J. Farm Sci., 37(1): (68-71) 2024

RESEARCH PAPER

Influence of genetic and environmental factors on incidence of bolting in short day onions

*B. B. MADALAGERI, PRAVEEN NOOJIBAIL, G. SHIVAKUMAR AND G. U. KARTHIK

Onion breeding group, I and B seeds Pvt. ltd., Bangalore, India
*E-mail: madalageribb@gmail.com

(Received: August, 2023 ; Accepted: March, 2024)

DOI: 10.61475/JFS.2024.v37i1.16

Abstract: Bolting is the premature flowering malady in bulb crop of onion cultivation. It has detrimental effects on bulb quality and market value. This research aimed to investigate the relationship between genetic predisposition and environmental conditions in relation to bolting in different onion genotypes and hybrids. Findings revealed that, the divergent patterns between the regions of Bengaluru and Bagalkot indicate that weather differences in geographical locations play a significant role in influencing the bolting tendencies of onions. The *rabi* season exhibited the highest bolting rate (15.09%), surpassing the *kharif* (0.21%) and *summer* (1.53%) seasons, emphasizing the role of seasonality in triggering bolting. Interestingly, even under identical environmental conditions, yellow onions demonstrated higher bolting percentage compared to red and white onions, suggesting the presence of genetic variation. This variation could be attributed to disparities in the presence and expression levels of the bolting genes. Collectively, these results highlight the combined influence of genetic and environmental factors, as well as their interactions on onion bolting tendencies.

Key words: Bolting, Epigenic, Onion

Introduction

Onion (*Allium cepa* L., 2n=16), a member of the Alliaceae family (Lower *et al.,*1986), is an important commercial vegetable crop grown extensively around the world. It originated in central Asia and has a rich history of cultivation dating back to ancient times. Its economic and nutritional value cannot be overstated, as it is a highly sought-after ingredient in many cuisines and is known for its numerous health benefits. Its nutritional value, coupled with its distinct flavor, makes it a common ingredient in different culinary traditions and is regarded as queen of the kitchen (Selvaraj, 1967).

Production of onion ranks second among the vegetables in the world with global production of 99.52 million tons in an area of 6.32 million hectares (FAO, 2019). China is the leading onion producer, followed by India, USA and Egypt. In India, onion is the second largest grown vegetable during 2020-21, with an area of 1.29 million hectares and an annual yield of 24.45 million tons (NHB, 2021) and it is one of the important exports earning vegetable crop. The leading onion producing states are Maharashtra, Madhya Pradesh, Karnataka, and Gujarat.

In Karnataka, short day onions are grown throughout the year. In *kharif* (rainy) as a rainfed crop, while as an irrigated crop in *rabi* and *summer* seasons wherever irrigation facilities are available. Low temperature in winter induces flower bud initiation in onion (Inductive period). Such bulbs are rejected in market and hence farmer's experience heavy loss in a commercial bulb crop. Therefore, this directs the researchers to develop a variety or hybrid those do not bolt unless it is required for seed production.

Temperature and photoperiod are the important environmental factor that affects the growth and development of plants. It has been reported that day length is crucial for bulb development whereas temperature for bolting (Brewster, 1983). If the temperature fluctuation occurs outside the range of 18°C and 25°C will significantly affect onion growth and development, including the occurrence of bolting. Bolting is a physiological process in which the plant develops a flowering stem and this phenomenon is essential for seed production, but undesirable for bulb production as it reduces the quality, yield and also bulbs become unfit for consumption and such bulbs do not have long keeping quality (Gupta *et al*., 2008). Bolting is a result of complicated interaction between genotype, plant age and environmental factors and it varies with genotype susceptibility and resistance, and with temperature (Ansari and Mamghani, 2008). Several studies have investigated the effect of temperature on bolting in short day onion and the reports shows that low temperature (below 15°C) increased the incidence of bolting (Brewster, 1983 and Bertaud, 1988).

These findings shed light on the influence of genetic and environmental factors and their interactions on regulation of bolting in onion. The study also has significant practical implications, as it provides a foundation for the development of new strategies to reduce bolting.

