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FLOWERING INITIATION IN ONION BULB CROP AS INFLUENCED BY TRANSPLANTING DATES AND NITROGEN FERTILIZER

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ABSTRACT

Bolting (pre-mature flowering) produced before completion of normal life cycle which directly affects the bulb yield in onion. The experiments were conducted in two consecutive seasons during 2013-14 and 2014-15 in a randomized complete block design (RCBD) replicated three times at Agricultural Research Institute, Mingora Swat. Nursery of onion cultivar Swat-1 was raised and healthy seedlings were transplanted on five different dates (15th Nov, 1st Dec, 15th Dec, 1st Jan, 15th Jan). Four levels of nitrogen fertilizer (75, 100, 125, 150 kg ha^{-1}) were applied with the objective to determine its influence on inflorescence development in onion bulb crop. Bolting percentage gradually decreased with increase in nitrogen fertilizer. Maximum bolting percentage was recorded in early transplanting and gradually declined with delay in transplanting. Bolting incidence did not occurred in very late transplanting (15th Jan) irrespective of the rate of nitrogen applied. Plant height, stem thickness, bulb diameter, bulb weight and total yield increased with increase in nitrogen fertilizer and conversely showed a downward trend with delay in transplanting. Nitrogen doses didn't significantly influenced leaves per plant. Early transplanting took maximum days to maturity than late transplanting. Maturity was delayed with increase in nitrogen fertilizer. Percent cull decreased with increase in the rate of nitrogen fertilizer. Marketable yield was maximum at mid transplanting (15th Dec) with maximum dose of nitrogen fertilizer. It can be concluded that 150 kg N ha^{-1} should be applied and transplanting should be delayed up to December 15th to avoid bolting and have maximum marketable yield.

Key words: *Allium cepa* L.; Bolting; Nitrogen fertilizer; Transplanting; Marketable yield.

INTRODUCTION

Bolting is the premature seed stalk development in some vegetables that reduces storage life and marketability of the produce (Rana and Hore, 2015). Inflorescence initiated in onion after plants have grown and developed to certain number of leaves, depending on cultivar, followed by exposure to low vernalizing temperature (Diaz-Perez, 2003, Dong *et al*, 2013).

Vernalization in onion has been of research interest because of the need to prevent bulbs from bolting in the first growing season and to enhance flowering in second growing season (Streck, 2003, Dong *et al*, 2013). In tropical regions onion plants neither flower nor produce seed due to lack of cold temperature (Kimani *et al.,* 1994). This is the reason that many countries in the tropics import onion seed from sub tropic or temperate countries where winter provide vernalization temperature for flowering and seed production (Khokhar, 2014). The response of plant to vernalization depends on the combination of two factors, the temperature during vernalization and duration of vernalization period (Streck, 2003).

Optimal day length and vernalization is not enough to induce flowering. Plants should be old enough to sense and respond to these environmental stimuli. Some perennial plants flower readily when exposed to environmental condition that enhance flowering such as photoperiod and vernalization. While others including onion cannot flower until pass the juvenile stage and grown to a certain age or size. (Rabinowitch, 1990; Khokhar *et al.*, 2007a). Leaf number rather than chronological time is the best sign of the plant's physiological age (Rabinowitch, 1990). Depending on cultivars, onion plant initiates flowering when have a minimum number of 7-10 leaves including leaf initial (Rabinowitch, 1990; Khokhar *et al.*, 2007a).

Other factors affecting bolting in onion are nitrogen and phosphorous (Brewester, 1983). Rabinowitch (1990) termed onion as nitro-neutral plant whose flowering time is unaffected by nitrogen. A few studies, however, indicates that nitrogen affect the flowering process in onion (Brewester, 1983). Brewester (1983) found that low nitrogen in nutrient solution speeded up flowering. According to the findings of Yamasaki and Tanaka, (2005) Bolting in bunching onion (*Allium fistulosum* L.) enhanced by low nitrogen following exposure to low temperature for a period of 35 days. Diaz-Perez *et al.* (2003) suggested that low nitrogen fertilizer application increased bolting and reported that bolting incidence decrease steadily with increase nitrogen fertilization rates up to 197 kg ha^{-1}. This trial was aimed to investigate the effect of transplanting dates and nitrogen fertilizer on premature bolting in onion.

MATERIALS AND METHODS

Experiment was conducted at Agricultural Research Institute Mingora Swat in two consecutive years from November 2013 to June 2014 and from November 2014 to June 2015. The experimental site is located in the Hindu Kush range at 34.3- 35.53° North Latitude and 71.5-72.5° Longitude in the north of west of Pakistan. Altitude of the site is 906 m above sea level. Field was ploughed with cultivator and the weeds, stubbles and residues of the previous crop, if any, were manually collected and removed. On the next day, soil was pulverized with rotovator and prepared to a good tilth. Experiments during both years were planned in a randomized complete block design (RCBD) with factorial arrangement replicated three times. FYM, well decomposed at the rate of 15 tons ha^{-1}, phosphorus at the rate of 90 kg ha^{-1} and potash at the rate of 60 Kg ha^{-1}, were applied during land preparation. Plot size was kept 2.5×0.8 m^2 with 5 rows and 25 plants per row. Row to row distance was 20 cm and plants were spaced 10 cm within a row. Nursery of onion cultivar Swat-1 was sown on different dates in a raised seedbed. Healthy seedling of uniform size and age of onion were transplanted on five different dates (15th Nov, 1st Dec, 15th Dec 1st Jan and 15th Jan). Four levels of nitrogen fertilizer 75, 100, 125 and 150 kg ha^{-1} were applied in three split doses. Nitrogen was applied in the form of ammonium sulphate, phosphorus in the form of single super phosphate (SSP) and potash in the form of potassium sulphate (SOP). Soon after transplanting a pre-emergence herbicide Pendymethalin was sprayed to disallow the emergence of weed seeds. On next day transplanted field was light irrigated. Subsequent irrigations were provided with seven days interval depending on the soil and weather conditions. Bulbs were harvested when 80% of the tops were down. Care was taken to avoid bulb injuries Data was collected from 20 randomly selected plants from two central rows in each unit plot.

