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Evaluation of Flower Dynamics, Fruit Yield and Quality of Pomegranate under Different Semi-arid Location of West Bengal

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ABSTRACT

The present study was conducted during January to June of 2018–19 to 2020–21 at the four locations (Chhatna, Pathri, Bamunpathri and Damodarpur) of red and lateritic agro-climatic zone of West Bengal, India to study the flowering dynamics and reproductive system of pomegranate cv. Bhagwa. The experiment was laid out in a Randomized Block Design (RBD). The observations regarding flowering and fruiting of pomegranate, based on pooled data of experimental period exhibited significant variation in different locations. These variations included duration of flowering (144.20–48.45 days), number of flower buds (148.15–47.45), number of flowers (130.60–38.3) in which anthesis observed, number of flowers dropped (93.00–6.85) before anthesis, number of flowers formed on young shoot (9.15–1.15) and aged shoot (26.55-12.30), number of hermaphrodite flowers (37.50–6.15), fruit drop per tree^{-1} (46.65–24.94%), number of fruits per tree at harvest (33.90-4.35), weight of fruit (198.06–85.17 g), fruit yield (6.70–0.36 kg tree^{-1}), fresh weight of seeds (31.22–16.42 g), aril rind ratio (3.44–1.58), seed test weight (6.54–4.0 g), TSS (14.45–13.24°B), acidity (0.75–0.17%), total sugar (14.17–13.53%), reducing sugar (10.96–10.62%) and non-reducing sugar (3.21–2.78%) at harvest. Most of the fruit yield and fruit quality parameters were observed highest at the Damodarpur location. It may be due to good vigour of plants, normal crop load, climatological factors and soil conditions. It can be concluded that the Damodarpur location could be the best location for improved production and productivity of pomegranate and the possibility of obtaining high quality fruits.

KEYWORDS: Flowering, pomegranate, red and lateritic region

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1. INTRODUCTION

Pomegranate (*Punica granatum* L.) is an ancient and valuable fruit crop that belongs to the Punicaceae family. India is one of the world's largest pomegranate producers and has a year-round production cycle with a peak season from February to May. The fruit is popular for its juicy, sweet arils that have a refreshing taste. Pomegranate is also a functional food that has many health benefits, as it contains several phytochemicals that can prevent diseases (Kanoun et al., 2020; Parashar, 2010).

Various pomegranate varieties thrive in diverse regions across India, encompassing more than 25 distinct types. Among the notable cultivars are Bhagwa, Ganesh, G-137, Mridula, Dholka, and Phule Arakta. The current preference leans towards varieties like Bhagwa and Mridula, distinguished by their soft-seeded nature, red rind, and vibrant aril color, along with a heightened juice percentage (Saroj and Kumar, 2019). Pomegranates are widely grown in many Mediterranean nations, including Spain, Morocco, Iran, Egypt, Afghanistan and Baluchistan (Ercisli et al., 2011). In India it is commercially cultivated in Maharashtra parts of Karnataka (Ghosh et al., 2009). In India, pomegranate is commercially cultivated in Maharashtra and parts of Karnataka and Gujarat, where good quality fruits are produced due to dry and hot climate. Presently pomegranate cultivation is gaining popularity in arid and semi-arid regions of India due to it's wide range of adaptability, higher yield, drought hardiness and tolerance to salinity (Reddy, 2011). Recently, the area under pomegranate cultivation in West Bengal is increasing to a large extent due to it's drought hardy nature, wider adaptability and suitability to marginal lands (Anonymous, 2014). In West Bengal, Bankura and Purulia district may be suitable for cultivation of good quality pomegranate due to its unique geographical situation and environmental conditions such as low rainfall (Chell et al., 2023).

In subtropical Central and Western India, there are three distinct seasons of flowering i.e., ambe bahar (January-February), mrig bahar (June–July) and hasth bahar (September-October) (Singh and Kingsly, 2007). Due to hot weather during July-August and inferior colour development and quality of fruits during January–February, both hasta bahar and ambe bahar are not recommended to be harvested in arid and semi-arid climate (Singh et al., 2007, Prasad et al., 1997). Pomegranate produces three types of flower sex form: male (bell shaped), hermaphrodite (vase shaped) and intermediate (tubular). Pollination in pomegranates appears to be ambiguous. Pomegranate can be self-pollinated or cross-pollinated by insects (Da Silva et al., 2013). Fruit grows exclusively from hermaphrodite flowers, while in intermediate flower even if fruit set occurs, the fruit can drop off before reaching to maturity. Wetzstein et al. (2015) revealed that cultivars with a high ratio of hermaphrodite to male flowers have a high fruit yield potential, so encouraging the differentiation of more hermaphrodite flowers may be an obvious way to increase pomegranate yield. The impact of pomegranate cultivation on economic upliftment of farmers is ignored in the research field. So, by doing the research on this aspect it is possible to make the farmers aware about various opportunities of pomegranate cultivation. With this background, a research work was carried out in Bankura district to study the flowering dynamics and reproductive system of pomegranate cv. "Bhagwa" in different locations viz., Pathri, Bamunpathri, Chhatna and Damodarpur of Bankura district of West Bengal.