Material and methods

Nine experiments (Table 2) were conducted to investigate the relationship between genetic and environmental factors in relation to bolting in different onion hybrids/varieties. The study was carried out at Bengaluru and Bagalkot experimental farms of I and B seeds in three seasons for three years (2020-21, 2021-22 and 2022-23). The Bengaluru farm is geographically situated at 12.97^0 N altitude, 77.56^0 E longitude; 920 m from MSL and the soil type at this farm is red. While, Bagalkot farm is geographically situated at 16.46^0 N latitude, 74.59^0 E longitude; 533 m from MSL and the soil type is black. Monthly weather data recorded from Agro meteorological station, GKVK, Bengaluru and UHS, Bagalkot for 2020 - 23 are presented in Table 1.

Table 1. Monthly mean temperature variations in Bengaluru and Bagalkot

Month	2020 Temperature (°C)				2021 Temperature (°C)				2022 Temperature (°C)			
	Bengaluru		Bagalkot		Bengaluru		Bagalkot		Bengaluru		Bagalkot	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	28.7	15.9	34.4	14.6	27.1	15.9	33.9	14.2	27.3	14.8	29.07	21.85
February	29.8	16.7	35.2	14.5	28.6	14.6	34.8	12.9	29.3	16	33.7	16.6
March	32.5	19.3	40	17.8	32.5	16.9	39.4	14.7	32	18.3	37.01	20.7
April	33.3	19.6	40.9	20.5	33.5	19.8	38.6	22.96	33.5	20.1	37.9	23.5
May	33	20.5	42.1	22.8	31.5	20.6	36.09	23.1	29.5	19.4	35.51	23.94
June	29	19.6	32.9	22.4	29.2	19.5	31.4	22.6	28.9	19	32.24	23
July	27.8	19	33.8	21.3	28	19.1	29.9	22.5	27.3	18.7	28.85	22.74
August	27.3	18.7	32.3	20.5	28.4	18.8	30.5	22	27.4	18.6	29.5	22.03
September	27.4	18.7	33.8	21.1	28	19	29.07	21.85	27.2	18.5	30.4	19.35
October	27.1	18.1	33.2	18.1	28.1	18.7	31.86	21.3	27	16.9	30.5	20.2
November	27	17.5	33.2	11.9	25.9	17.3	29.6	20.69	25.2	16.6	30.15	17.23
December	25.9	15.7	32.7	9.3	25.9	17.3	29.5	16.59	25.8	16.4	30.6	16.07

Table 2. Mean summary of bolting percentage of different onion hybrids and varieties grown across various location, seasons and years

Year	Type of Hybrid	*Kharif* season		*Rabi* season		*Summer* season		Mean
		Bengaluru	Bagalkot	Bengaluru	Bagalkot	Bengaluru	Bagalkot	
2020 - 21	Red type	0.08	0.00	0.00	-	1.58	0.00	0.33
	White type	0.00	0.00	0.05	-	0.25	0.00	0.06
	Yellow type	0.11	0.00	1.20	-	5.97	0.00	1.46
	Mean	0.06	0.00	0.42	-	2.60	0.00	0.62
2021 - 22	Red type	0.06	-	30.02	-	1.15	0.00	7.81
	White type	0.00	-	5.19	-	0.00	0.00	1.30
	Yellow type	2.47	-	42.50	-	6.60	0.00	12.89
	Mean	0.84	-	25.90	-	2.58	0.00	7.33
2022 - 23	Red type	0.04	0.00	16.99	6.12	0.43	0.20	3.97
	White type	0.00	0.00	9.92	3.47	0.00	0.00	2.23
	Yellow type	-	-	40.48	25.12	9.48	1.89	19.24
	Mean	0.02	0.00	21.69	11.57	3.30	0.70	7.13
General mean	0.21	15.09	1.53					

The experimental material consisted of different onion hybrids developed at I and B farms using Cytoplasmic Male Sterile (CMS) lines. The group of 19 RH series hybrids were developed by crossing red CMS female parent with red male parents, 11 WH series hybrids by crossing white CMS female parent with white male parents and six YH series by crossing yellow CMS female parent with yellow male parents in the year 2019-20 and these hybrids were evaluated in the field during 2020-21. Similarly, 18 ONH series hybrids were developed in the year 2020-21 by crossing a red CMS female parent with a set of red, white, and yellow male parents and these hybrids were evaluated in the field during 2021-22. In the subsequent year (2022-23), eight best-performing hybrids from the RH, WH, YH and ONH series were selected for large scale evaluation along with five checks *viz*., Virat, Vega, Marshall, Dhawal and 16/7Y GR3.

