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Bolting in onion bulb crops as influenced by cultivars and transplanting dates

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Abstract

Bolting reduces the quality and commercial yield of bulb onion, however, seed production is directly dependent on flower induction and bolting. Field experiments were conducted during two cropping seasons 2013-14 and 2014-15 at the Agricultural Research Institute, Swat, Pakistan to study the effects of three onion cultivars with five transplanting dates on bolting and marketable yield of onion. Seedlings of three onion cultivars were transplanted on five different dates with 15 days interval in a randomized complete block design. Onion cultivars varied in their susceptibility to bolting. Cultivar Swat-1 took significantly maximum days to bolting initiation and recorded a minimum bolting percentage compared to 'Saryab Red' and 'Chiltan-89'. Early transplanting took 108.06 days to bolting initiation. The Bolting percentage was maximum at early transplanting and reduced with delay in transplanting from 25th November to 25th December. Bolting has not been recorded at late, (10th and 25th January) transplanting irrespective of the cultivar. Compare to 'Saryab Red' and 'Chiltan-89', 'Swat-1' has maximum plant height, leaves per plant, bulb diameter, bulb weight, total and marketable yield ton ha^{-1}. Bulb diameter, bulb weight, days to maturity, and total yield ton ha^{-1} was maximum at early transplanting and decreased with delay in transplanting. Marketable yield was maximum at mid transplanting date (25th December); attributed to less bolting and percent cull compared to early transplanting. Unmarketable yield at early transplanting was largely due to bolting while at late transplanting it was due to small ungraded bulbs.

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Introduction

Onion is a biennial vegetable, and its growth and development are greatly affected by temperature and photoperiod (Brewster, 2008). These environmental factors and their interactions with genotype determine the performance of an onion cultivar (Brewster, 1994; Khan *et al.,* 2001; Jilani and Ghaffoor, 2003), and this interaction defines the selection of variety for the specific area (Bosekeng and Coetzer, 2013).

Onion cultivars differ in their vernalization requirement for flower initiation. Cold temperatures between 5˚C - 13˚C for 20 to 120 days were optimum for flower induction in most cultivars. Yet, bolting resistant cultivars needed comparatively longer (154 - 185 days) cold stimulus (Khokhar *et al.*, 2007a; Khokhkar, 2008). Onion, depending on cultivars, initiate flowering when having a minimum number of 7-10 leaves including leaf initial (Rabinowitch, 1990; Khokhar *et al.*, 2007a; Khan *et al.*, 2019).

Bolting is premature seed stalk development (Voss *et al.,* 1999) that decreases the marketability of onion bulbs (Cramer, 2003). Bolting cuts the storage potential and quality of the bulbs as whole of the energy of the plant is exhausted and nothing is left in the bulbs to accumulate. Thus, bulbs become fibrous and lightweight (Rana and Hore, 2015; Khan *et al.*, 2019).

Onion is an important cash crop in Pakistan. It is a source of income and livelihood for small farmers. An appreciable quantity of onions is also exported earning precious foreign exchange for the country. It occupies an area of 147.2 thousand ha, with the production of 1981.7 thousand tons in 2017-18. (Pakistan Economic Survey 2017-18).

Onion has many production constraints like the lake of quality seed, lack of more productive cultivars, diseases & insect pests and premature bolting. Premature bolting poses a serious threat to onion cultivation. Onions sown for bulb production send seed stalks causing them to be unmarketable. And this occurred for the last many years and the intensity of the problem is more than 50% in most onion bulb crops across the country. The climate change particularly the shifting of winter rains from January-February to April-May aggravated the problem. This problem not only affects the socio-economic condition of the farmers but also the availability of onion in local markets resultantly leads to the price hike (Khan, 2017). We cannot control the weather but can re-adjust the cropping season to mitigate the problem. The objective of this trial is to select an appropriate cultivar and adjust the sowing date to prevent the onion bulb crop from bolting and get maximum marketable yield.

Materials and methods

These experiments were carried out in two growing seasons from November 2013 to June 2014 and from November 2014 to June 2015. Nursery of onion varieties Swat-1, Saryab Red, and Chiltan- 89 were sown on raised seedbed on different dates so that the same size and age of seedlings be transplanted on each date. The first transplanting was done on November, 25 and the subsequent 4 transplantings were carried out at 15 days interval.

The plot size was 1×3 m^2 with 4 rows each 25 cm apart having 30 plants per row. Thus, the total number of plants in a unit plot was 120. Experiments were arranged in RCB design with factorial arrangements replicated three times.

