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Quantifying Effects of Photoperiod, Temperature and Humidity on Flowering Initiation in Basmati Rice Lines

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Abstract

The results suggested that all the pure Basmati lines or genotypes initiate flowering within a specific range of day length duration and temperature. Delaying the transplanting date did not significantly affect the flowering time of studied Basmati lines. Maximum threshold of daily minimum temperature (MT) was 24˚C during both the years. Likewise, maximum threshold of daily day-length (DL) durations was 12 hours and 18 minutes during both the study years. Results showed that the flowering was maximum when the MT and DL values were optimum as depicted by peak of the trend lines, where maximum lines flowered. Maximum flowering initiations took place when DL was about 11 hours and 15 minutes indicating Basmati as short day plant which flowers maximum when day lengths are shorter and dark or night duration is longer. During 2013, 1st date trial showed strong relationship between flowering initiation with dates of flowering during the flowering period as depicted by higher regression (R^2 = 0.837) values. In 2nd date trial during the same year, the value is lower (R^2 = 0.513) depicting less relationship of flowering initiation with the dates of flowering. The same trend was observed in 2014 trial. In 1st date trial, strong relationship between flowering initiation with dates of flowering during the flowering period as depicted by higher regression (R^2 = 0.864) values, was observed. In 2nd date trial during the same year, the value is lower (R^2 = 0.1789) depicting very poor relationship of flowering initiation with the dates of flowering, and the same trend (R^2 = 0.0544) in 3rd date of trial.

Keywords

Basmati Rice, Flowering, Photoperiod, Temperature, Humidity

1. Introduction

Basmati is the type of rice (*Oryza sativa* L.) which is long, slender-grained aromatic rice traditionally from Pakistan and India. Basmati rice is considered sensitive to photoperiod as well as temperature, and is highly affected by these climatic factors resulting in significant yield fluctuations. Time of transplanting is the most important factor among all the agronomic components of yield that directly affect the yield in any crop especially in Basmati rice (*Oryza sativa* L.) varieties or lines [1]. Three climatic factors *i.e.* Photoperiod sensitivity, Temperature and Humidity are reported to caste crucial effects in flowering of the Basmati rice lines. Pure Basmati lines only flower between specific ranges of these climatic factors. Any fluctuation in these factors during flowering time results in incomplete flowering. Likewise, during grain filling period, these factors are also of the same importance and significantly affect grain filling and yield reductions. Most of the Basmati rice cultivars are naturally bred to flower between the temperature ranges from 20 to 25 Celsius [2]. Pure Basmati lines twitches anthesis in the last week of September when temperature falls below 25 degree Celsius and completes in flowering within first week October until the temperature falls below 20 degree Celsius.

Transplanting Basmati rice too early or too late, either shortens or prolongs the duration of rice crop respectively from transplanting to panicle initiation causing sterility and lower milling quality. It is observed that variations in growth temperature by varying the transplantation dates caused variation in productivity and quality of rice crop [3]. Previous studies exploring the effects of temperature on kernel development by various researchers have showed that higher temperatures during the plant development stage of grain-filling result in decrease in rice kernel width and thickness and increased chalkiness [4]. However, effects of temperatures on amylase content of different rice cultivars were recorded significantly variable [5]. Too high or too low night time air temperature stress causes reduced substrate supply to the grain endosperm, which results in slow growth of starch granules and irregular granular organization [6]. Ahmed *et al*. [7] showed that high temperature decreased the grain filling period from 32 to 26 days, reducing yield by 6%.

It has been reported by many researchers that average rice yield as well as its nutritional and cooking quality are significantly affected by weather conditions. Studies carried out on rice demonstrated the negative impact of drastic changes in rainfall patterns coupled with rising temperatures could be managed by changes in planting dates, transplanting dates, transplant age, and crop spacing [8].

2. Material and Methods

The experiment was conducted during kharif season of 2013 and 2014at the research farms of Rice Research Institute, Kala Shah Kaku in Pakistan. Average, maximum and minimum values of temperature and humidity during months of September and October of both the study years are shown in Figure 1(a) & Figure 1(b). Likewise, minimum temperature and day length (photoperiod) values of each day during the months of September and October of both the study years are shown in Figure 1(a) & Figure 1(b). The experiment was laid out in Randomized Complete Block Design (RCBD) with plot size of 0.229 × 2.286 m^2 replicated twice and thrice in 2013 and 2014 respectively (Table 1). The treatments included two dates of transplanting in 2013 and three dates in 2014. Forty (40) advance rice lines, landraces and cultivars including checks *i.e.* Basmati 370, Super Basmati were used in the study. Graphs depicted as Figure 2(a) & Figure 2(b) describes the fluctuations in daily minimum temperature along with the photoperiod/day length durations of the two months during 2013 and 2014 respectively.