Weather data of 2013-14 and 2014-15 have been recorded using Remote Automatic Weather Station-Fire (RAWS-F) of Cambel Scientific (Fig. 1, 2). Data was pooled and analyzed by the technique of analysis of variance on all studied parameters using statistical software 'Statistix 8.1'. Significant differences between treatments means were calculated using LSD test.

RESULTS AND DISCUSSION

Plant Height and Leaves per plant: Transplanting dates and nitrogen levels significantly ($p < 0.05$) affected plant height and number of leaves $plant^{-1}$ in both years (Table 1). Year as source of variation was significant for plant height and non-significant for number of leaves $plant^{-1}$. All the interactions were found non-significant. Maximum plant height of 61.08 cm with maximum number of leaves 12.46 were recorded when transplanting was done early on 15th November (D_1). Plant height and number of leaves decreased to 57.49 cm and 10.05 when transplanting was delayed to 15th January (D_5). Bulb formation starts when temperature begin to increase and the required minimum day length of the specific cultivar is met. Thus, when same variety is sown at different times at the same locality bulbing will start more or less at the same time. Earlier sown plants, therefore, will have longer vegetative growth, larger plants with more leaves as compared to late sown plants (Brewster, 2008). Cramer (2003) observed that earlier sowing produced larger plants with more leaves compared to later seeding in a growing season. Sawant *et al.* (2002) found that plant height and the number of leaves were significantly affected by sowing dates. On the other hand, Bosekeng and Coetzer (2013) stated that sowing date did not influence plant height and leaf number significantly over a period of two years, however, early sowing dates in one year resulted in maximum plant height.

Likewise, minimum plant height of 57.74 cm with minimum number of leaves $plant^{-1}$ were recorded when nitrogen was applied at the rate of 75 Kg ha^{-1} and was found to increase with increase in nitrogen level. Maximum plant height with maximum number of leaves $plant^{-1}$ were noted in above optimal nitrogen of 150 kg ha^{-1} application treatment. These result are in conformity with the findings of Vachhani and Patel (1993a) that plant height, number of leaves $plant^{-1}$, bulb weight, size and onion yield were maximum with the application of 150 kg N ha-^{1} while Pandey and Ekpo (1991) reported that application rate of 160 kg N ha^{-1} produced maximum plant height of 63.9 cm. Bungard *et al.* (1999) argued that nitrogen is a constituent of many fundamental cell components and it plays an essential role in all living tissues of the plant. No other element has such an effect on promoting vigorous plant growth. Abdissa *et al.* (2011) stated that increase in plant height could be attributed to its involvement in the synthesis of amino acids, as they link together and form proteins and make up metabolic processes needed for plant growth.

Stem Thickness: Thickest stem of 17.37 mm were produced from D_1 (15th, Nov) while minimum stem thickness of 15.31 mm produced when transplanting was delayed to D_5 (15th January) (Table 1). Muhammad *et al.* (2016) also reported that early transplanting resulted thick neck of bulbs. Pandey *et al.* (1992) found that neck thickness problem was more in early (June) sowing onion. Results of this study also confirm the finding of Boyhan *et al.* (2009) that early transplanting reduces the bulb quality by producing thick neck bulbs. In the same way the thinnest stem plant of 15.85 mm were recorded when N was applied @ 75 Kg/ha while 150 kg/ha N application produced the thickest stem of 17.23 mm plants. Stem thickness over the year were found non-significant. All the interactions for stem thickness were found non-significant. Similar results were reported by Jilani (2004) and Muhammad *et al.* (2016) that increasing N fertilizer increasing neck thickness. As neck develop from the base of the leaves and early transplanted produce more and larger leaves compared to later transplanting. Thus, early transplanting produce thick neck.

Bulb Diameter and Weight: Maximum bulb diameter of 69.45 mm and maximum bulb weight of 206.17 g were recorded in early transplanting D_1 (15th, Nov) whereas minimum bulb diameter of 55.68 mm and minimum bulb weight 166.04 g was noted when transplanting delayed to D_5 (15th January). An ascending trend was observed in bulb diameter and bulb weight when application of nitrogen was increased. Minimum bulb diameter of 59.38 mm and bulb weight of 177.33 g was recorded when nitrogen was applied at the rate of 75 Kg ha^{-1} and the diameter and weight increased to 68.40 mm and 203.60 g when the level of nitrogen was increased to 150 kg ha^{-1}. Transplanting dates and nitrogen levels significantly ($p < 0.05$) affected bulb diameter and weight in both years. Small difference in the weather elements (Fig 1 and 2) resulted no significant difference over the two growing seasons (Table 1). More than 80 % of the bulb dry matter is added during the first few weeks from the start of the bulb formation. The final size of the bulb, however, is closely related to the size of the plant when it starts bulbing. So anything that affects how large a plant is before bulbing affects the bulb size and yield after bulbing. In this study early transplanting and increase in the levels of nitrogen fertilizer produced large size plants at bulbing and hence, resulted maximum bulb diameter and weight at maturity. .Temperature, irrigation, nutrition, weeds and pest control and environmental factors also contribute to bulb diameter and weight. Plants gained more height with more numbers of leave and produced bigger size bulbs because of high temperature in 2014-15 than 2013-14. According to Bosekeng and Coetzer (2013) bulb diameter was significantly influenced by both cultivar and sowing date and earlier sown crop produced the largest bulbs. Sawant *et al.* (2002) reported that early planting produced maximum polar and equatorial diameter and hence, produced large size bulbs. Variations in bulb diameter are mostly due to variation in the genetic makeup of varieties but is also affected by environment and management practices (Yang *et al.,* 2004). Onion bulb size can be increased by application of N during the growing period (Rice *et al.,* 1993). Results of a field experiment of Abdissa *et al.* (2011) showed that regardless of the rate of application, nitrogen fertilization increased bulb diameter and average bulb weight by about 12 and 21.5%, respectively over the control. Increase in N fertilizer up to 69 kg N ha^{-1} increased bulb weight by about 26% while further increase did not resulted increase in bulb weight (Abdissa *et al.*, 2011). From the result they concluded that increase in bulb weight to N could be attributed to the increase in plant height, number of leaves, leaf length and extended physiological maturity in response to the fertilization all might have increased assimilate production and allocation to the bulbs. Increase in the levels of the nitrogen caused a linear increase in fresh mass of the bulbs (Resende *et al.,* 2014).