The experimental field was irrigated soon after transplanting and the subsequent irrigation was carried out at 10 days interval depending on climate and soil condition. Pendimethalin was sprayed at the rate of 5 ml per liter of water after the first irrigation to discourage the emergence of weed seeds. One hand weeding and hoeing was carried out 45 days after transplanting. Farmyard manure was applied at the rate of 15 tons ha^{-1} during soil preparation. Potash at the rate of 60 tons ha^{-1} and phosphorus at the rate of 90 kg $ha^{-1}$and half of nitrogen 60 kg was applied at transplanting. The remaining half of nitrogen 60 kg was applied at two split doses. The crop was harvested when 80% of plants stem fall down. Twenty plants were randomly selected and marked from two central rows for data collection. The collected data were pooled and analyzed using statistical software "Statistix 8.1". Remote Automatic Weather Station-Fire (RAWS-F) of Cambel Scientific installed in the research field was used to record weather data for both the growing seasons (Fig. 4).

Results and discussion

Plant height and number of leaves plant^{-1}

Plant height and leaf numbers showed (Table 1) a slight decrease with delay in transplanting. Transplanting dates and cultivars caused significant effect ($p < 0.05$) on plant height and the number of leaves plant^{-1}. The influence of the year was significant for the number of leaves plant^{-1} and non-significant for plant height. As 2014-15 was a little warmer than 2013-14, plants were taller with more leaves. The maximum plant height of 61.24 cm with the maximum number of leaves plant^{-1} 10.96 was recorded in early transplanting on 25th November while the minimum plant height of 56.08 cm with the minimum number of leaves plant^{-1} 9.21 was recorded by almost two months late transplanting on 25th January. Cultivar also varied significantly for plant height and number of leaves plant^{-1}. Swat-1 produced a maximum plant height of 65.58 cm with 10.64 number of leaves plant^{-1} than Saryab Red and Chiltan-89. Sawant *et al.* (2002) found that plant height and the number of leaves were significantly affected by sowing dates. The reason behind the difference in plant height and number of leaves on different transplanting dates is the difference in length of the growing season. Early transplanted plants receive more days, more sunshine, and uptake more nutrients from the soil. Thus early transplanted plants produce more photosynthates and resultantly gain more height and produce the maximum number of leaves than late transplanted plants. Brewster (2008) reported that earlier sown plants will have a longer vegetative growth period and consequently have larger plants with more leaves. Cramer (2003) argued that early seeded yield more leaves and taller plants. Each variety has a specific plant height and number of leaves in a given environment. The difference in plant height and number of leaves plant^{-1} among the cultivars in trials are due to difference in genetic potential of the theses cultivars. Bosekeng and Coetzer (2013) also found different plant height for different cultivars.

Table 1. Effect of transplanting dates and cultivars.

Treatments/ characters	Plant height (mm)			No. of leaves plant^{-1}			Days to bolting initiation		
Transplanting date	2013-14	2014-15	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean
25th November	60.33 a	62.16 a	61.24 a	10.53 a	11.39 a	10.96 a	105.22 b	111.67 c	108.06 c
10th December	58.77 a	61.36 ab	60.06 a	9.83 b	10.86 b	10.34 b	108.56 b	116.56 b	112.22 b
25th December	55.20 b	59.99 bc	57.60 b	9.56 bc	10.33 c	9.94 c	113.56 a	121.00 a	117.28 a
10th January	53.98 b	58.59 c	56.29 b	9.41 bc	9.86 d	9.63 c	0.00	0.00	0.00
25th January	53.47 b	58.68 c	56.08 b	9.09 c	9.33 e	9.21 d	0.00	0.00	0.00
LSD	2.74	1.60	1.41	0.55	0.42	0.34	3.72	2.74	2.07
Cultivars									
Swat-1	63.97 a	67.18 a	65.58 a	10.22 a	11.06 a	10.64 a	76.67 a	81.27 a	78.67 a
Saryab Red	52.83 b	57.35 b	55.09 b	9.79 b	10.34 b	10.07 b	56.80 c	60.60 c	58.47 c
Chiltan-89	52.25 b	55.94 c	54.10 b	9.04 c	9.66 c	9.35 c	63.53 b	67.67 b	65.40 b
LSD	2.12	1.24	1.20	0.43	0.33	0.26	2.88	2.12	1.60
Year	56.35	60.16	58.25	9.68 b	10.35 a	10.02	65.18	69.84	67.51
Interactions									
D × Cv	ns	ns	ns	ns	ns	ns	*	*	*
Year × D			ns			ns			*
Year × C			ns			ns			ns
Year × D × Cv			ns			ns			*

*significant at 5% level of probability

ns non-significant at 5% level of probability.