2. MATERIALS AND METHODS

2.1. Location of the experimental site and treatment details

The experiment was initiated from January to June of 2018–19 to 2020–21 and laid out in a Randomized Block Design (RBD), having four treatments i.e., locations (Chhatna, Pathri, Bamunpathri and Damodarpur) with ten replications. Geographically, the experimental fields were situated under red and lateritic agro-climatic zone of West Bengal. The experimental area was located at an altitude of 448 meters above MSL between 22°38' and 23°38'N latitude and 86°36' and 87°46'E longitude. Tissue cultured propagated Pomegranate plants of Bhagwa variety planted on September, 2017 at a spacing of 4.5×4.5 m^2 were used for the experiment in Bankura district.

2.2. Observations recorded

Flower length and diameter, length of stamen, fruit size in terms of length and diameter were measured with digital Vernier Callipers; fruit weight, aril weight and fresh weight of seed were measured using electric Top Pan Balance,

Fruit set percentage was calculated according to the following formula:

Fruit set (%): (Total no. of fruit set/Total no. of hermaphrodite flowers)×100

Fruit retention percentage was calculated according to the following formula:

Fruit retention (%): (Number of fruits at harvest time/ (Initial no.of fruit set)×100

Fruit drop percentage was calculated according to the following formula:

Fruit drop (%): (Total no. of fruit set/branch-Total no.of fruits at harvest/branch)/Total no. of fruit set/branch)×100

TSS content was determined by Hand refractometer, acidity as well as total sugar and reducing sugar content of fruits were determined using the method described in Anonymous

(2000). Statistical analysis was done through the method detailed by Panse and Sukhatme (1985).

3. RESULTS AND DISCUSSION

The observation on duration of flowering has been presented in Table 1. The pooled data of both the years showed significant variation and the maximum duration of flowering (144.20 days) was recorded at Damodarpur, which was followed at Pathri location (107.10 days). The minimum duration of flowering (48.45 days) was recorded at Chhatna location. According to Komeda (2004), numerous autonomous signaling pathways have been recognized to facilitate flower stimulation in pomegranate as well as blossoming time, such as vernalization, photoperiod, along with autonomic trail.

The data related to the total number of flower buds on branch at different locations are presented in Table 1. The total number of flower buds developed at different locations varied significantly. Pooled data showed that maximum number of flower buds were recorded at Damodarpur location (148.15), while minimum number were observed at Chhatna (47.40).

Table 1: Duration of flowering and Number of flowers formed on branch of pomegranate

Treatments	Duration of flowering (Days)	No. of flower buds	No. of flowers in which anthesis observed	No. of flowers dropped before anthesis
Chhatna	48.45	47.40	38.30	9.10
Pathri	107.10	49.00	41.90	6.85
Bamunpathri	83.10	97.15	83.50	52.55
Damodarpur	144.20	148.15	130.60	93.00
SEm±	3.293	7.733	6.738	4.668
CD (p=0.05)	9.484	22.269	19.403	13.444

The pooled data of both the years showed significant variation and the maximum number of flowers in which anthesis observed (130.60) was recorded at Damodarpur, which was followed at Bamunpathri location (83.50). The minimum number (38.30) was at Chhatna location. In the pooled analysis, the maximum number of flowers dropped before anthesis (93.00) was recorded at Damodarpur, which was followed at Bamunpathri location (52.55). Minimum number (6.85) was at Pathri location. Initiation of flowering is due to both environmental cues and endogenous pathways (Amasino and Michaels, 2010). Control of flowering is an important adaptive trait influenced by environmental and genetic factors (Wetzstein et al., 2015). Depends on genotypes, pomegranates generally take 120–210 days from initiation of flowering to harvest (Kumar et al., 2021).

The data regarding the number of flowers formed on young as well as aged shoot at different locations are presented in Table 2. In the pooled analysis, the highest number of flowers formed on young shoot was observed at Damodarpur (9.15) followed by Bamunpathri (7.55). The lowest number (1.15) was observed at Chhatna. The maximum number of flowers formed on aged shoot was observed at Damodarpur (26.55) followed by Bamunpathri (20.80). The minimum number was observed at Chhatna (12.30). The maximum value at Damodarpur location may be due to good vigour of plants, normal crop load, climatological factors and soil conditions.