Seedlings of 30 days old nursery of each variety were transplanted on a well puddled soil with a spacing of 20 cm between rows and 20 cm between hills. Puddling was done by running a cultivator in standing water (75 mm) followed

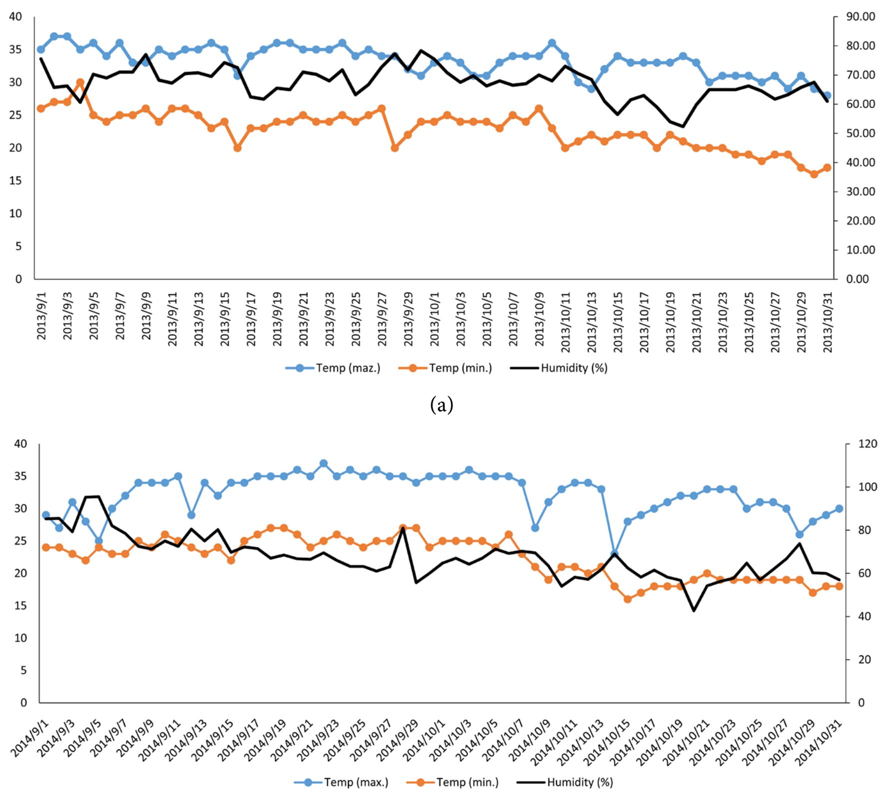


Figure 1. Daily minimum, maximum and relative humidity of RRI KSK during the months of September and October of both the study years 2013 and 2014. (a) 2013; (b) 2014.