Days to bolting initiation

Early transplanting took fewer days 108.06 to bolting initiation which gradually increased with delay in transplanting and 25th December transplanting took 117.28 days to initiation of bolting (Table 1). Bolting has not been initiated in the late 10th and 25th January transplanting. According to Cramer (2003) bolting in onion bulb crop is produced in response to low temperature (8-13 °C) in the post-juvenile stage. The sensitivity to cold temperature increases with an increase in plant age. Khokhar *et al* (2007a) reported that the number of leaves has been used to determine the critical plant size at which bolting occurs when exposing to low temperature. They found that the 7-10 leaves stage was critical plant size at which transition from juvenile to regenerative phase occurred. When seedlings are transplanted early, plants will reach the critical stage for bulbing when the temperature is still low and initiate bolting instead of bulbing. Thus early transplanting will take less day to bolting initiation compared to late transplants. Cultivars also varied for days to bolting initiation. Cultivar 'Swat-1' took maximum days 78.67 to inflorescence initiation and 'Saryab Red' and 'Chiltan-89' took 58.47 and 65.40 days respectively. The results indicate that all the three cultivars are prone to bolting, cultivar 'Swat-1' is a little better among them.

The mechanism of bolting is not understood (Cramer, 2003). There isn't complete bolting resistance variety in the world. As such variety will not flower even at normal condition and cannot be propagated.

Table 2. Effect of transplanting dates and cultivars**.**

Treatments/ Characters	Bolting percentage			Bulb diameter (mm)			Bulb weight (g)		
Transplanting date	2013-14	2014-15	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean
25th November	36.67 a	32.37 a	34.52 a	61.26 a	64.90 a	63.08 a	146.2a	152.39 a	149.31 a
10th December	22.46 b	24.21 b	23.33 b	55.51 b	59.86 b	57.69 b	132.6b	138.38 b	135.50 b
25th December	15.68 c	13.87 c	14.77 c	48.72 c	51.47 c	50.10 c	117.6c	122.46 c	120.06 c
10th January	0.00 d	0.00 d	0.00 d	41.92 d	43.66 d	42.79 d	97.51 d	102.68 d	100.09 d
25th January	0.00 d	0.00 d	0.00 d	35.33 e	37.69 e	36.51 e	79.71 e	82.26 e	80.98 e
LSD	2.96	2.67	1.95	3.35	3.05	2.22	9.34	8.44	6.15
Cultivars									
Swat-1	12.90 b	12.12 b	12.51 b	58.12 a	62.04 a	60.08 a	166.7a	171.44a	169.08 a
Saryab Red	14.25 b	13.24 b	13.75 b	45.95 b	48.60 b	47.27 b	97.69 b	102.59b	100.14 b
Chiltan-89	17.73 a	16.91 a	17.32 a	41.58 c	43.90 c	42.74 c	79.83 c	84.87 c	82.35 c
LSD	2.29	2.07	1.51	2.59	2.37	1.71	7.24	6.53	4.77
Year	14.96	14.09	14.53	48.55	51.52	50.03	114.7a	119.63a	117.19
Interactions									
D × Cv	*	*	*	*	*	*	*	*	*
Year × D			*	-	-	ns	-	-	ns
Year × C			ns	-	-	ns	-	-	ns
Year × D × Cv			ns	-	-	ns	-	-	ns

*Significant at 5% level of probability

ns non-significant at 5% level of probability.

Interaction of D× Cv, Y×D, and Y×D × Cv was significant and that of Y × Cv was not significant ($p < 0.05$). Interaction of D× Cv indicated (Fig. 2) that early transplanting took fewer days to bolting initiation and the number of days increased as transplanting delayed. Cultivar 'Swat-1' took more days to bolting initiation compared to 'Saryab Red' and 'Chiltan-89'. Bolting has not been initiated in late 10th and 25th January transplanting irrespective of the cultivar.

From the interaction of Y×D, it is evident that early transplanting took less days to premature seed stalk development in both the years compared to late transplanting on 10th and 25th December. As year 2 was warmer than year 1, the number of days to bolting initiation was more in year 2 compared to year 1. Bolting was not initiated in late transplanting on 10th and 25th January in either year.

Bolting percentage

Both transplanting dates and cultivars made a significant difference in bolting percentage while year as a source of variation remained non- significant at 5% level of probability (Table 2). The interaction of D× Cv, Y×D was significant and the rest of the interaction was not significant.