Table 2: Distribution of flowers formed according to the age of the shoot of pomegranate

Treatments	No. of flowers formed on young shoot	No. of flowers formed on aged shoot
Chhatna	1.15	12.30
Pathri	1.75	13.00
Bamunpathri	7.55	20.80
Damodarpur	9.15	26.55
SEm±	0.723	0.835
CD (p=0.05)	2.083	2.404

The data concerning to number of male, hermaphrodite and intermediate flowers on branch at different locations has been presented in Table 3. The pooled data of both the years showed significant variation and the maximum number of male flowers on branch (93.00) was recorded at Damodarpur, which was followed at Bamunpathri location (52.55). The minimum number (31.55) was observed at Pathri location. The maximum number of hermaphrodite flowers on branch (37.50) was recorded at Damodarpur, which was followed by Bamunpathri location (30.65). The minimum (6.15) was observed at Pathri location. Pooled data of both the years showed that Bamunpathri location recorded the highest number of intermediate flowers (0.45)

Table 3: Sex form of flowers on branch of pomegranate

Treatments	No. of male flowers	No. of hermaphrodite flowers	No. of intermediate flowers
Chhatna	31.85	6.15	0.30
Pathri	31.55	10.20	0.20
Bamunpathri	52.55	30.65	0.45
Damodarpur	93.00	37.50	0.15
SEm±	5.116	1.986	0.117
CD (p=0.05)	14.734	5.719	NS

while lowest was recorded at Damodarpur (0.15).

The observation regarding the male flower characters at different locations has been presented in Table 4. Pooled data for both the years at Pathri location recorded maximum flower length (4.62 mm) of male flower while minimum was recorded at Damodarpur (3.44 mm). The maximum diameter of flower was observed at Pathri (11.24 mm) followed by Bamunpathri (10.87 mm) and Damodarpur (10.80 mm) locations. The minimum flower diameter was observed at Chhatna (10.60 mm). Pathri location (354.00) recorded maximum number of stamens, while the minimum was recorded at Bamunpathri (205.25). Length of stamens were recorded highest at Chhatna (7.95 mm) followed by Damodarpur (7.66 mm) and lowest (6.37 mm) were recorded at Bamunpathri.The observation regarding the hermaphrodite flower characters at different locations has been presented in Table 5. Pooled data for both the years at Pathri location recorded maximum flower length (5.30 mm) while the minimum was recorded at Damodarpur (4.96 mm). The maximum diameter of flower was observed at Pathri (18.54 mm) followed by Damodarpur (17.84 mm), whereas the minimum was observed at Chhatna (15.52 mm). Pathri location (348.50) was recorded maximum number of stamens, while the minimum was recorded at Bamunpathri (243.40). Highest length of stamens were recorded at Chhatna (9.97 mm) followed by Damodarpur (8.79 mm) and the minimum (5.60 mm) were recorded at Bamunpathri. According to Cizmovic et al. (2016) male flower has shortest pistil (3.93 mm) than hermaphrodite flower with highest number of stamens (320), which is in the function of production of a sufficient amount of pollen and better fertilization. They also observed that hermaphroditic type of flower has maximum length and width (4.75 cm), longer pistil (13.58 mm) and lowest number of stamen (272) than male flower.

Table 4: Flower characters of male flower of pomegranate

Treatments	Flower length (mm)	Diameter of flower (mm)	No. of stamens	Length of stamens (mm)
Chhatna	4.01	10.60	248.80	7.95
Pathri	4.62	11.24	354.00	7.24
Bamunpathri	3.44	10.87	205.25	6.37
Damodarpur	3.56	10.80	272.90	7.66
SEm±	0.074	0.143	5.095	0.315
CD (p=0.05)	0.213	0.411	14.673	0.908

Table 5: Flower characters of hermaphrodite flower of pomegranate

Treatments	Flower length (mm)	Diameter of flower (mm)	No. of stamens	Length of stamen (mm)
Chhatna	5.29	15.52	258.70	9.97
Pathri	5.30	18.54	348.50	8.01
Bamunpathri	5.12	17.40	243.40	6.68
Damodarpur	4.96	17.84	283.85	8.79
SEm±	0.060	0.263	9.795	0.122
CD (p=0.05)	0.173	0.757	28.209	0.352

The observation regarding the intermediate flower characters at different locations has been presented in Table 6. Pooled data of both the years at Chhatna and Pathri locations recorded maximum flower length (5.02 mm), while the minimum length was recorded at Damodarpur (4.88 mm). The maximum diameter of flower was observed at Damodarpur (15.65 mm) followed by Chhatna (15.14 mm) and the minimum was observed at Bamunpathri (13.42 mm). At Bamunpathri location (228.20) number of stamens were maximum, while the minimum was recorded at Pathri (205.30). Length of stamens were recorded highest at Chhatna (8.72 mm) followed by Pathri (8.49 mm) and the minimum (5.60 mm) were recorded at Bamunpathri.

