amirizadeh (2015) reported similar results that the bolting percentage increased with increasing seedling age.

As per the two year means interaction results of the D×S combination maximum bolting percentage of 66.33 was recorded in D_1S_1 combination, followed by 48.33 D_2S_1 combinations (Fig. 1). The Lowest bolting percentage of 4.33 was observed in D_3S_3. No bolting was recorded in D_4S_3 and D_5, irrespective of the seedling age. Early transplanting of larger seedlings takes less time to reach minimum critical size, sense the cold response and bolt readily instead of making bulbs. On the other hand, younger seedlings with late transplanting take more time to mature and escape the cold weather-inducing bolting. Brewster (1994) showed that there is a relationship between sowing date, bulb yield and bolting. Muhammad *et al*., (2016) also found a significant interaction between transplanting dates and seedling age for bolting percentage.

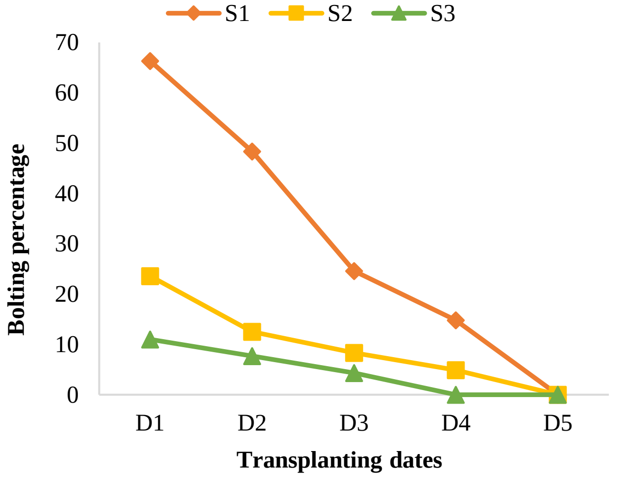

Fig. 1. Mean data showing interaction of transplanting dates and seedling age for bolting percentage.

Bulb diameter and bulb weight: The highest bulb diameter (6.97 cm) and bulb weight (224.39 g) were noted in early transplanting on 30th November and decreased with delayed transplanting (Table 3). Early transplanting had received more time for vegetative growth before the minimum temperature and day length requirement for bulbing was fulfilled. Hence, they attained maximum plant height with more leaves and produced large-size bulbs (Khan *et al*., 2021). The findings of Sawant *et al*., (2002) confirm this report that early planting produced larger bulbs. Similarly, cultivar and date of sowing had significant effect on the diameter of bulb (Bosekeng & Coetzer, 2013), thus, the larger bulbs were produced in the plants sown earlier. The results of Bijarniya *et al*., (2015), Hiray (2001), Kumar *et al*., (1998) and Mosleh & Deen (2008) upheld the findings of this study.

Similarly, seedling age exerted a significant effect on bulb diameter and weight. A maximum bulb diameter of 6.31 cm and bulb weight of 209.55 g was noted in 60 days old seedling, while a minimum bulb diameter of 5.61 cm and bulb weight of 178.93g was recorded when 75 days old nursery was transplanted. These results are in conformity with the findings of Kanton *et al*., (2003) and Aubyn & Abutiate (1994) that mean bulb weight and bulb diameter decreased with increasing seedling age. Younger seedlings recovered from transplanting shock more quickly compared to older seedlings. (Norman, 1992). According to NeSmith (1993) delaying nursery transplanting than the optimum time in which they are making active growth, then growth after transplanting and yield would be suffered.

Kanton *et al*., (2003) stated in their arguments that higher bulb yields produced from plants developed from younger transplants could be attributed to better plant growth, as revealed in taller plants having the maximum leaf and bulb dimensions compared to their older seedlings. Plants grown from younger seedlings seemed to be more efficient in the conversion of photosynthate into harvestable bulbs than plants derived from older transplants.

Total yield ton ha^{-1}: Transplanting date and seedling age made a significant difference in yield ton ha^{-1} at a 5% level of probability (Table 3). A maximum yield of 39.90-ton ha^{-1} was obtained on 15th December transplanting, followed by 39.71-ton ha^{-1} on the 30th November transplanting, whereas a minimum yield of 15.99-ton ha^{-1} was recorded when transplanting was delayed to 30 January. Ample vegetative growth before bulb formation is essential to get a high yield (Ibrahim, 2010). When sowing is delayed, plants start bulbing before attaining sufficient vegetative growth, resulting in small bulbs and lesser yield. Smaller plant canopy of a small plant in a late transplanting crop intercepts less light and consequently produces the low yield (Bosekeng & Coetzer, 2013). They also found that delayed sowing dates significantly reduce bulb fresh mass and yield from 40.96 to 28.20 tons ha^{-1}.