Bolting was maximum of 34.52% in early transplanting 25th November and decline steadily with delay in transplanting Bolting has not been recorded in very late transplanting on 10th and 25th January. These results are in agreement with the findings of Madisa (1994) who reported that onion plants sown late did not bolt because when low temperatures responsible for bolting prevailed, plants were still in the juvenile stage and being unable to respond to a cold stimulus. Tendaj and Mysiak (2013) recorded maximum seed stalk development in early transplanting irrespective of the cultivars in the trial. Alliums including bulb onions need to reach a certain physiological age or size to be able to bloom after exposure to low vernalizing temperature. Earlier transplanting of seedlings clenches that critical stage sooner when the low temperature still prevails and initiate inflorescence instead of bulb formation. Late transplanting plants will be at the juvenile stage when the temperature is low late in the season and flowering cannot be induced by vernalization in the juvenility stage. Hence, bolting did not occur in late transplanting on 10th and 25th January in this trial. Among the cultivars 17.32% of plants developed premature seed stalk in 'Chiltan-89' while 13.75 % and 12.51% initiated premature inflorescence development in 'Saryab Red' and 'Swat-1' respectively.

Mushtaq *et al.* (2013) reported that onion cultivars differ in yield and yield-related traits and bolting in specific agro-conditions. Among the nineteen evaluated onion varieties, high bolting percentage (46.67%) was found in Desi Red, while it was the lowest in Faisal Red and VRIO-6 (13.33%). Bolting resistant cultivar has less bolting incidence and can be seeded/transplanted earlier (Cramer, 2003).

Table 3. Effect of transplanting dates and cultivars.

Treatments/ Characters	Total Yield ton ha-1			Marketable Yield ton ha-1		
Transplanting date	2013-14	2014-15	Mean	2013-14	2014-15	Mean
25th November	29.44 a	32.71 a	31.07 a	16.73 c	17.72 c	17.23 c
10th December	27.97 a	31.49 a	29.73 a	19.88 b	22.53ab	21.21 b
25th December	24.67 b	27.09 b	25.88 b	22.62 a	24.27 a	23.45 a
10th January	21.33 c	23.21 c	22.27 c	18.56 b	21.97 b	20.27 b
25th January	19.68 c	18.78 d	20.00 d	14.27 d	16.58 c	15.42 d
LSD	2.90	2.17	1.54	1.56	1.98	1.19
Cultivars						
Swat-1	32.19 a	33.70 a	32.94 a	24.16 a	25.98 a	25.07 a
Saryab Red	22.73 b	25.21 b	23.97 b	17.96 b	20.22 b	19.09 b
Chiltan-89	18.94 c	21.06 c	22.09 c	13.12 c	15.64 c	14.38 c
LSD	2.24	1.68	1.19	1.21	1.53	0.92
Year	24.62 a	26.65 a	26.39	18.41 b	20.61 a	19.51
Interactions						
D × C	ns	ns	*		*	*
Year × D	-	-	ns	-	-	ns
Year × C	-	-	ns	-	*	ns
Year × D × C	-	-	ns	-	-	ns

The bolting tendency varies with cultivars. To our knowledge, there is no complete bolting resistance cultivar. According to Cramer, (2003) many theories may explain the phenomenon of bolting. Bolting resistant cultivars may require more chilling hours than bolting susceptible cultivars. Bolting resistant cultivars may require a larger plant size than bolting susceptible cultivar to become receptive to a cold stimulus. Likewise, bolting resistant plants may be slow in growth during the initial period of low temperature and thus not receptive to a cold stimulus. The interaction of D× Cv indicated (Fig. 2) that bolting percentage was maximum in early transplanting and decreased gradually as transplanting was delayed from 25th November to 25th December. Bolting has not been recorded in late transplanting 10th and 25th January regardless of the cultivar. The interaction of Y×D showed that delaying transplanting from 25th November to 25th December bolting percentage from 36.67% to 13.87%. Premature bolting has not been noted in late transplanting 10th and 25th in both years.

Bulb diameter (mm)

Transplanting dates and cultivars significantly influenced ($p < 0.05$) bulb diameter. A little difference in weather made no significant difference between the two seasons (Table 2). A maximum bulb diameter of 63.08 mm was recorded in early transplanting on 25th November and it reduced consistently with delay in transplanting. A minimum bulb diameter of 36.51 mm was noted in late transplanting treatment on 25th January. Sawant *et al.* (2002) reported that early planting produced maximum polar and equatorial diameter and hence, produced large size bulbs. According to Bosekeng and Coetzer (2013), bulb diameter was significantly influenced by both cultivar and sowing date, and earlier sown crops produced the largest bulbs. Among cultivars, a maximum bulb diameter of 60.08 mm was produced by cultivar 'Swat-1'. 'Saryab Red' and 'Chiltan 89' produced bulb diameters of 47.27 mm and 42.74 mm respectively. According to Bosekeng and Coetzer (2013), bulb size varies with different cultivars. Mushtaq *et al.* (2013) in a trial evaluating 19 onion varieties for yield and quality found a significant difference in bulb diameter.