Table 6: Flower characters of intermediate flower of pomegranate

Treatments	Flower length (mm)	Diameter of flower (mm)	No. of stamens	Length of stamens (mm)
Chhatna	5.02	15.14	216.50	8.72
Pathri	5.02	14.75	205.30	8.49
Bamunpathri	4.94	13.42	228.20	5.60
Damodarpur	4.88	15.65	214.00	6.40
SEm±	0.076	0.189	6.781	0.102
CD (p=0.05)	NS	0.545	NS	0.295

The data pertaining to fruit set per cent on branch at different locations has been presented in Table 7. The percentage of fruit set on branch varied significantly at different locations during 1st year and 2nd year. Pomegranate fruit production requires the coordination of a number of key reproductive processes, including flower development, pollination, bisexual and male flower types, fruit set, fruit attributes related to size, flower vigor, flower receptivity, and aril development (Wetzstein et al., 2015). Pooled data of both the years revealed that fruit set was highest (61.73%) at Damodarpur location followed by Bamunpathri (61.49%), whereas the lowest was recorded at Pathri (37.83%).

The data regarding fruit retention on aged as well as young shoot at different locations are presented in Table 7. Pooled data of both the years showed that Damodarpur location recorded highest fruit retention (74.62%) on aged shoot

Table 7: Fruit retention percentage on aged and young shoot of pomegranate

Treatments	Fruit set on branch (%)	Fruit retention on aged shoot (%)	Fruit retention on young shoot (%)
Chhatna	49.36	31.66	22.50
Pathri	37.83	51.30	44.16
Bamunpathri	61.49	67.07	53.66
Damodarpur	61.73	74.62	54.75
SEm±	3.701	3.378	7.586
CD (p=0.05)	10.658	9.730	21.847

while lowest was recorded at Chhatna (31.66%). Babu (2010) found the highest fruit retention on aged shoot of pomegranate. For young shoot, highest (54.75%) was recorded at Damodarpur location followed by Bamunpathri (53.66%), whereas the lowest (12.50%) was recorded at Chhatna. Male flowers have rudimentary ovary, whereas intermediate have degenerative ovary and drop before maturity (Babu et al., 2011). It has been observed that initially emerged flowers are male and they drop within a short period (Chandra and Meshram, 2010). Therefore, cultivars with higher hermaphrodite flower to male flower ratio will have a higher fruit yield potential (Holland et al., 2009).

The data recorded on percentage of fruit drop at different locations are presented in Table 8. Pooled data of both the years showed that Chhatna location (46.65%) recorded highest fruit drop tree^{-1} while lowest value was recorded at Damodarpur (24.94%).

Table 8: Fruit drop percentage and yield of pomegranate

Treatments	Fruit drop tree^{-1} (%)	No. of fruits tree^{-1} at harvest	Yield (kg tree^{-1})
Chhatna	46.65	4.35	0.364
Pathri	38.69	7.70	1.221
Bamunpathri	29.49	29.75	3.872
Damodarpur	24.94	33.90	6.709
SEm±	3.281	1.191	0.172
CD (p=0.05)	9.450	3.430	0.497

The pooled data showed significant variation and maximum number of fruits tree^{-1} were observed at Damodarpur (33.90) followed by Bamunpathri (29.75). The minimum number of fruits tree^{-1} (4.35) were observed at Chhatna. Masalkar et al. (2009) noted that the yield and quality of pomegranate fruits depend upon the flower regulation which includes selection of flowering flush, leaf shedding intensity after the rest period, pruning method and intensity, application of fertilizers and use of micronutrients.

The fruit yield per tree varied significantly at different locations. Pooled data of both the years revealed that highest yield was recorded at Damodarpur (6.709 kg) followed by Bamunpathri (3.872 kg) while the minimum (0.364 kg) was recorded at Chhatna. The minimum value at Chhatna location might be due to low soil fertility, low rainfall and less vigour of plants. Similar result also found by Boussaa et al. (2020), they revealed a significant variation of yield from one region to another.