Different age nursery transplanting was also found to have a significant effect on yield ton ha^{-1}. The highest yield of 32.43 tons ha^{-1} was produced by plants derived from 60 days old seedlings, while the lowest yield of 27.24 tons ha^{-1} was recorded when 45 days old seedlings were transplanted. Similar results have been reported by Kanton *et al*., (2003) that higher bulb yields produced from plants developed from younger transplants could be attributed to better plant growth compared to their older seedlings. They further stated that younger seedlings revived vegetative growth more quickly, which might have contributed to more vigorous development. Plants derived from younger transplants seemed to be more efficient in the conversion of photosynthate into harvestable bulbs than plants grown from older seedlings. According to Fathi (2009), the optimum seedling age of an onion is 60 days and the 60 days-old transplants had a higher yield than other transplant ages. The findings of this study are also matched with the results of Jahromi & Amirizadeh (2015), who obtained the maximum total yield from 60 days old transplants.

Table 2. Effect of transplanting dates and seedling age on plant height, No. of leaves, days to Maturity & bolting percentage.

Treatments/characters	Plant height (cm)			No. of leaves at bolting			Days to maturity			Bolting percentage		
Transplanting date	2013-14	2014-15	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean
30 November	58.43 a	59.16 a	58.80 a	8.19 a	8.38 a	8.29 a	182.56 a	179.22 a	180.89 a	34.55 a	32.72 a	33.63 a
15 December	57.06 ab	58.18 ab	57.62 ab	7.50 b	7.58 b	7.54 b	177.89 a	175.11 a	176.50 b	23.44 b	22.23 b	22.83 b
30 December	55.72 b	56.87 bc	56.29 bc	7.11 bc	7.17 bc	7.13 b	164.00 b	167.11 b	165.56 c	12.67 c	12.16 c	12.41 c
15 January	55.19 b	56.03 c	55.61 c	6.53 cd	6.50 cd	6.51 c	158.22 c	156.78 c	157.50 d	6.03 d	7.14 d	6.57 d
30 January	52.41 c	55.07 c	53.74 d	6.31 d	6.28 d	6.29 c	153.56 c	151.89 d	152.72 e	---	----	----
LSD	**1.19**	**2.09**	**1.39**	**0.65**	**0.69**	**0.51**	**5.63**	**4.29**	**3.43**	**3.44**	**3.81**	**2.47**
Seedling Age												
75 days old seedlings	57.86 a	57.95 a	57.91 a	8.17 a	8.00 a	8.08 a	167.93 a	164.73 a	165.73 a	29.73 a	31.90 a	30.81 a
60 days old seedlings	55.32 b	57.02 ab	56.17 b	7.00 b	7.10 a	7.05 b	166.13 a	165.33 a	166.33 a	10.60 b	9.12 b	9.86 b
45 days old seedlings	54.11 b	56.21 b	55.16 b	6.21 c	6.45 b	6.33 c	167.67 a	168.00 a	167.83 a	5.67 c	3.53 c	4.60 c
LSD	**1.75**	**1.95**	**1.36**	**0.50**	**0.53**	**0.46**	**4.36**	**3.32**	**2.66**	**2.67**	**2.95**	**1.91**
Year	55.04	57.02		7.13	7.18		167.24	166.02	166.46	15.33	14.85	15.79
Interactions												
D × S	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	*	*
Year × D	-	-	ns	-	-	ns	-	-	ns	-	-	ns
Year × S	-	-	ns	-	-	ns	-	-	ns	-	-	ns
Year × D × S	-	-	ns	-	-	ns	-	-	ns	-	-	Ns

ns- Non-significant at 5% level of probability

Table 3. Effect of transplanting dates and seedling age on bulb diameter, weight total yield, percent cull and marketable yield.