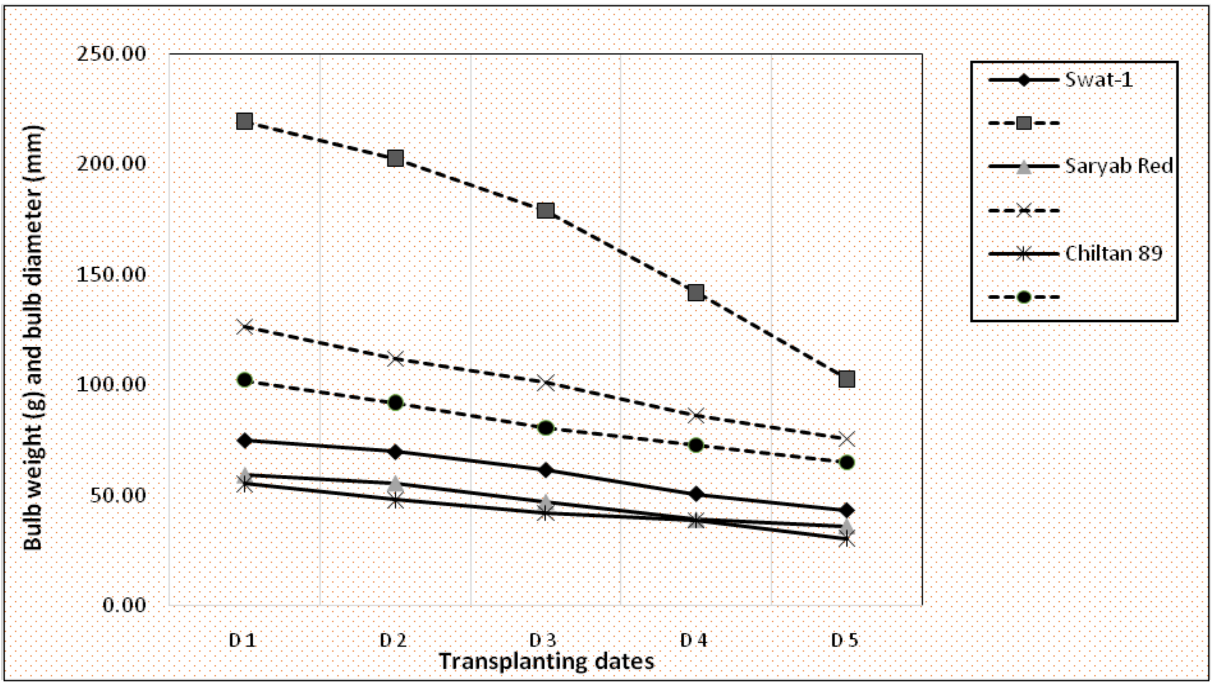

Fig. 1. The doted lines show bulb weight (g) while the Solid lines show bulb diameter (mm).

The interactions of D× Cv indicated that bulb diameter was maximum in early transplanting and 'Swat-1' cultivars (Fig. 1). Bulb diameter declined with delay in transplanting irrespective of the cultivars used in the trial.

Bulb weight (g)

Transplanting dates and cultivars produced a significant effect in bulb weight at a 5% level of probability while the year's effect was not significant. D×Cv interaction was significant ($p < 0.05$) while the rest of the interaction was found non-significant (Table 2). Maximum bulb weight 149.31 g was produced by early transplanting 25th November and the weight reduced steadily with each 15 days delay in transplanting. Minimum bulb weight 80.98 g was recorded in very late transplanting 25th January. Early transplanting has more time for vegetative growth and more leaves and maximum plant height. Abdissa *et al.* (2011) found a strong and positive correlation of mean bulb weight with plant height, number of leaves, bulb length, and diameter. Plants with more vegetative growth translocated more photosynthate towards bulb formation. Thus, early transplanted plants produced bigger bulbs than late transplanting. Bosekeng and Coetzer (2013) reported that delayed sowing significantly decreased average bulb fresh mass while early sown plants produced the largest bulbs. Cultivars also caused a significant difference in bulb weight as each cultivar has its characteristic bulb size and weight in a given environment. Cultivar 'Swat-1' produced the heaviest bulbs 169.08 g compared to 'Saryab Red' 100.14 g and 'Chiltan-89' 82.35 g.