Seedlings were raised in protrays filled with coco peat media under greenhouse nursery for 45 days and transplanted on well-prepared raised beds at Bengaluru farm, while on flat beds at Bagalkot at a spacing of 15x10 cm. The experiment was laid out under randomized block design with two replications. All the recommended package of practices was followed (Anon., 2018) for raising the crop. Bolting observations were recorded at the time of harvest from all the replications.

Results and discussion

The onion bolting data from two locations, Bengaluru and Bagalkot, over the course of three years reveals intriguing patterns. In Bengaluru, during the 2020-21 *kharif*, *rabi*, and *summer*, the incidence of bolting remained remarkably low, recorded at mere percentages of 0.06%, 0.42%, and 2.60%, respectively. However, the subsequent year of 2021-22, climate change (A deviation of about 27.08% in low temperature in Bengaluru) brought about a shift in the bolting trends in Bengaluru. While, the *kharif* (0.84%) and *summer* (2.58%) seasons still experienced relatively low incidences of bolting, the *rabi* season witnessed a significant increase of 25.90%. Interestingly, the *rabi* season of 2022-23 in Bengaluru displayed a relatively high bolting rate of 21.69%, maintaining an elevated level compared to the *kharif* (0.02%) and *summer* (3.30%) seasons of the same year. The average bolting data for different onion hybrids cultivated in various seasons and years is summarized in Table 3.

In Bagalkot region, no instances of bolting were reported during the *kharif* and *summer* seasons of 2020-21. This trend persisted in subsequent *summer* season of 2021-22 and the *kharif* season of 2022-23 also. However, the *rabi* season of 2022-23 in Bagalkot exhibited a bolting rate of 11.57%. Despite this increased, the figure remained significantly lower compared

to the bolting rates observed in Bengaluru during the same season. Additionally, the *summer* season in Bagalkot during 2022-23 witnessed a minimal bolting rate of 0.70%.

The divergent climatic patterns observed between the regions of Bengaluru and Bagalkot indicate (Table 1 and 2) that geographical location plays a significant role in influencing the bolting tendencies of onion hybrids. This distinction can be attributed to the notable differences in climatic conditions especially temperature between the two regions. Bengaluru, situated at a higher elevation within the Deccan Plateau, generally exhibits a cooler temperate especially in winter in comparison to Bagalkot, which is located in the northern plains of Karnataka. As a result, the relatively cooler temperatures prevalent in Bengaluru have a greater influence on triggering bolting genes in onion hybrids/varieties when compared to the conditions in Bagalkot region, as temperatures below 15°C were found to over express flowering genes like AcFT 2 genes (Lee *et al*, 2013).

During the *rabi* season, the mean values over the years and locations showed highest bolting rate of 15.09% (Table 3) irrespective of any colored varieties (Fig. 1), showcasing the significance of this season in triggering bolting. In contrast, the *kharif* and *summer* seasons displayed the lowest bolting rates, with a mere 0.21% and 1.53%, respectively. This unexpected surge in bolting during the *rabi* season implies the presence of environmental factors (low temperature) that influenced the onion crops differently across the seasons and locations. Along with this seasonal variations, significant year-to-year variations in bolting were also noticed. Irrespective of location, season and type of hybrid, the cropping year of 2020-21 exhibited an exceptionally low bolting rate of only 0.62%. However, subsequent cropping years, namely 2021-22 and 2022-23, witnessed a substantial increase in bolting, with rates of 7.33% and 7.13%, respectively (Table 3). These results show the significant variations across different seasons and variations from one year to another cropping year due to climate change.

It is important to note that onions require a specific number of daylight hours to remain in the vegetative growth phase.