Days to Harvesting: Though days to harvesting between the two growing seasons were non-significant at 5% level of probability (Table 1), plants reached to harvesting a few day earlier in 2014-15 because of higher temperature particularly, in May and June. The interactions were found non-significant. Both transplanting date and nitrogen level significantly influenced days to maturity. In this study early transplanting on 15th November took 12.13 more days than almost 2 month late transplanting on 15th January treatment. However, maturity was earlier in early transplanting. Early sown plant resulted in earlier bulb maturity while later seeded crop resulted in later maturity of the crop (Almanza-Sandoval and Wall, 2000). Cramer in (2003) also reported delay in maturity with delay in seeding dates.

Minimum days 165.77 to maturity were recorded when nitrogen was applied at the rate of 75 Kg ha^{-1} and the maturity was prolonged for 8.5 days when the rate of nitrogen was increased from 75 Kg ha^{-1} to 150 kg ha^{-1}. Abdissa *et al.* (2011) found that nitrogen fertilization, regardless of the rate, prolonged physiological maturity by about 6 days over the control.

Bolting Percentage: Transplanting dates and N levels significantly ($p < 0.05$) affected bolting percentage during both years (Table 1). Though year effect was not significant yet, bolting percentage was higher in 2013-14 because low winter temperature than 2014-15. It is evident from the results that maximum bolting percentage of 53.92 was recorded in early transplanting D_1 (15th November) followed by 50.54 % on 1st December transplanting (Table 1). Premature seed stalk development was not observed in D_5 (15th January) transplanting. Madisa (1994) reported that onion plants sown late did not bolt because when low temperatures responsible for bolting prevailed, the plants were still small and had not yet reached reproductive stage. Agic *et al.* (2007) found that bolting was enhanced by early sowing while cultivars differs in bolting tendency in their study. When seedlings are transplanted early, the onion plants will grasp the sensitive size for bulbing when temperature are still low, the plants will bolt instead of making bulbs. Both cultivar and environment influence the phenomenon of bolting and, thus, it is challenging to give the exact date for transplanting to reduce bolting and increase yield at the same time (Cramer, 2003). Sowing should be adjusted in such a way to minimize plants exposure to cold spell at sensitive plant size to avoid bolting. (Khokhar *et al.,* 2007b; Cramer, 2003). Sowing dates are, therefore, important factor that needs to be considered while avoiding bolting.

Likewise, bolting percentage was maximum 45.43% when nitrogen was applied at the rate of 75 Kg ha^{-1} and decreased as the level of nitrogen increased and was minimum 16.90% when nitrogen was given at the rate of 150 kg ha^{-1}. Thus bolting percentage was decreased 28.53% when nitrogen application was increased from 75-150 kg ha^{-1}. Bolting percentage between the years was non-significant. Rabinowitch (1990) termed onion as nitro-neutral plant whose flowering time is unaffected by nitrogen. Brewster (1983) found that low nitrogen in nutrient solution speeded up flowering. Low carbon-to-nitrogen ratio (C/N) favors vegetative growth and high C/N ratio favors reproductive growth in horticultural plants (Díaz-Pérez *et al.,* 2003). The C/N ratio determines whether onion plants to be vegetative or initiate flowering (Rabinowitch, 1990). Díaz-Pérez *et al.* (2003) found that bulb nitrogen content increased with increasing nitrogen fertilizer and bolting decreased steadily with increasing bulb and shoot nitrogen contents. Nitrogen fertilizer modify plant's C/N ratio. Increasing N fertilizer rates likely decrease C/N ratio and decrease the bolting incidence. Appropriate nitrogen fertilizer at the time when onion plant at the transition stage from vegetative to reproduction stage is very important. Application of second dose of nitrogen fertilizer should be applied just before the onset of bulbing to lower C/N ratio and avoid bolting.

Abdissa *et al.* (2011) reported that percentage of bolters per plot decreased by about 11 and 22% in response to the application of 69 and 92 kg N ha^{-1}, respectively over the control. According to the findings of Yamasaki and Tanaka (2005) low nitrogen enhanced bolting in bunching onion (*Allium fistulosum* L.) exposed to low temperature for 35 days. Díaz-Pérez *et al.* (2003) suggested that low N fertilizer application increased bolting and reported that bolting incidence decrease steadily with increase N fertilization rates up 197 $kg.ha^{1}$.