The D×Cv interaction (Fig. 1) showed significant effect ($p < 0.05$) on bulb weight. Bulb weight was maximum at early transplanting in Swat-1 cultivar and constantly decreased with delay in transplanting. This trend was more prominent in cultivar 'Swat-1' than 'Saryab Red' and 'Chiltan-89'. Similar results were reported by Kimani *et al.,* (1993) evaluated 9 onion cultivars in a different environment in Kenya and found that bulb weight differs between cultivar and environment.

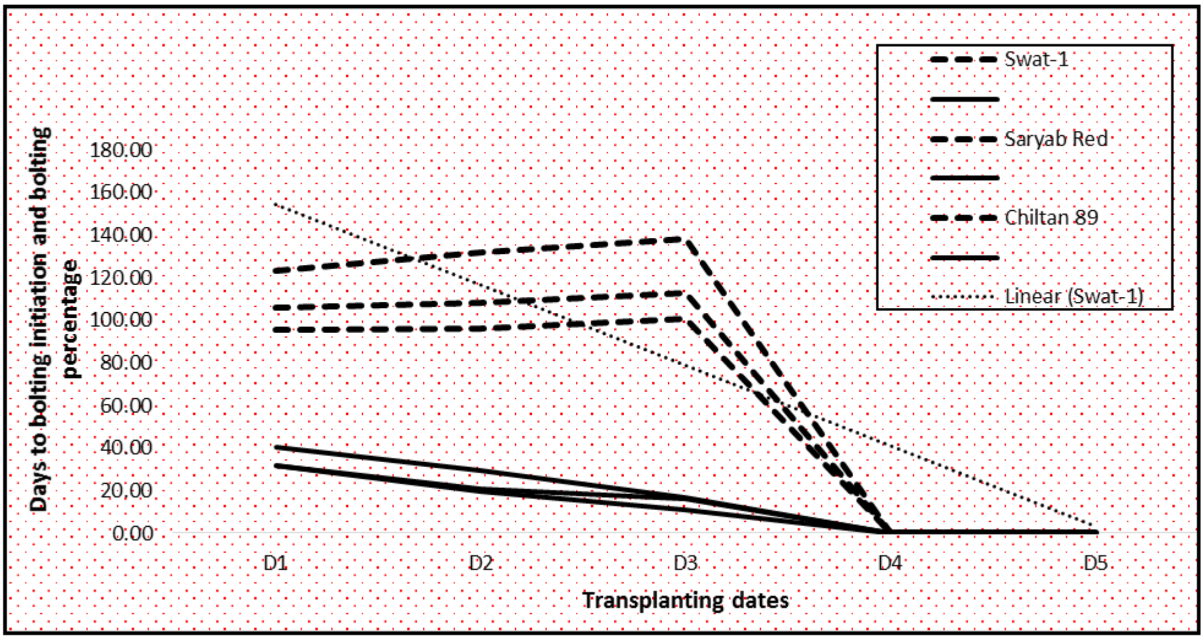

Fig. 2. Days to bolting initiation and bolting percentage of onion cultivars at 15 days interval. Solid lines and dotted lines represent days to bolting initiation and bolting percentage respectively.

Total yield (ton ha⁻¹)

Transplanting dates and cultivars significantly shaped total yield ton ha^{-1}. Year as a source of variance remained non-significant. All the interaction were non-significant ($p < 0.05$) except D × Cv (Table 3). Early transplanting on 25th November produced a maximum yield 31.07 ton $ha^{-1}$and the yield showed a declining trend with delay in transplanting and 25th January produced a minimum yield of 20.00 ton ha^{-1}. A total of 60 days delay in transplanting caused a reduction in yield from 31.07 to 20.00 ton ha^{-1} amounting to 11.07 ton ha^{-1}. From this, it can be concluded that each 10-day delay in transplanting caused a 1.85 ton ha^{-1}reduction in yield. Ample vegetative growth before bulb formation is essential to get high yield (Ibrahim, 2010). Bulb formation starts when temperature and day length requirements is fulfilled.