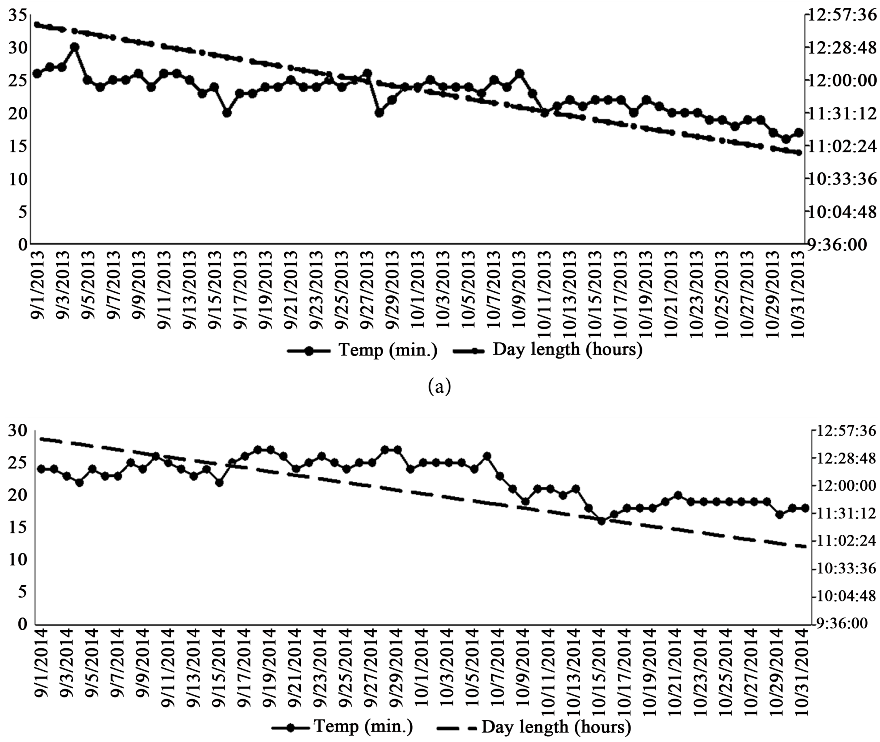


Figure 2. Daily photoperiod/day lengths and minimum temperatures of RRI KSK during the months of September and October of both the study years 2013 and 2014. (a) 2013; (b) 2014.

Table 1. Dates of sowing and transplanting during 2013 and 2014.

	2013		2014		
	1st Date	2nd Date	1st Date	2nd Date	3rd Date
Date of nursery sowing	20th May	5th June	28th May	18th June	1st July
Dates of nursery transplanting	25th June	10th July	14th June	19th July	7th August

by planking. Forty kg N per hectare was applied at 5 days after transplanting (DAT). The crop was maintained according to the recommended doses of fertilizers. All the other agronomic practices were carried out according to the recommendations. The criterion of the flowering initiation or anthesis was taken as the inflorescences of more than 5% plants of total population were exerted through the flag leaf (upper most/last leaf) sheath of the main tiller/shoot. Observations were taken each day at about 11.00 a.m.

3. Results and Discussion

The results confirmed that almost all the studied Basmati genotypes showed flowering initiation after mid of September both the years and continue flowering till first half week of October. The date of flowering of each lines/genotype is given in Table 2. During the year 2013, 1st date trial, genotypes started flowering on 20th September and continued flowering up to 20th October, while the 2nd date

Table 2. Dates of flowering initiation of each studied genotype during 2013 and 2014.

Sr#	Name of Genotype	1st Date 2013	2nd Date 2013	1st Date 2014	2nd Date 2014	3rd Date 2014
1	454	20-Sep	06-Oct	22-Sep	29-Sep	05-Oct
2	1021-3	25-Sep	06-Oct	27-Sep	29-Sep	04-Oct
3	1021-5	24-Sep	01-Oct	22-Sep	30-Sep	02-Oct
4	1021-6	25-Sep	03-Oct	27-Sep	26-Sep	04-Oct