Treatments/ characters	Bulb diameter (cm)			Bulb weight (g)			Total yield ton ha-1			Percent cull			Marketable yield ton ha-1		
Transplanting date	2013-14	2014-15	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean
30 November	7.13 a	6.81 a	6.97 a	221.56 a	226.89 a	224.39 a	38.64 a	40.78 a	39.71 a	35.85 a	31.84 a	33.85 a	24.81 b	26.82 b	25.81 b
15 December	6.71 a	6.69 a	6.70 a	218.00 a	218.78 a	218.39 a	39.81 a	40.00 a	39.90 a	32.46 b	29.81 b	31.15 b	25.50 b	27.22 ab	26.36 b
30 December	5.86 b	6.00 b	5.93 b	188.06 b	195.33 b	191.69 b	29.75 b	31.47 b	30.61 b	12.62 c	11.81 c	12.21 c	27.29 a	29.70 a	28.50 a
15 January	5.14 c	5.15 c	5.15 c	168.44 c	171.00 c	169.72 c	20.31 c	23.06 c	21.68 c	6.89 d	8.35 d	7.62 d	20.75 c	21.50 c	21.13 c
30 January	4.82 c	4.70 c	4.76 d	159.56 c	158.22 d	158.89 d	12.78 d	19.19 d	15.99 d	2.21 e	2.64 e	2.42 e	14.50 d	16.79 d	15.64 d
LSD	**0.43**	**0.29**	**0.30**	**9.26**	**8.19**	**6.05**	**3.35**	**2.51**	**2.05**	**2.25**	**1.86**	**1.43**	**2.16**	**2.78**	**1.72**
Seedling Age															
75 day's old seedlings	5.75 b	5.81 b	5.78 b	186.47 b	192.27 b	189.37 b	25.42 a	29.07 a	27.24 a	22.78 a	21.25 a	21.89 a	19.10 b	21.67 b	20.39 b
60 day's old seedlings	6.32 a	6.29 a	6.31 a	207.10 a	212.00 a	209.55 a	31.77 b	33.08 b	32.43 b	18.07 b	17.07 b	17.57 b	24.91 a	26.09 a	25.50 a
45 day's old seedlings	5.72 b	5.51 b	5.61 b	180.00 b	177.87 c	178.93 c	27.58 b	30.55 b	29.07 c	13.40 c	12.37 c	12.89 c	23.70 a	25.45 a	24.58 a
LSD	**0.33**	**0.35**	**0.23**	**7.17**	**6.35**	**4.68**	**2.60**	**1.95**	**1.58**	**1.74**	**1.44**	**1.11**	**1.67**	**2.15**	**1.33**
Year	5.93	5.87		189.22 a	193.87 a		28.26	30.90		14.51	17.17		22.57	24.41	23.49
Interactions															
D × S	ns	ns	ns	*	*	*	*	ns	ns	*	*	*	*	*	*
Year × D	-	-	ns	-	-	ns	-	-	ns	-	-	ns	-	-	ns
Year × S	-	-	ns	-	-	ns	-	-	ns	-	-	ns	-	-	ns
Year × D × S	-	-	ns	-	-	ns	-	-	ns	-	-	ns	-	-	ns

D- Transplanting dates
S- Seedlings age
ns- Non-significant at 5% level of probability
* -Significant at 5% level of probability