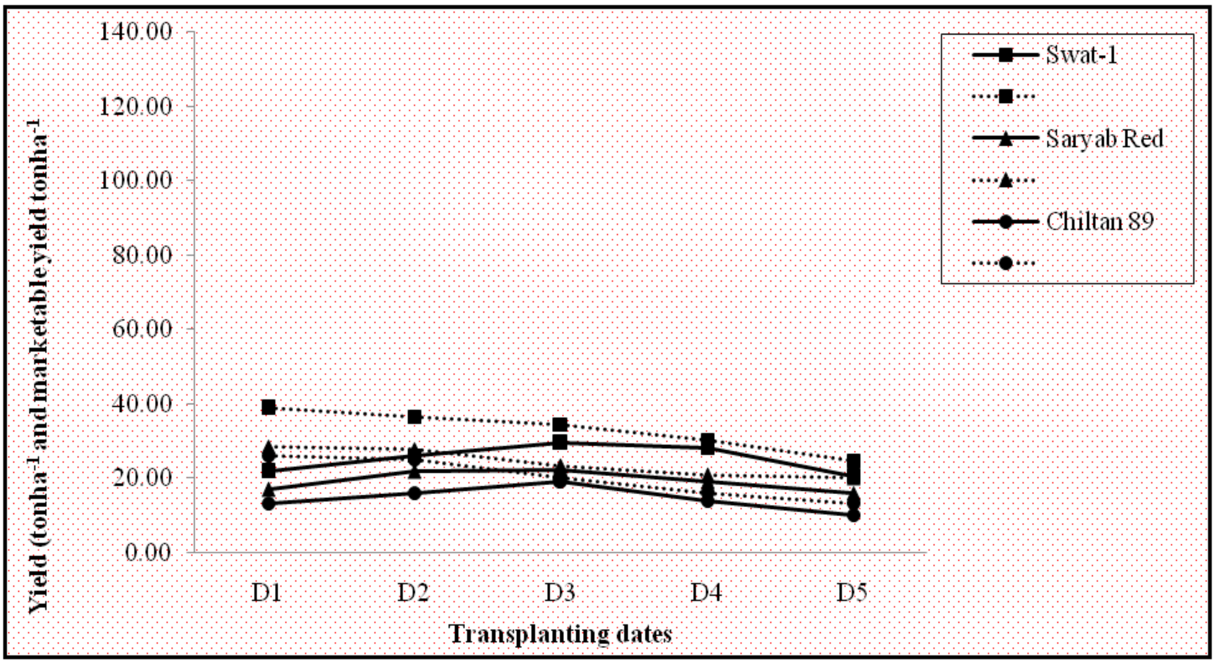

Fig. 3. Yield ton ha^{-1} and marketable yield ton $ha^{-1}$of onion cultivars at 15 days interval. Solid lines and dotted lines represent Yield ton ha^{-1} and marketable yield ton ha^{-1} respectively.

Though when a variety is sown on different dates yet, bulbing will starts more or less at the same time. Hence, anything which affects how large a plant is before bulbing will influence the final yield after bulbing. Early transplants have larger plants with greater leaf canopy, produce more photosynthate which is transferred to harvestable materials. Hence early transplanting produced high yield than late transplanting. The results of Patil *et al.* (2012) showed that early transplanting (15th November) of onion significantly produced high yield. Among the cultivars 'Swat-1' produced a total yield of 32.94 ton ha^{-1}while 'Saryab Red' and 'Chiltan-89' yielded 23.97 and 22.09 ton ha^{-1}respectively. Lancaster *et al.* (1995) evaluating 32 onion varieties for commercial production in New Zealand found a significant difference in yield. The interaction of D × Cv revealed (Table 3) a descending trend in yield ton ha^{-1} with a delay in transplanting from 25th November to 25th January in all the three cultivars.