5	33608	25-Sep	07-Oct	18-Sep	25-Sep	27-Sep
6	34050	30-Sep	06-Oct	21-Sep	30-Sep	02-Oct
7	47456	10-Oct	13-Oct	17-Sep	02-Oct	12-Oct
8	Basmati T3	18-Oct	18-Oct	22-Sep	27-Sep	03-Oct
9	Basmati 385	30-Sep	16-Oct	23-Sep	26-Sep	04-Oct
10	Basmati 385-244	30-Sep	16-Oct	22-Sep	22-Sep	02-Oct
11	Basmati 6129	20-Oct	14-Oct	21-Sep	10-Oct	12-Oct
12	besudi	07-Oct	14-Oct	21-Sep	22-Sep	08-Oct
13	BN 6311	06-Oct	14-Oct	18-Sep	26-Sep	08-Oct
14	Muskhan	30-Sep	13-Oct	17-Sep	22-Sep	22-Sep
15	T3	07-Oct	18-Oct	24-Sep	27-Sep	14-Oct
16	44156A	07-Oct	20-Oct	19-Sep	01-Oct	11-Oct
17	PK8677	25-Sep	05-Oct	22-Sep	29-Sep	29-Sep
20	Rexoro	07-Oct	18-Oct	20-Sep	26-Sep	30-Sep
21	98410	30-Sep	19-Oct	02-Oct	02-Oct	10-Oct
22	98316	30-Sep	07-Oct	02-Oct	04-Oct	08-Oct
23	PK99417	23-Sep	30-Sep	22-Sep	27-Sep	02-Oct
24	PK99512	30-Sep	17-Oct	02-Oct	06-Oct	10-Oct
25	PK99513	30-Sep	17-Oct	02-Oct	02-Oct	09-Oct
26	PK99408	30-Sep	18-Oct	02-Oct	05-Oct	11-Oct
27	99404	30-Sep	05-Oct	11-Oct	02-Oct	08-Oct
28	99515	30-Sep	06-Oct	11-Oct	02-Oct	10-Oct
29	1121	30-Sep	10-Oct	26-Sep	02-Oct	08-Oct
30	PK7392	29-Sep	01-Oct	26-Sep	27-Sep	02-Oct
31	515	28-Sep	05-Oct	02-Oct	02-Oct	02-Oct
32	1121	30-Sep	10-Oct	26-Sep	02-Oct	08-Oct
33	Basmati 2000	27-Sep	06-Oct	02-Oct	02-Oct	08-Oct
34	Pusa Bas 1	08-Oct	11-Oct	01-Oct	29-Sep	02-Oct
35	Pusa Bas 834	30-Sep	18-Oct	22-Sep	02-Oct	09-Oct
36	Basmati 198	18-Oct	22-Oct	17-Sep	22-Sep	14-Oct
37	Basmati 370	07-Oct	12-Oct	18-Sep	23-Sep	08-Oct
38	Basmati 370-1	18-Oct	18-Oct	21-Sep	02-Oct	09-Oct
39	Basmati 370-13	07-Oct	18-Oct	21-Sep	02-Oct	10-Oct
40	Basmati 370-24	29-Sep	07-Oct	21-Sep	30-Sep	02-Oct
	Average	**02-Oct**	**11-Oct**	**24-Sep**	**29-Sep**	**06-Oct**
	Min	**20-Sep**	**30-Sep**	**17-Sep**	**22-Sep**	**22-Sep**
	Max	**20-Oct**	**22-Oct**	**11-Oct**	**10-Oct**	**14-Oct**