All the interactions except transplanting dates and nitrogen were found non-significant. It is evident from the interaction of transplanting dates and nitrogen that maximum bolting percentage was in $D_1 \times$ N1 (73.0) followed by (66.5) in $D_2 \times N_1$ (Fig. 3). Minimum bolting percentage of 8.67 was recorded in $D_4 \times N_4$. No bolting was observed when transplanting was delayed to 15th January irrespective of the N level applied.

Yield: Transplanting dates and nitrogen levels have significantly ($p<0.05$) affected yield ton ha^{-1} in 2014 and 2015. The yield in 2014-15, though, non-significant was little higher than yield in 2013-14. Because of high air temperature in 2014-15, plants were taller with more number of leaves that produce large bulbs and more yield. Interactions for yield ton ha^{-1} were non-significant at 5% level of probability (Table 2). Maximum yield of 37.81 ton ha^{-1} was produced by early transplanting on 15th November. Late transplanting on 15th January produce minimum yield of 19.22 ton ha^{-1}. Similar results have been reported by Patil *et al.* (2012) that early transplanting (15th November) of onion produce maximum yield. They recorded a yield of 37.5 ton ha^{-1} in second season when transplanted on 15th November, while lowest yield of 14.3 ton ha^{-1} in first season when transplanted on 15th January. In the same way low nitrogen level at the rate of 75 Kg ha^{-1} produce minimum yield of 24.39 ton ha^{-1} and maximum yield of 35.92 ton ha^{-1} was recorded when nitrogen was applied at the rate of 150 kg ha^{-1}. According to the findings of Vachhani and Patel (1993a) plant height, number of leaves $plant^{-1}$, bulb weight, size and onion yield were highest with the application of 150 kg N ha^{-1}. Total and marketable yield increased by about 5.74 and 4.06 ton respectively at the application of nitrogen at the rate of 69 kg ha^{-1}. Different researcher at different times reported increase in bulb yield in response to nitrogen fertilization (Patel and Patel, 1990; Pandey and Ekpo, 1991; Vachhani and Patel, 1993b; Patel and Vachhani, 1994).

Percent Cull: Cull is split, double, diseased and bolters which is culled and discarded from marketable product. Transplanting dates and nitrogen level significantly ($p<0.05$) influenced percent cull while it remained non-significant between the years. Maximum cull of 55.71% was recorded in early transplanting on 15th November and minimum produce 12.80% went to cull in late transplanting on 15th January (Table 2). Farmers in Malakand division tend to transplant early in November to capture early market. This practice increased the incidence of bolting and that make the bulbs unmarketable. Kandil *et al.* (2013) found maximum total culls resulted from early transplanting date (15th November) during both seasons. In this study yield loss in early transplanting was due to bolting which decrease with delay in transplanting. In very late transplanting very small bubs contributed to percent cull. Poor crop management and environmental factors also play a part in unmarketable produce. Bolting incidence was higher in 2013-14 because low winter temperature than 2014-15.

The nitrogen application at the rate of 75 Kg ha^{-1} contributed maximum to percent cull and percent cull was minimum when nitrogen was applied at the rate of 150 kg ha^{-1}. Similar results have been reported by Jilani *et al.* (2004) that % cull was maximum at control treatment while minimum when nitrogen was applied at the rate of 160 kg ha^{-1}. Díaz-Pérez (2003) reported that loss in marketable yield was a combination of bolting and bulb decay and was minimum at 162 kg N application ha^{-1}. In this study percent cull in low nitrogen application is due to bolting while in high nitrogen application is due to bulb decay. This confirm the finding of Díaz-Pérez (2003) who stated that yield losses at minimum nitrogen rate was due to bolting while at higher nitrogen rate it was due to bulb decay. All the interactions of transplanting and nitrogen fertilizer (except D × N and Y × N) were found non-significant (Fig. 4).

Marketable Yield: Statistical analysis of the data revealed that transplanting dates and nitrogen levels significantly influenced marketable yield ton ha^{-1} at 5% level of probability (Table 1). Year as a source of variation was not significant. The D×N interaction was significant ($p < 0.05$) while the remaining interactions were found non-significant. Maximum marketable yield of 21.60 ton ha^{-1} was recorded in D_3 i.e., 15th December followed by 20.82 ton ha^{-1} in D_2 and minimum 16.95 ton ha^{-1} was recorded in late transplanting treatment D_5. Marketable yield increased with increase in nitrogen application and maximum 28.46 ton ha^{-1} was produced when nitrogen was applied at the rate of 150 kg ha^{-1}. Minimum marketable yield 10.34 ton ha^{-1} was recorded when N was applied at the rate of 75 kg ha^{-1}. Abdissa *et al.* (2011) found that nitrogen significantly increased total and marketable bulb yield of onion. Total and marketable yield increased by about 5.74 and 4.06 ton respectively at the application of nitrogen at the rate of 69 kg ha^{-1}. Muhammad *et al.* (2016) also reported increase in marketable yield with increase in N fertilizer. Similar results has also been presented by Maier *et al.* (1990) that marketable yield was significantly increased with increase in nitrogen fertilizer. The results of this study are in agreement with finding of Díaz-Pérez (2003) who reported that total and marketable yield was minimum at low nitrogen rate 102 kg ha^{-1} and highest at 146 kg N ha^{-1}. Nitrogen application beyond 146 kg ha^{-1} had no significant effect on either total or marketable yield.

Environmental factors also contribute to marketable yield. As bolting incidence and consequently percent cull was higher in 2013-14 because low winter temperature than 2014-15. This higher incidence of bolting resulted for lower marketable yield in 2013-14.

The D × N interaction showed that maximum marketable yield was produced by mid transplanting dates (15th December) and high level of N application (Fig. 5). Early and late transplanting and low nitrogen application gave low marketable yield. Maximum marketable yield of 32.82 ton ha^{-1} has been recorded in D_2N_4 combination followed by 30.41 ton ha^{-1} in D_3N_4 combination, while, minimum of 6.56 ton ha^{-1} was produced by D_1N_1 combination.