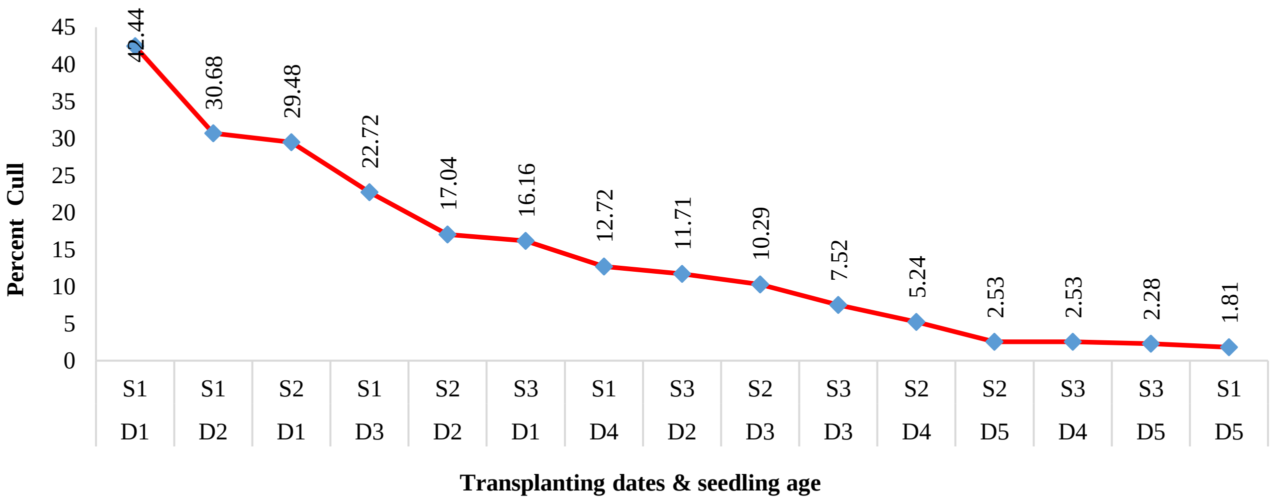

Fig. 2. Mean data showing interaction of transplanting dates and seedling age for percent cull.

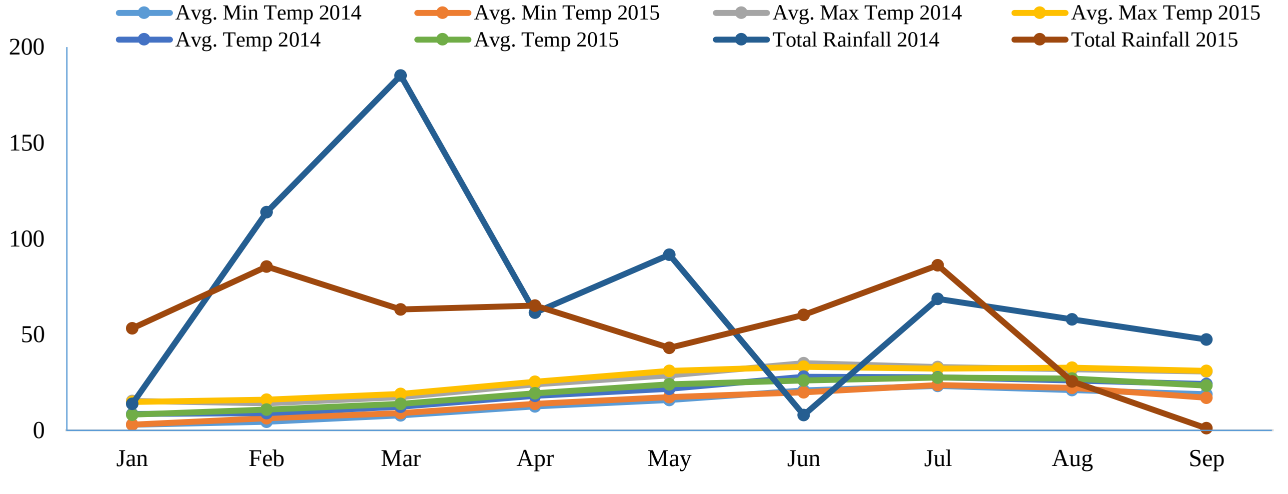

Fig. 3. Mean monthly temperature during the growing season in 2014-15.

Percent cull: Transplanting date and seedling age caused a significant difference in the percent cull. However, Year had no effect as shown in Table 3. A maximum % cull (29.36%) was recorded in early transplanting on 30th November, followed by 19.81% on 15th December transplanting.

A reduction of 27.15% in unmarketable yield was recorded when transplanting was reduced from 30th November to 30th January. Early transplants complete the vegetative phase and reach a reproductive stage when cold temperatures still prevail. This low temperature induces bolting, which contributes to unmarketable yield. In this study, a maximum of 33.63% bolting and maximum unmarketable yield were recorded in early transplanting. The lowest % cull in late transplanting was due to small ungraded bulbs. The results of this trial matched with the findings of Bijarniya *et al*., (2015), who recorded a maximum % cull in early transplanting compared to later transplanting. Kandil *et al*., (2013) reported similar results that the highest values on total culls resulted from transplanting seedlings on 15th November (early transplanting date) in 2010-2011 and 2011-2012. Similar results have been reported by Kumar *et al*., (1998). In the same way, the highest % cull, 22.07, was recorded in 75 days old seedlings, while the lowest, 8.04% cull was noted in 45 days old seedlings. Older seedlings take less time to attain maturity and run to premature bolting instead of making bulbs. In this study, a highest % cull in older seedlings was due to maximum bolting, while in younger seedlings small bulbs contributed to unmarketable yield. Bijarniya *et al*., (2015) reported the highest unmarketable yield, 7.66 kg/plot, was recorded in 8-week-old seedlings compared to 6-week-old seedlings.