trial, flowering started on 30th September and showed flowering initiation up to 22nd of October in the same year 2013. Similarly, during the second year of study, genotypes transplanted in 1st date, 2nd date and 3rd date started flowering from 17th September, 22nd September and 22nd September respectively and continued flowering initiation up to 11th, 10th and 14th October of the same year 2014.

Regression analysis values show trends in flowering initiations in all the studied genotypes with respect to the dates of flowering during the flowering period during both the years 2013 and 2014 as depicted in Figure 3(a) and Figure 3(b) respectively. Higher regression (R^2) value depicts that the flowering initiations had a strong association with flowering dates while the lower regression values show no or poor relationship of flowering initiation with flowering dates within the flowering periods. During 2013, 1st date trial showed strong relationship between flowering initiation with dates of flowering during the flowering period as depicted by higher regression (R^2 = 0.837) values. In 2nd date trial during the same year, the value is lower (R^2 = 0.513) depicting less relationship of flowering initiation with the dates of flowering. The same trend was observed in 2014 trial. In 1st date trial, strong relationship between flowering initiation with dates of flowering during the flowering period as depicted by higher regression (R^2 = 0.864) values, was observed. In 2nd date trial during the same year, the value is

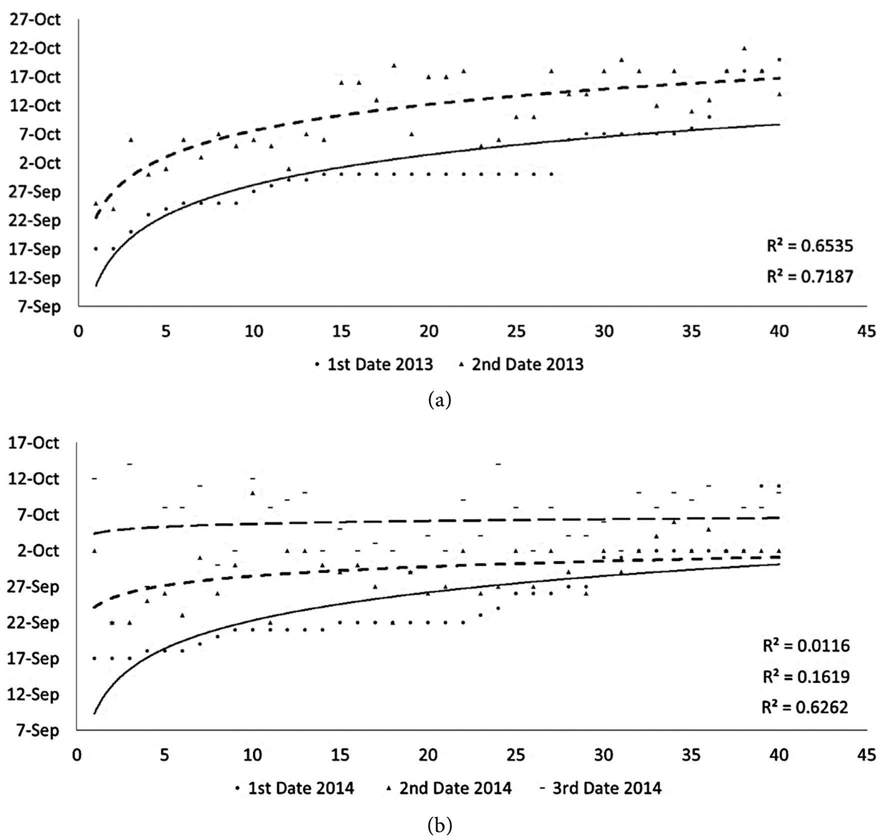
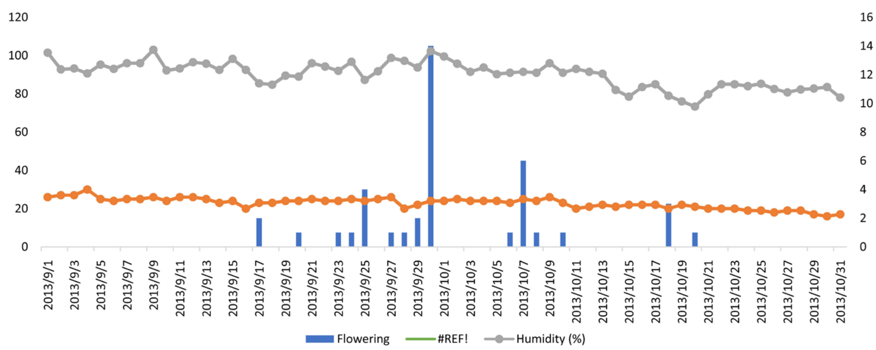


Figure 3. Regression analysis showering trends of flowering initiation in studied genotypes with respect to the dates of flowering during the flowering period during both the years 2013 and 2014. (a) 2013; (b) 2014.

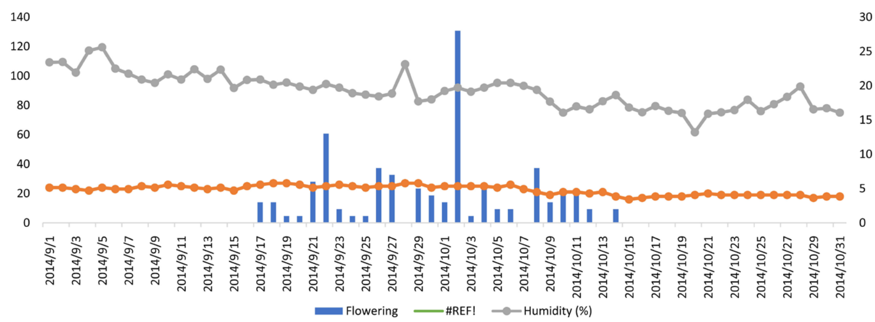
lower ($R^2 = 0.1789$) depicting very poor relationship of flowering initiation with the dates of flowering, and the same trend ($R^2 = 0.0544$) in 3rd date of trial. Higher regression values in 1st date trial demonstrates that genotypes initiated flowering over a longer range of days. The difference in flowering initiation in first date trial was due to genotypic differences among the lines for anthesis. While in second date in 2013 and second & third date trials in 2014, poor relationship showed genotypes flowering over a short range of period of days representing normal period for flowering of Basmati lines.

Trends of flowering initiation in studied genotypes with respect to the dates of flowering, minimum temperature (MT) and relative humidity percentage (RH%) during the study periods of both the years 2013 and 2014 starting from 1st September to end of October in given in Figure 4(a) and Figure 4(b) respectively. Graphs show that in 2013, flowering started when daily MT fell below 24˚C down to 20˚C (on 16th September) and RH% below 72%, whereas in 2014, flowering was initiated as daily MT fell below 24˚C down to 22˚C (on 15th September) and RH% was again 72%. The data show that maximum limit to start anthesis in Basmati lines is as above as 24˚C indicating its higher temperature limit *i.e.* only below this temperature, Basmati lines initiates flowering.