Conclusion: Early transplanting produce maximum total yield and maximum bolting percentage. Early transplanting have less marketable yield due to yield reduction caused by bolting. When there is no bolting resistant cultivar transplanting should be delayed to avoid bolting and have maximum marketable yield. Plant height, stem thickness, bulb diameter and weight and total yield increased with increase in nitrogen fertilizer. Likewise bolting percentage and percent cull decreased with increase in nitrogen fertilizer. Marketable yield was maximum at mid transplanting date (15th December) and with maximum rate of nitrogen fertilizer.

Recommendations: Early transplanting produced maximum total yield but maximum bolting as well. Early transplanting have less marketable yield due to yield reduction caused by bolting. When there is no bolting resistant cultivar available transplanting should be delayed up to December 15th to avoid bolting and have maximum marketable yield. The 2nd dose of nitrogen fertilizer should be applied just before the critical plant stage, at 6-7 leaf stage to modify its C/N ratio and minimize bolting.

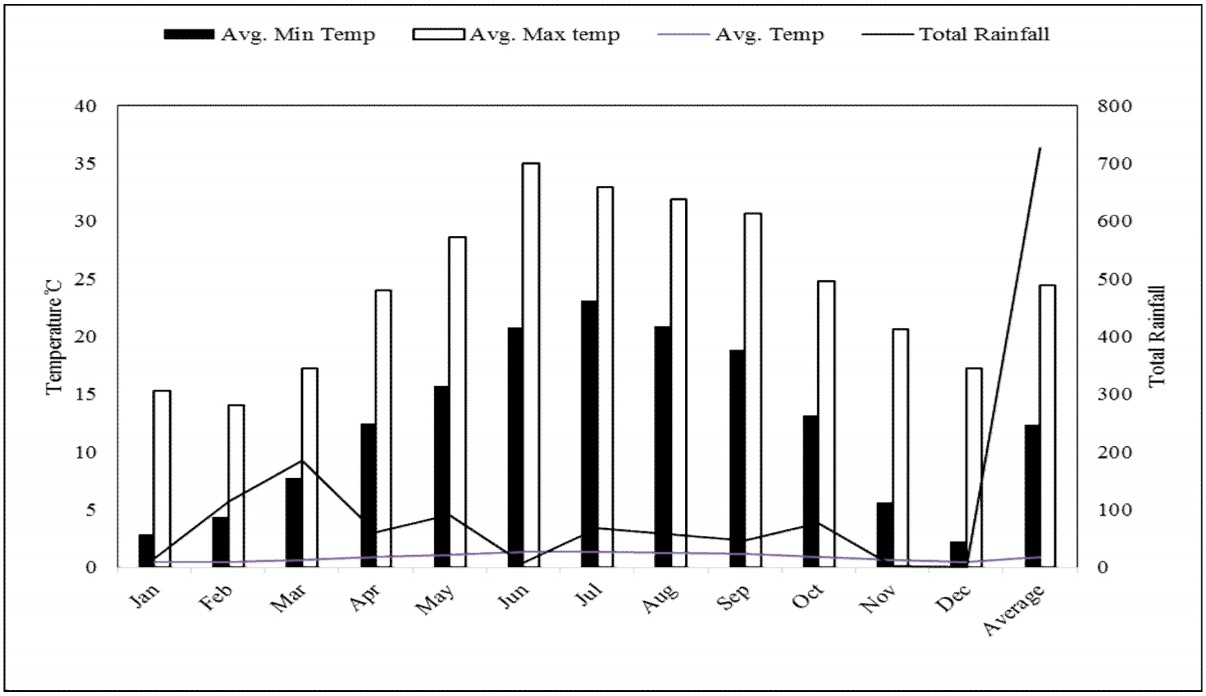

Fig. 1. Mean monthly temperature and rainfall during the growing season 2013-14.

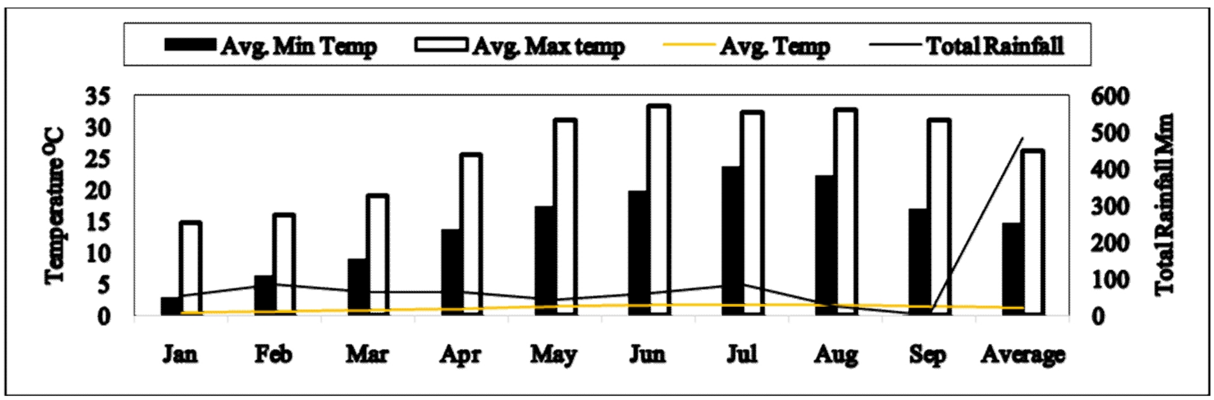

Fig. 2. Mean monthly temperature and rainfall during the growing season 2014-14.