The interaction of D × S was found significant, while the remaining. Interactions were non-significant. The D × S interaction pointed out (Fig. 2) that the percent cull was maximum in the D_1S_1 combination 42.44 and declined consistently as transplanting delayed and seedling age decreased. A minimum cull of 1.81% was recorded in the D_5S_3 combination.

Marketable yield ton ha^{-1}: The highest marketable yield of 32.49 tons ha^{-1} was obtained from 15th December transplanting, followed by 28.54 tons ha^{-1} in 30th November transplanting, whereas the lowest marketable yield of 16.65 tons ha^{-1} was noted in 30th January transplanting. Similarly, the maximum marketable yield of 28.08 tons ha^{-1} was recorded from 60 days old seedlings, while the minimum marketable yield of 20.53 tons ha^{-1} was recorded from 75 days old transplanting.

According to Cramer (2003), early transplanting and larger seedlings resulted in a maximum bolting percentage. Bolters occurred in early transplanting (30th November-15th January) and contributed to unmarketable yield. Bolting and cull are both negatively correlated with marketable yield. Marketable yield decreased when the bolting percentage and percent cull increased (Khan, 2017). Ibrahim (2010) also found the maximum cured yield from 3rd date of transplanting. Bijarniya *et al*., (2015) also reported similar results. There is a tendency to decline total yield with a delay in transplanting, but early transplanting has the risk of bolting, splitting and doubles. Thus, later dates produced medium-sized bubs with the highest marketable yield (Sinclair, 1989, Khan *et al.*, 2019).

Transplanting should be adjusted to prevent plants from receiving enough cold at the reproductive stage. Too much delay will diminish the bolting at the cost of marketable yield.

Conclusion

Early transplanting has the maximum total yield but the highest bolting percentage which reduces marketable yield. Early transplanting may be a good option for maximum marketable yield when there is bolting resistant cultivar available. If bolting resistant onion cultivar is not available then transplanting would be adjusted to keep bolting in an acceptable range and get maximum marketable yield. Delay in transplanting decreases bolting but yield as well. In this study, 30th December transplanting has a 12.41% bolting incidence and maximum marketable yield. Transplant age also influences the incidence of bolting. Larger plants switch from the juvenile stage to the reproductive stage earlier when the temperature gets low and start bolting instead of bulbing. 50-60 days old seedlings give maximum marketable yield and minimum bolting.

References

Aubyn, A. and W.S. Abutiate. 1994. Effect of age of transplant on the establishment and yield of onion cultivar Bawku. Proc. National Workshop of Food and Industrial Crops. *Kumasi*, 25-27 Oct. 1994. pp. 67-69.

Bijarniya, N., M. Jat, B. Patel and M. Bana. 2015. Effect of age of seedling and dates of transplanting on growth, yield and quality of onion (*allium cepa* L.) in rabi under north Gujarat condition. *J. Rural Agri. Res.*, 15(2): 38-42.

Bosekeng, G. and G.M. Coetzer. 2013. Response of onion (*Allium cepa* L.) to sowing dates. *Afr. J. Agri. Res.*, 8(22): 2757-2764.

Boyhan, G.E., R.L. Torrance, M.J. Cook, C. Riner and C.R. Hill. 2009. Sowing date, transplanting date and variety effect on transplanted short-day onion production. *Hort. Technol.*, 19(1): 66-71.

Brewster, J.L. 1994. Onions and other vegetable alliums. 1st ed., *CAB International,* Wallingford, United Kingdom.

Cramer, C.S. 2003. Performance of fall-sown onion cultivars using four seeding dates. *J. Amer. Soc. Hort. Sci.*, 128: 472-478.

Dong, Y., Z. Cheng, H. Meng, H. Liu, C. Wu and A.R. Khan. 2013. The effect of cultivar, sowing date and transplant location in field on bolting of welsh onion (*Allium fistulosum* L.). *BMC Plant Biol.*, 13: 154.

Fathi, S.M.R. 2009. The most suitable age for planting onion. Fars News Service (Persian).

Gao, L.M., Z.W. Ren, Y.Q. Chen, W. Chen and F. Dong. 2011. Effects of accumulated temperature and seedling age on welsh onion bolting. *Shandong Agri. Sci.*, 11: 011.