Trends of flowering initiation in studied genotypes with respect to the dates of flowering and daily day length durations or daily photoperiods during the study



(a)

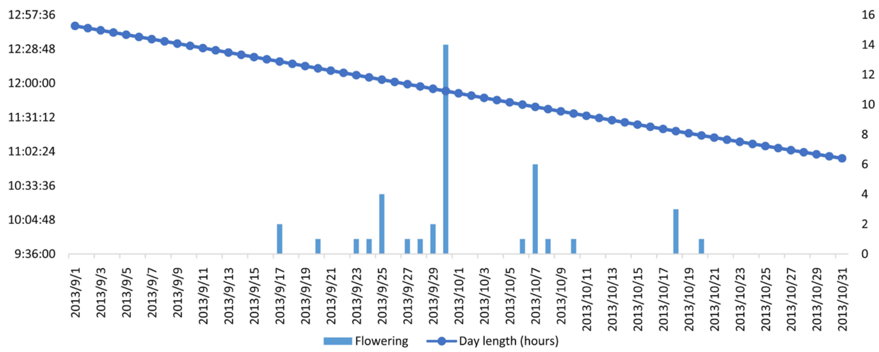


(b)

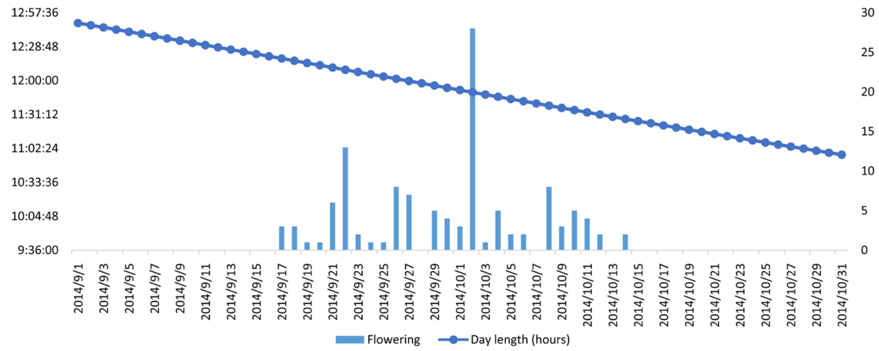
Figure 4. Trends of flowering initiation in studied genotypes with respect to the dates of flowering, minimum temperature and relative humidity (%) during the study periods from 1st September to end of October of both the years 2013 and 2014. (a) 2013; (b) 2014.

months of both the years 2013 and 2014 starting from 1st September to end of October in given in Figure 5(a) and Figure 5(b) respectively. Graphs show that in 2013, flowering started when daily day-length durations (DLs) or daily photoperiods reached down to 12 hours and 18 minutes, whereas in 2014, flowering was initiated as daily DLs reached down to 12 hours and 18 minutes. The data show that maximum photoperiod/day length duration limit to start anthesis in Basmati lines is as lengthy as 12 hours 18 minutes and continued down to 11 hours 27 minutes and 11 hours 15 minutes during 2013 and 2014 respectively.

Maximum and minimum thresholds of daily minimum temperature and day-length durations for flowering initiation in pure Basmati lines is depicted in Figure 6(a) & Figure 6(b) respectively. Figure 6(a) clearly shows that all the Basmati lines initiated anthesis after specific range of temperature during both the years. Maximum threshold of daily minimum temperature was 24˚C during both the years. Likewise, Figure 6(b) clearly shows that all the Basmati lines initiated anthesis after specific range of daily day-length cycles during both the years. Maximum threshold of daily day length durations was 12 hours and 18 minutes during both the study years. Bell-shaped trend lines showed that the flowering was maximum when the MT and Dl values were optimum as depicted by peak of the bell-shaped trend lines, where maximum lines flowered. Trend lines in case of MT is slightly projected to right side indicating that maximum