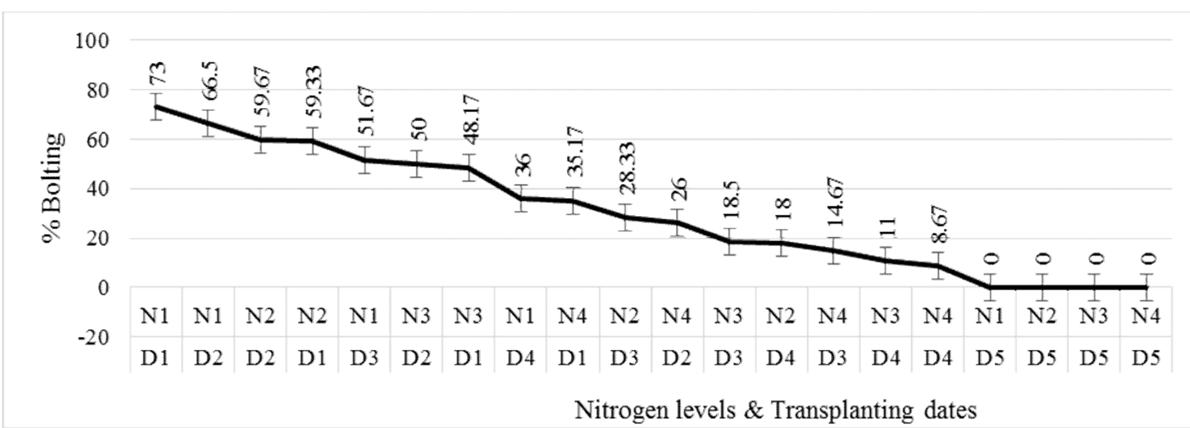

Fig. 3. Interaction of transplanting dates and nitrogen fertilizer for bolting percentage.

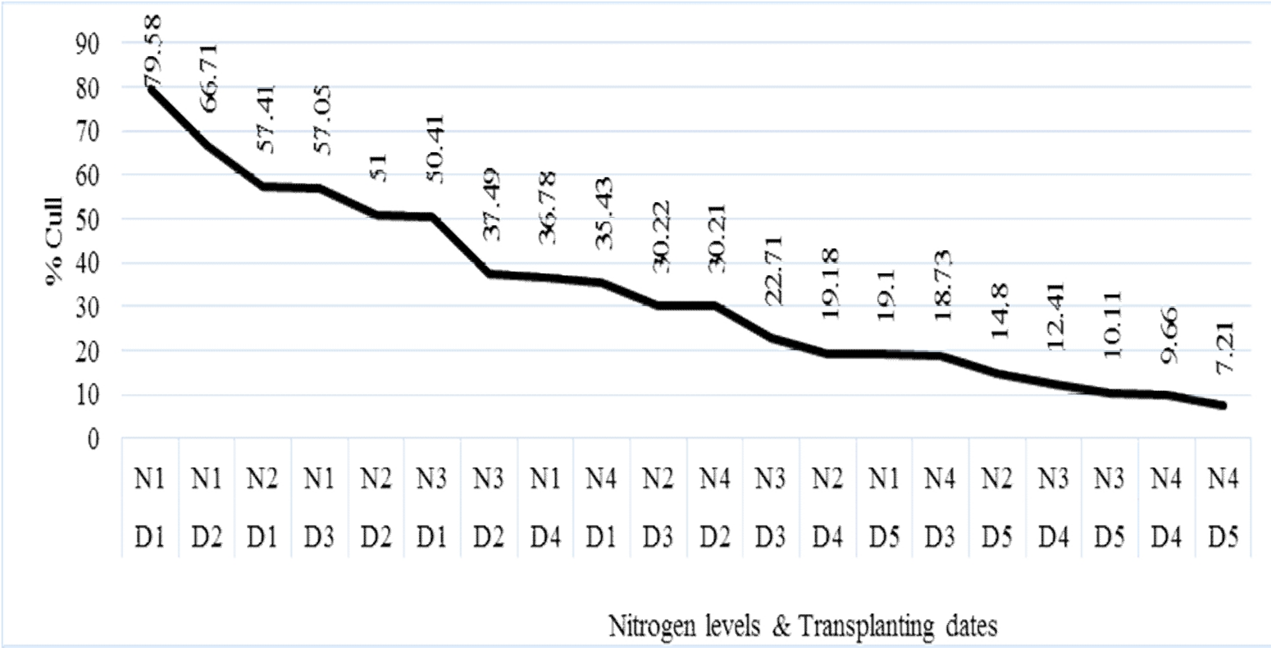

Fig. 4. Interaction of transplanting dated and nitrogen fertilizer for percent cull