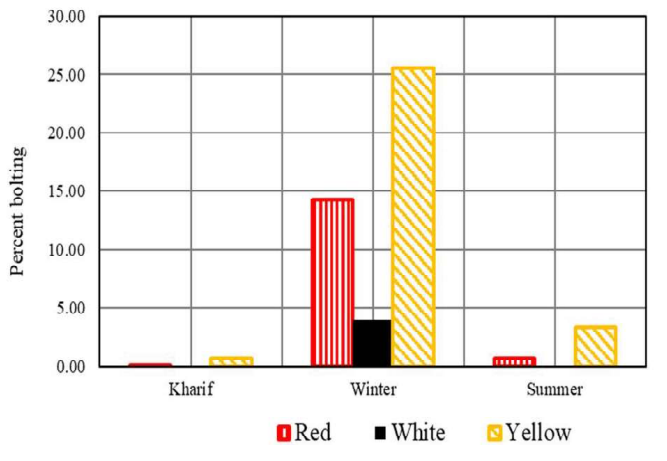

Fig1. Bolting percentage of onion genotypes in different seasons over the years

Table 3. Year wise mean bolting percentage data of selected onion hybrids and varieties

Hybrids	2020-21	2021-22	2022-23	Mean	Mean over genotypes
RH1	0.09	2.55	2.13	1.59	3.62
RH2	0.10	3.38	-	1.74	
RH5	0.00	-	7.90	3.95	
RH6	0.11	2.75	-	1.43	
RH9	0.21	4.00	-	2.10	
RH11	0.24	6.15	9.82	5.40	
RH13	2.91	17.24	-	10.07	
ONH9	-	4.10	4.17	4.14	
ONH12	-	8.50	6.73	7.61	
VIRAT	0.08	2.23	0.92	1.08	
VEGA	0.00	-	1.58	0.79	
MARSHAL	0.77	12.05	-	6.41	
YH1	0.29	-	24.98	12.64	9.84
YH3	1.61	12.89	25.90	13.47	
16/7Y GR3	0.00	-	6.84	3.42	
WH8	0.00	1.88	3.71	1.86	1.37
DHAWAL	0.23	0.72	1.65	0.87	
Mean	0.53	7.79	7.07	4.54	

Short-day onion varieties require approximately 10 to 12 hours of daylight to sustain vegetative growth (Bachie *et al*., 2019). However, when they expose to cold temperatures below 15°C can disrupt this process, leading to bolting (Brewster, 1983). This interruption in growth is attributed to significant alterations in plant hormones, particularly gibberellins and cytokinins, which play vital roles in the regulation of bolting. The hormonal changes induced by cold temperatures trigger the transition to reproductive growth, ultimately culminating in bolting (Wu *et al.,* 2016). During the *rabi* season, when the temperature dropped to around 15°C that likely influence the bolting. Conversely, in the *summer* and *kharif* seasons, where the temperature is typically above 15°C, bolting was less (Khokhar, 2017). Which indicates the occurrence of bolting in onions influenced by the seasonal variations in temperature.

Analyzing the overall mean across different seasons over the years, it becomes evident that the yellow onions are prone to bolting than other types (Fig.1) as they were recently introduced and domesticated from long days to short days over the years. Among the yellow onions, hybrids YH-1 and YH-3 stood out with the highest levels of bolting, reaching 12.64% and 13.47%, respectively (Table 3) suggesting possible dominance of bolting over one of their parents like 16/7Y GR3 which had only 3.42%.

Even among the red onions, hybrids RH-13 (10.07%) and ONH-12 (7.61%) had higher bolting percentage, indicate the possibility of selecting parents in developing hybrids with low bolting tendency. However genotypes Vega, a red synthetic variety developed at I & B seeds and similarly Virat (open pollinated selection) exhibited the low bolting percentages suggesting that other breeding methodologies like synthetic breeding can be a useful tool in this regard.