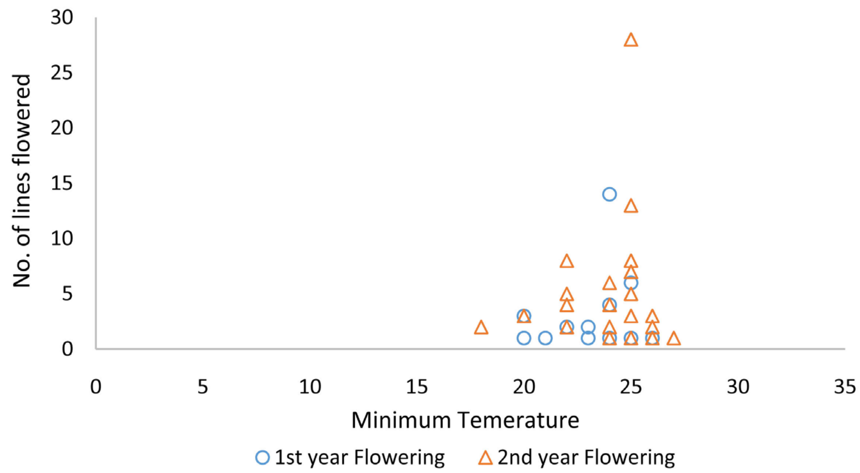


(a)

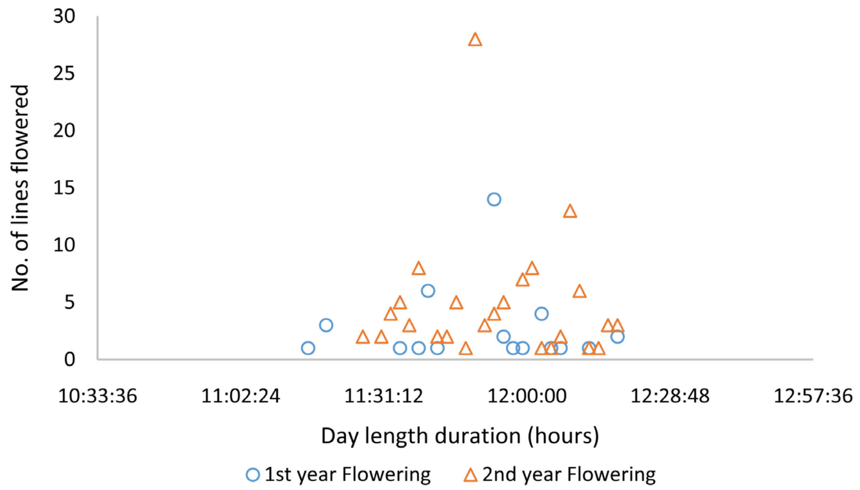


(b)

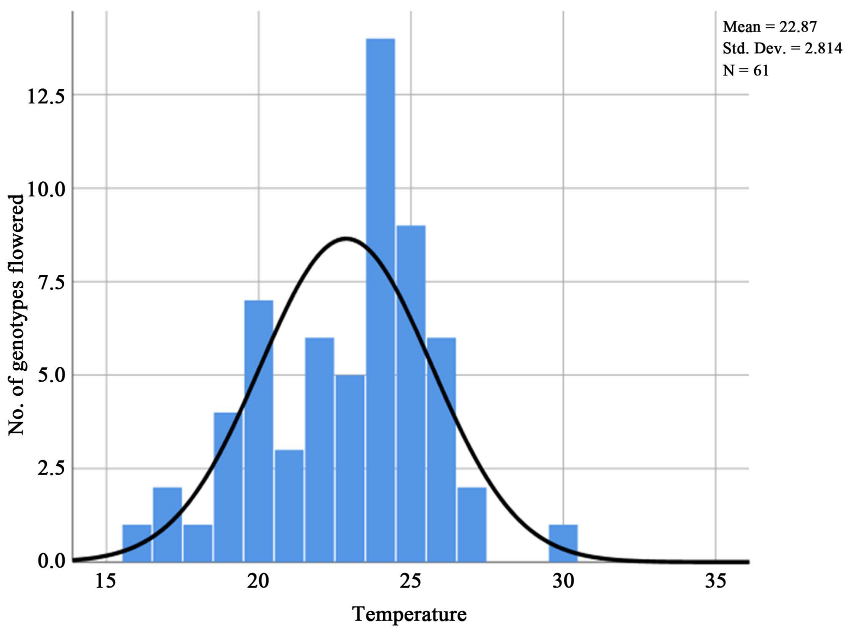
Figure 5. Trends of flowering initiation in studied genotypes with respect to the dates of flowering and daily day length durations during the study periods from 1st September to end of October of both the years 2013 and 2014. (a) 2013; (b) 2014.