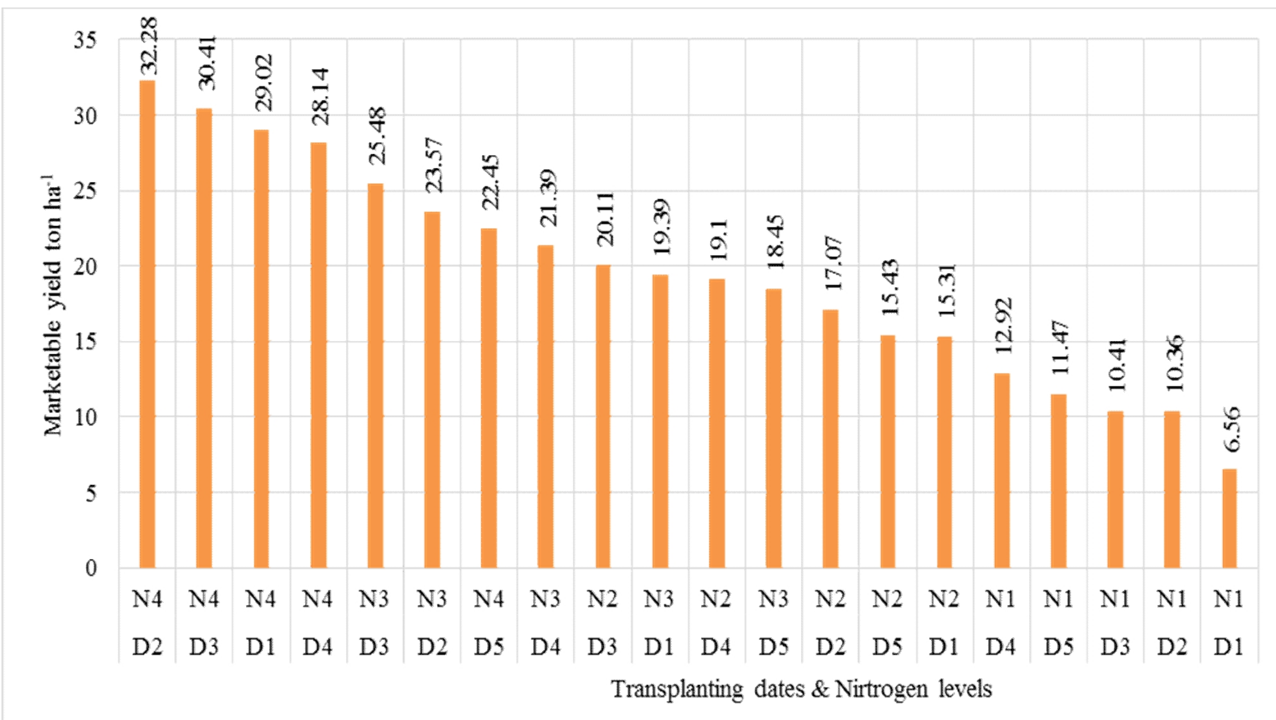

Fig. 5. Interaction of transplanting dates and nitrogen fertilizer for marketable yield.

Table 1. Effect of transplanting dates and N fertilizer on various traits.

Treatments/ Characters	Plant height (mm)			Leaves plant^{-1}			Stem thickness (mm)			Days to maturity			Bolting percentage		
Transplanting dates	**2013-14**	**2014-15**	**Mean**	**2013-14**	**2014-15**	**Mean**	**2013-14**	**2014-15**	**Mean**	**2013-14**	**2014-15**	**Mean**	**2013-14**	**2014-15**	**Means**
D_1	58.76^{a}	63.40^{a}	61.08^{a}	12.37^{a}	12.55^{a}	12.46^{a}	16.87^{a}	17.83^{a}	17.37^{a}	177.58^{a}	174.17^{a}	175.88^{a}	54.25^{a}	53.58^{a}	53.92^{a}
D_2	58.15^{a}	62.04^{ab}	61.10^{b}	12.31^{a}	12.52^{a}	12.41^{a}	16.62^{a}	17.73^{a}	17.18^{ab}	175.58^{ab}	171.58^{a}	173.58^{b}	51.41^{a}	49.67^{a}	50.54^{b}
D_3	56.96^{ab}	61.38^{abc}	59.17^{bc}	11.47^{ab}	11.51^{ab}	11.49^{b}	16.03^{ab}	17.10^{ab}	16.57^{bc}	172.50^{abc}	169.00^{ab}	170.75^{c}	31.83^{b}	24.75^{b}	28.29^{c}
D_4	56.06^{b}	61.06^{bc}	58.56^{c}	10.81^{bc}	10.95^{bc}	10.88^{c}	15.64^{ab}	16.52^{bc}	16.08^{c}	169.75^{bc}	164.75^{bc}	167.25^{d}	20.75^{c}	16.08^{c}	18.42^{d}
D_5	55.31^{b}	59.67^{c}	57.49^{d}	10.08^{c}	10.02^{c}	10.05^{d}	14.87^{b}	15.74^{c}	15.31^{d}	166.33^{c}	161.17^{c}	163.75^{e}	00.00^{d}	00.00^{d}	00.00^{e}
$LSD_{0.05}$	1.99	2.13	0.96	1.11	1.32	0.54	1.44	1.19	0.74	6.46	6.61	1.27	4.52	4.08	2.91
Nitrogen levels															
N_1	55.32^{c}	60.16^{b}	57.74^{c}	11.48^{a}	11.26^{a}	11.37^{b}	14.96^{b}	16.74^{a}	15.85^{b}	167.67^{b}	163.87^{b}	165.77^{d}	47.47^{a}	43.40^{a}	45.43^{a}
N_2	56.38^{bc}	60.44^{b}	58.41^{c}	11.16^{a}	10.99^{a}	11.08^{b}	15.98^{ab}	16.83^{a}	16.41^{b}	172.13^{ab}	167.27^{ab}	169.70^{c}	33.07^{b}	33.07^{b}	33.07^{b}
N_3	57.84^{ab}	61.86^{ab}	59.85^{b}	11.03^{a}	11.75^{a}	11.39^{b}	16.00^{ab}	17.03^{a}	16.51^{b}	172.87^{ab}	169.60^{ab}	171.23^{b}	27.33^{c}	23.73^{c}	25.53^{c}
N_4	58.65^{a}	63.57^{a}	61.11^{a}	11.96^{a}	12.03^{a}	12.00^{a}	17.60^{a}	17.38^{a}	17.23^{a}	176.73^{a}	171.80^{a}	174.27^{a}	18.73^{d}	15.07^{d}	16.90^{d}
$LSD_{0.05}$	1.78	1.90	0.85	0.99	1.18	0.42	1.29	1.06	0.66	5.77	5.91	1.14	4.04	3.65	2.60
Years	57.04^{b}	61.51^{a}	59.26	11.39	11.51	11.45	15.94	17.00	16.47	172.35^{a}	168.13^{a}	170.24	31.65	28.81	
Interactions															
D × N	ns	ns	ns	ns	ns	Ns	ns	ns	ns	Ns	ns	ns	*	*	*
Year × D	-	-	ns	-	-	Ns	-	-	ns	-	-	ns	-	-	ns
Year × N	-	-	ns	-	-	Ns	-	-	ns	-	-	ns	-	-	ns
Year × D × N	-	-	ns	-	-	Ns	-	-	ns	-	-	ns	-	-	ns