It is worth noting that certain onions are more susceptible to bolting than others, even when exposed to optimal

temperature conditions. These variations in genotype difference are due to presence and expression levels of the flowering gene (*AcFT2*) (Baldwin *et al*., 2014). The *AcFT2* gene plays a crucial role in the florigen signaling pathway in onions for floral initiation. In the presence of inductive conditions, such as low temperatures (below 15°C), the *AcFT2* gene might have over expressed and forms a florigen activation complex (Lee *et al.,* 2013). In view of this few hybrids that had high percentage of bolting (YH-1, YH-3, RH-13 and ONH-12) might have had genes similar to *AcFT2* with greater expressivity compared to others. This indicates that there is a need to find out a genotype having gene for gene silencing if any or method like methylation. Breeding methods like rigorous selection of genotype at hotspots (low temperature conditions) may be worthwhile to eliminate bolting genes over a period of time. Such parents can be candidates for developing good non bolting hybrids/varieties.

Conclusion

Bolting, the premature flowering and subsequent elongation of the stem, is a significant concern in onion bulb crop cultivation as it negatively affects bulb quality and market value. The present investigation has unveiled fascinating insights into the significant variation in bolting among different hybrids grown across various seasons and years. Notably, the highest incidence of bolting was observed during the *rabi* season, highlighting the intricate interplay between genetic and environmental factors. Even when exposed to the same environmental conditions, yellow onion hybrids exhibited higher bolting percentages compared to red and white onion hybrids, suggesting the presence of genetic variation. This variation can be attributed to differences in the presence and expression levels of bolting genes among the hybrids and varieties. This genetic variation among onion genotypes offers a promising avenue for breeders to develop cultivars with enhanced bolting resistance, ultimately minimizing losses in onion production. Further more, understanding the environmental triggers, such as low temperatures, that exacerbate the genetic predisposition to bolting can aid in the development of cultivation practices that mitigate bolting risk and ensure optimal bulb yield and quality. Furthermore, researchers can leverage this information to make informed decisions regarding the selection of genotypes and their suitability for specific environmental conditions.

References

Anonymous, 2018, Cultivation practices for horticultural crops, University of Horticultural Sciences, Bagalkot.

Ansari N A and Mamghani R, 2008, Effect of screening of onion (*Allium cepa* L) ecotypes of southern Iran on bulb yield and bolting. *Asian Journal of Plant Sciences*, 7: 584-588.

Bachie O G, Santiago L S and Mc Giffen M E, 2019, Physiological responses of onion varieties to varying photoperiod and temperature regimes. *Agriculture*, 9(10): 214.

Baldwin S, Revanna R, Pither-Joyce M, Shaw M, Wright K, Thomson S, Moya L, Lee R, Macknight R and McCallum J, 2014, Genetic analyses of bolting in bulb onion (*Allium cepa* L.). *Theoretical and Applied Genetics*, 127: 535-547.

Bertaud D S, 1988, Effects of chilling duration, photoperiod and temperature on floral initiation and development in sprouted and unsprouted onion bulbs. *In Allium symposium sep 6-9, 1988 United Kingdom: Eucarpia-section vegetables; Proceedings*. Institute of Horticultural Research.

Brewster J L, 1983, Effects of photoperiod, nitrogen nutrition and temperature on inflorescence initiation and development in onion (*Allium cepa* L.) *Annual Botany,* 51(4): 429-440.

FAO, 2019, Food and Agriculture Organization, https: www.fao.org.in.

Gupta A J, Mahajan V and Lawande K E, 2008, Genotypic response to bolting tolerance in short day onion (*Allium cepa* L.). *Vegetable Science*, 45(1): 92-96.

Khokhar K M, 2017, Environmental and genotypic effects on bulb development in onion–A review. *The Journal of Horticultural Science and Biotechnology*, 92(5): 448-454.

Lee R, Baldwin S, Kenel F, Mc Callum J and Macknight R, 2013, FLOWERING LOCUS t genes control onion bulb formation and flowering. *Nature Communications,* 4(1)-2884.

Lower R L, Edwards M D and Basset M E, 1986, Breeding vegetable crops. Vegetable crops Department, University of Florida, Gainesville, Florida.

NHB, 2021, Indian Horticulture Database, http: www.nhb.gov.in.

Selvaraj S, 1967, Onion: Queen of the kitchen. *Kisan World*, 3(12): 32-34.

Wu C, Wang M, Cheng Z and Meng H, 2016 Response of garlic (*Allium sativum* L.) bolting and bulbing to temperature and photoperiod treatments. *Biology Open*, 5(4): 507-18.