30
25
20
15
10
5
0
No. of lines flowered
0
5
10
15
20
25
30
35
Minimum Temerature
1st year Flowering
2nd year Flowering

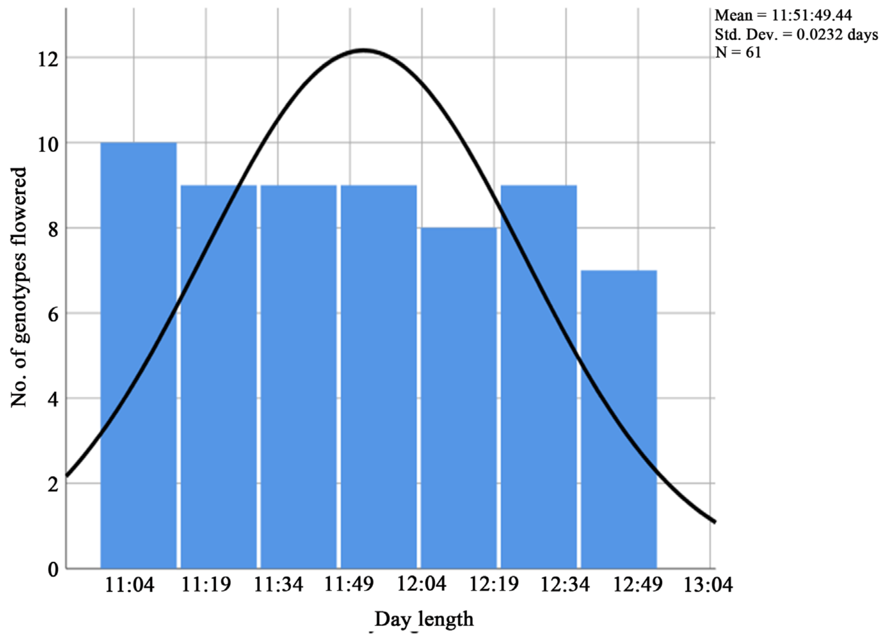
(a)


30
25
20
15
10
5
0
No. of lines flowered
10:33:36
11:02:24
11:31:12
12:00:00
12:28:48
12:57:36
Day length duration (hours)
1st year Flowering
2nd year Flowering

(b)


Mean = 22.87
Std. Dev. = 2.814
N = 61
12.5
10.0
7.5
5.0
2.5
0.0
No. of genotypes flowered
15
20
25
30
35
Temperature

(c)



(d)

Figure 6. Scatter plots ((a), (b)) and histograms ((b), (c)) of daily minimum temperature and day-length durations for flowering initiation in pure Basmati lines showing specific range of minimum temperature and day length durations for flowering initiation time in pure Basmati lines.

lines from all the date trials initiated flowering just as the MT fell below 24˚C. however, in case of DLs, maximum flowering occurred at the mid of DL range starting from 12 hrs and 18 min and continued to 11 hrs 27 mins while the maximum flowering initiated took place when DL was about 11 hours and 15 minutes indicating Basmati as short day plant which flowers maximum when day lengths are shorter and dark time duration is longer.

4. Conclusion

The results suggested that all the pure Basmati lines or genotypes initiates flowering within a specific range of day length duration and temperature. Delaying the transplanting date did not affect the flowering time of studied basmati lines that indicates the lines were pure basmati in nature and had a strong basmati background. Maximum threshold of daily minimum temperature (MT) was 24˚C during both the years. Likewise, maximum threshold of daily day length (DL) durations was 12 hours and 18 minutes during both the study years. Results showed that the flowering was maximum when the MT and DL values were optimum as depicted by peak of the trend lines, where maximum lines flowered. However maximum flowering initiations took place when DL was about 11 hours and 15 minutes indicating Basmati as short day plant which flowers maximum when day lengths are shorter and dark time duration is longer. During 2013, 1st date trial showed strong relationship between flowering initiation with dates of flowering during the flowering period as depicted by higher regression (R^2 = 0.837) values. In 2nd date trial during the same year, the value is lower (R^2 = 0.513) depicting less relationship of flowering initiation with the dates of flowering. The same trend was observed in 2014 trial. In 1st date trial, strong relationship between flowering initiation with dates of flowering during the flowering period as depicted by higher regression (R^2 = 0.864) values, was observed. In 2nd date trial during the same year, the value is lower (R^2 = 0.1789) depicting very poor relationship of flowering initiation with the dates of flowering, and the same trend (R^2 = 0.0544) in 3rd date of trial.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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