Hiray, S.A. 2001. Effect of nitrogen levels, spacing and planting dates on the growth, yield and quality of onion bulbs (*Allium cepa* L.) cv. N-53 under heavy rainfall zone – I under South Gujarat condition. M. Sc. (Agri.) Thesis, Submitted to Gujarat Agricultural University, Sardarkrushinagar.

Ibrahim, N.D. 2010. Growth and yield of Onion (*Allium cepa* L.) in Sokoto, *Nigeria. Agric. Biol. J.*, 1(4): 556-564.

Jahromi, A.A. S.R. Amirzadeh. 2015. Production potential of onion (*Allium cepa* L.) as influenced by different transplant age. *Inian. J. Fund. Appl. Life Sci.*, 5 (2): 118-121.

Kandil, A.A., A.E. Sharief and F.H. Fathalla. 2013. Effect of transplanting dates of some onion cultivars on vegetative growth, bulb yield and its quality. E-Sci, *J. Crop Prod.*, 2(3): 72-82.

Kanton, R.A.L., L. Abbey, R.G. Hilla, M.A. Tabil and N.D. Jan. 2003. Influence of transplanting age on bulb yield and yield components of onion (*Allium cepa* L.), *J. Veg. Crop Prod.*, 8(2): 27-37.

Khan, N.H. 2017. Bolting in onion bulb crops; effect of transplanting dates, seedling age, nitrogen fertilizer and cultivars. PhD Thesis. Pages: 36-37. Departtment of Agricultural Sciences. The University of Haripur, Pakistan.

Khan, N.H., S.M. Khan, N.U. Khan, A. Khan, A. Farid, S.A. Khan, N. Ali, M. Saeed, I. Hussain and S. Ali. 2019. Flowering initiation in onion bulb crop as influenced by transplanting dates and nitrogen fertilizer. *J. Ani. Plant Sci.*, 29(3): 2019.

Khan., N.H., S.M. Khan. A. Khan and M. Zamin. 2021. Bolting in onion bulb crop as influenced by Cultivars and transplanting dates. *Int. J. Biosci*., 18(1): 36-45, January 2021. DOI: http://dx.doi..org/10.12692/ijb/18.1.36-45

Khokhar, K.M., P. Hadley and S. Pearson. 2007. Effect of cold temperature durations of onion sets in store on the incidence of bolting, bulbing and seed yield. *Sci. Hort.*, 112: 16-22. ISSN: 0304-4238 DOI: 10.1016/j.scienta.12.038. Elsevier Science

Khokhar, K.M. 2008. Effect of temperature and photoperiod on the incidence of bulbing and bolting in seedlings of onion cultivars of diverse origin. *J. Hort. Sci. Biotech*., 83 (4): 488-496.

Kumar, H., J.V. Singh, A. Kumar and M. Singh. 1998. Influence of time of transplanting on growth and yield of onion (*Allium cepa* L) Cv' Patna red'. *Ind. J. Agri. Res.*, 32(1): 6-10.

Mosleh, M.D. and U.D. Deen. 2008. Effect of mother bulb size and planting time on growth, bulb and seed yield of onion. *Banglad. J. Agri. Res.*, 33(3): 531-537.

Muhammad, T., M. Amjad, S. Hayat, H. Ahmad and S. Ahmed. 2016. Influence of nursery sowing dates, seedling age and nitrogen levels on bulb quality and marketable yield of onion (*Allium cepa* L.). *Pure Appl. Biol.*, 5(2): 223-233.

NeSmith, D.S. 1993. Transplant age influences summer squash growth and yield. *Hort. Sci*., 28:618-620.

Norman, J.C. 1992. Tropical Vegetable Crops. 2nd Ed. Stockwell London, UK.

Rana, M.K. and J.K. Hore. 2015. Onion. In: Technology for vegetable production. (Ed.): Rana, M.K. *Kalyani publishers,* New Delhi, India.

Sawant, S.V., M.T. Inciavale, K.K. Manciave, B.K. Wxih and N.R. Biiat. 2002. Effect of date of planting on growth, yield and quality of onion (*Allium cepa* L.). *Veg. Sci.*, 29 (2): 164-166.

Sinclair, P. 1989. Physiology of the onion. Australian Onion Grower, Vol. 6, November, 1989.

(Received for publication 5 July 2023)