The data concerned to physical characteristics of fruit at different locations has been presented in Table 9 and Table 10. Pooled value of fruit weight showed that Damodarpur recorded the highest weight of fruit (198.06 g) which was followed by Pathri (158.09 g), while lowest (85.17 g) was recorded at Chhatna. Highest fruit length was recorded at Damodarpur (74.85 mm) followed by Bamunpathri (69.19 mm) and the lowest (55.93 mm) was recorded at Chhatna. Highest diameter of fruit was observed at Damodarpur (74.59 mm) followed by Pathri (103.24 mm) and the lowest (55.58 mm) was recorded at Chhatna. Maximum aril weight fruit^{-1} (130.33 g) was recorded at Damodarpur, whereas the lowest (51.55 g) was recorded at Chhatna. According to Zaouay et al. (2012) fruit size varies among varieties and is influenced by climate and methods of cultivation. In other research, it was found that the pomegranate fruit size was

Table 9: Physical characteristics of fruit of pomegranate

Treatments	Weight of fruit (g)	Length of fruit (mm)	Diameter of fruit (mm)	Weight of arils (g)
Chhatna	85.17	55.93	55.58	51.55
Pathri	158.09	65.78	66.77	103.24
Bamunpathri	130.72	69.19	71.03	100.60
Damodarpur	198.06	74.85	74.59	130.33
SEm±	3.528	1.101	0.959	2.195
CD (p=0.05)	10.160	3.170	2.761	6.323

Table 10: Physical characteristics of fruit of pomegranate

Treatments	Fresh weight of seeds (g)	Aril rind ratio	Seed test weight (g)
Chhatna	16.42	1.58	4.00
Pathri	20.47	1.88	4.82
Bamunpathri	26.19	3.44	4.69
Damodarpur	31.22	1.99	6.54
SEm±	0.633	0.108	0.167
CD (p=0.05)	1.824	0.312	0.482

highly influenced by the climate (Mditshwa et al., 2013; Schwartz et al., 2009). The highest fresh weight of seeds (31.22 g) fruit^{-1} was observed at Damodarpur followed by Bamunpathri (26.19 g). The lowest value (16.42 g) was noticed at Chhatna location. Pooled value for both the years of aril/rind ratio was maximum (3.44) at Bamunpathri followed by Damodarpur (1.99) location. The lowest aril/rind ratio (1.58) was recorded at Chhatna. Among the physical parameters of fruit, based on pooled data of both the years, maximum weight of fruit, length of fruit, diameter of fruit, weight of arils/fruit, fresh weight of seeds, seed test weight was recorded at Damodarpur location might be due to good vigour of plants, normal crop load on the plant, good soil moisture and fertility of soil. The flower characteristics of Damodarpur location might have favoured higher fruit weight. These physical parameters of fruit were minimum at Chhatna location might be due to soil fertility condition.

The data regarding the bio-chemical characteristics of fruits at different locations has been presented in Table 11. Pooled data of both the years revealed that total soluble solid content of fruits was highest at Chhatna (14.45°Brix) while the minimum (13.24°Brix) was recorded at Bamunpathri location. The Pathri location recorded highest acidity (0.75%). The lowest acidity was recorded at remaining three locations (0.17%) viz., Chhatna, Bamunpathri and Damodarpur. Highest total sugar in fruits was observed at Bamunpathri (14.15%), whereas the lowest (13.53%) was recorded at Chhatna. At Bamunpathri highest reducing sugar (10.96%) was observed while lowest was recorded at Chhatna (10.62%). The pooled data of both the years for non-reducing sugar was highest (3.21%) at Damodarpur and Bamunpathri. The lowest non-reducing sugar of fruits (2.78%) was recorded at Pathri. According to Thakur et al. (2011) among the chemical characteristictics of fruits, no specific trend was observed at any particular locations. According to Ghasemi et al. (2023), pomegranate cultivars in different regions had show different fruit quality characters. Musyarofah et al. (2020) found that there was a variation of fruit quality of guava in response to different locations.

Table 11: Bio-chemical characteristics of fruit of pomegranate

Treatments	Total soluble solid (°B)	Acidity (%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)
Chhatna	14.45	0.17	13.53	10.62	2.91
Pathri	13.85	0.75	13.63	10.84	2.78
Bamunpathri	13.24	0.17	14.17	10.96	3.21
Damodarpur	13.78	0.17	14.12	10.94	3.21
SEm±	0.184	0.295	0.359	0.394	0.419
CD (p=0.05)	0.531	NS	NS	NS	NS

4. CONCLUSION

The observations regarding flowering and fruiting of pomegranate were maximum at Damodarpur location. It might be due to good vigour of plants, normal crop load, climatological factors and soil conditions.

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