D_1 Transplanting on 30th November; D_2 Transplanting on 15th December; D_3 Transplanting on 30th December; D_4 Transplanting on 15th January; D_5 Transplanting on 30th January; N_1-75 Kg ha^{-1}, N_2 -100 Kg ha^{-1},N_3 -125 Kg ha^{-1}N_4 -150 Kg ha^{-1}, * significant at 5% level of probability; ns non-significant at 5% level of probability

Table 2. Effect of transplanting dates and nitrogen fertilizer on various traits.

Treatments/ Characters	Bulb diameter (mm)			Bulb weight (g)			Total yield (ton ha^{-1})			Percent cull			Marketable yield (ton ha^{-1})		
Transplanting dates	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
D_1	65.11^{a}	73.79^{a}	69.45^{a}	203.75^{a}	208.58^{a}	206.17^{a}	36.45^{a}	39.17^{a}	37.81	56.68^{a}	54.73^{a}	55.71^{a}	17.25^{bc}	17.89^{b}	17.57^{b}
D_2	64.53^{a}	72.16^{a}	68.34^{b}	197.08^{ab}	200.67^{ab}	198.88^{b}	34.89^{a}	38.00^{a}	36.45	45.97^{b}	44.06^{b}	45.01^{b}	20.23^{ab}	21.42^{ab}	20.82^{a}
D_3	60.36^{b}	68.93^{b}	64.65^{c}	185.50^{bc}	189.42^{bc}	187.46^{c}	29.74^{b}	31.79^{b}	30.77	33.92^{c}	30.43^{c}	32.18^{c}	21.23^{a}	21.97^{a}	21.60^{a}
D_4	55.61^{c}	65.03^{c}	60.31^{d}	174.83^{c}	188.58^{bc}	181.71^{c}	23.40^{c}	26.38^{c}	24.89	21.25^{d}	17.77^{d}	19.51^{d}	19.57^{ab}	21.21^{ab}	20.39^{a}
D_5	51.17^{d}	60.19^{d}	55.68^{e}	158.00^{d}	174.08^{c}	166.04^{d}	18.19^{d}	20.25^{d}	19.22	13.35^{e}	12.26^{d}	12.80^{e}	16.06^{c}	17.83^{b}	16.95^{b}
$LSD_{0.05}$	3.62	4.65	1.08	14.94	18.72	7.26	2.75	2.86	1.46	5.73	5.85	2.33	3.27	3.59	1.51
Nitrogen levels															
N_1	54.70^{c}	64.27^{d}	59.38^{d}	172.00^{c}	182.67^{b}	177.33^{c}	23.46^{d}	25.33^{c}	24.39^{d}	55.30^{a}	48.39^{a}	51.85^{a}	10.56 ^{d}	10.13^{d}	10.34^{d}
N_2	57.65^{bc}	67.00^{c}	62.46^{c}	177.87^{bc}	183.13^{b}	180.50^{c}	26.89^{c}	29.47^{b}	28.18^{c}	35.96^{b}	33.09^{b}	34.52^{b}	17.03 ^{c}	17.78^{c}	17.40^{c}
N_3	60.37^{b}	68.53^{b}	64.51^{b}	188.73^{ab}	192.80^{b}	190.77^{b}	29.94^{b}	31.67^{b}	30.80^{b}	25.34^{c}	27.91^{b}	26.63^{c}	20.65 ^{b}	22.67^{b}	21.66^{b}
N_4	64.72^{a}	72.07^{a}	68.40^{a}	196.73^{a}	210.47^{a}	203.60^{a}	33.85^{a}	38.00^{a}	35.92^{a}	20.34^{c}	18.01^{c}	19.18^{d}	27.24 ^{a}	29.67^{a}	28.46^{a}
$LSD_{0.05}$	0.79	1.34	0.96	5.12	12.17	6.49	2.46	2.56	1.30	5.12	5.23	2.08	2.93	3.22	1.35
Years	59.36^{a}	68.02^{a}	63.55	183.83	192.27	188.05	28.53^{a}	31.12^{a}	29.83	34.24^{a}	31.85^{a}	33.04	18.87	20.06	19.47
Interactions															
D × N	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	*	*	*	*	*
Year × D	-	-	ns	-	-	ns	-	-	ns	-	-	ns	-	-	ns
Year × N	-	-	ns	-	-	ns	-	-	ns	-	*	ns	-	-	ns
Year × D × N	-	-	ns	-	-	ns	-	-	ns	-	-	ns	-	-	ns

D_1 Transplanting on 30th November; D_2 Transplanting on 15th December; D_3 Transplanting on 30th December; D_4 Transplanting on 15th January; D_5 Transplanting on 30th January; N_1.75 Kg ha^{-1}, N_2 -100 Kg ha^{-1},N_3 -125 Kg ha^{-1}N_4 -150 Kg ha^{-1}, * significant at 5% level of probability; ns non-significant at 5% level of probability

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