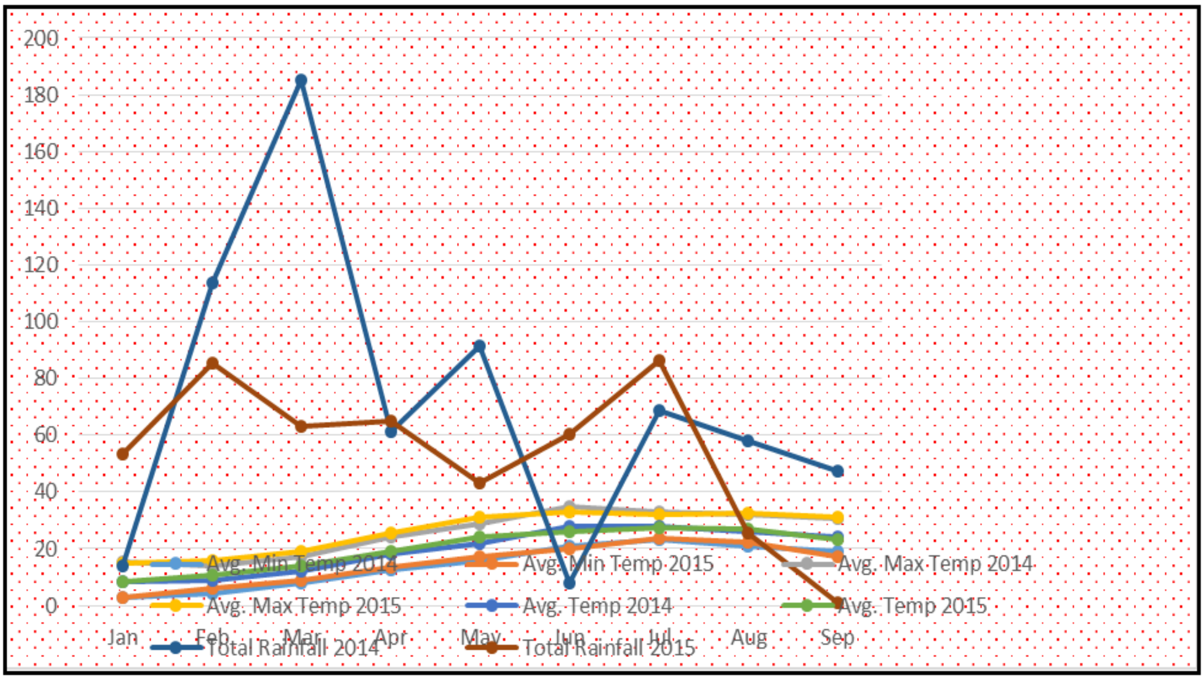

Fig. 4. Temperature data for the growing season 2014 and 2015.

Marketable Yield ton ha^{-1}

Transplanting dates and cultivar produced significant effect ($p < 0.05$) on marketable yield ton ha^{-1}. Year as a source of variation was also significant (Table 3). The maximum marketable yield 23.45 ton $ha^{-1}$was recorded in mid transplanting date D_3 i.e., 25th December. While the marketable yield of 10th December (D_2) and 10th January was statistically at par. Very early and very late transplanting produce less marketable yield 17.23 and 15.42 ton ha^{-1}. In very early transplanting 34.52 % of plants run to premature bolting and become unmarketable and were discarded. In very late transplanting small ungraded bulbs contributed to cull. The result of this study conform with the findings of Bijarniya *et al.* (2015) and Ibrahim (2010) who reported maximum marketable yield from mid transplanting dates. Among the cultivars 'Swat-1' produced a maximum marketable yield 25.07 ton $ha^{-1}$and 'Saryab Red' and 'Chiltan-89' produced 19.09 and 14.38 ton ha^{-1} marketable yield. Baliyan (2014) in trial evaluated six onion varieties and found that Texas Grano produced the highest total yield of 54.07 ton ha^{-1}, however, the Hanna variety produced the highest marketable yield of 43.01 ton ha^{-1}. Texas Grano produced the lowest marketable (60%) in Botswana. Cramer (2003) in a five-year varietal trial found that marketable yield ranged from 61-82%. In this study cultivar, 'Swat-1' produced the highest total and marketable yield 32.94 and 25.07 ton ha^{-1} respectively.

The interaction of transplanting dates and cultivars (D× Cv) revealed (Fig. 3) that marketable yield was maximum in cultivar "Swat -1" at mid transplanting date. In very early and late transplanting produced less marketable yield ton ha^{-1} less marketable yield in early transplanting was due to a high percentage of bolting while in late transplanting it was due to small ungraded bulbs.

Conclusion

It is very difficult to give an exact date for transplanting to control bolting and increase yield simultaneously as it is cultivar and environment-dependent. A 15 days delay in transplanting from 25th November to 10 December caused a reduction in bolting from 34.52% to 23.33%. A further 15 days delay in transplanting from 10 December to 25th December caused a reduction in bolting from 23.33% to 14.77. Cultivar Swat-1 took significantly maximum days to bolting initiation and had a minimum bolting percentage compared to Saryab Red and Chiltan-89. Early transplanting took fewer days to bolting initiation.

The bolting percentage was maximum at early transplanting and reduced with delay in transplanting from 25th November to 25th December in all cultivars. Bolting was not recorded in late transplanting (10th and 25th January) irrespective of the cultivar. Marketable yield was maximum at mid transplanting date (25th December) attributed to less bolting and percent cull compared to early transplanting. Unmarketable yield at early transplanting was largely contributed by bolting while at late transplanting it was due to small ungraded bulbs.

Recommendations

Transplanting should be done from December 15 to January 15 it will produce a low bolting percentage and maximum marketable yield. As bolting resistant cultivar is currently not available in Pakistan, research work should be initiated to develop bolting resistant variety or produce bolting resistance in existing cultivars through phenotypic recurrent selection.

Authors' contribution

NH Khan carried out the research work including data collection, analysis, and writing of the manuscript. SM Khan helped in designing the experiment, data analysis, and correcting the manuscript. M Zamin helped in writing and correcting the manuscript.

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