

Original Research Paper

Heat unit requirement and performances of litchi under Sub-Himalayan terai region of West Bengal

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ABSTRACT

To determine the heat unit requirement and assess its subsequent effects on flowering and fruiting characteristics, a field experiment was conducted during 2018-19 with seven cultivars of litchi viz., Calcuttia, Elaichi, Bedana, Bombai, China, Shahi and Muzaffarpur in randomized block design. Bedana showed better result in terms of maximum fruit weight (17.88g), lowest seed content (10.84%), maximum fruit diameter (3.01 cm), maximum fruit volume (18.70 ml), highest TSS (15.87^o Brix), total sugar (15.96%), reducing sugar (12.61%), and ascorbic acid (29.47 mg/100g) content.

Keywords: Bud break, flowering, fruiting, growing degree days and panicle.

INTRODUCTION

Litchi (*Litchi chinensis* Sonn.), belonging to the family Sapindaceae is an evergreen, subtropical fruit and popularly known as 'Queen of sub-tropical fruits', 'Pearl of India' for its excellent aromatic flavour and sweet aril taste (Nakasone and Paull, 1998). Litchi flowers are of three types, staminate or purely male flowers, female or hermaphrodite functioning as female and hermaphrodite flower functioning as male or pseudo-hermaphrodite (Chaudari, 1940, Mustard *et al.*, 1953 and Menzel, 1984). Litchi is very specific to its climatic requirement and requires seasonal temperature variation for best flowering and fruiting (Garcia-Perez and Martins, 2006). It is considered as the essential sub-tropical fruit crops and requires diurnal variation for flowering and fruiting. Litchi cultivation is successful in areas having average minimum temperature of 10°C from December to February and 32°C in April to June is considered more congenial. Climate is the most important limiting factor in the expansion of area under this fruit. The role of growing degree days (GDD) or heat units are often used to predict the growth stages including the date when a flower will bloom or a crop will reach to the maturity. Heat units or growing degree days is the number of

temperature degrees above a certain threshold base temperature within consecutive 24 hours period. The heat unit varies among the crops or even within cultivars of the same crop (Kanzaria *et al.*, 2015). Heat units have an important role in horticultural crops and it helps in estimating the growth stages of plants, determines harvesting index. It also assesses the suitability of a region for growing a crop to estimate the length of various phenological stages and to predict maturity and quality characteristics of fruits (Khan *et al.*, 2007; Shinohara, 2013; Koshita, 2014). The effect of temperature on the phenological development, flowering and fruiting performance was studied by the different workers for predicting the growth stages, yield and physiological maturity (Swan *et al.*, 1989, Singh *et al.*, 2007). The prevailing agro-climatic condition in the sub-Himalayan Terai region is suitable for litchi cultivation. However, the information regarding the influence of heat units on flower bud development, panicle emergence, flowering and fruiting characteristics of litchi is very limited in literature. Keeping in view the utmost importance of heat units, the present study was designed to determine the effect of heat units and performance of different litchi cultivars in the foothills of eastern Indian sub-Himalayan Terai region of West Bengal.



MATERIALS AND METHODS

To determine the heat unit requirement and assess its subsequent effects on flowering and fruiting characteristics of litchi, the experiment was conducted at Instructional Farm under the Dept. of Pomology and Post-Harvest Technology, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, situated in the foothills of eastern Indian Himalayas. Seven important commercial litchi cultivars (T_1 - Calcuttia, T_2 – Elaichi, T_3 – Bedana, T_4 - Bombai, T_5 - China, T_6 - Shahi and T_7 - Muzaffarpur) were selected as treatments and the experiment was carried out in randomized block design with three replication and two plants per replication. Heat unit was calculated by taking the average of the daily maximum and minimum temperatures compared to a base temperature, T_{base} (usually 10°C). The formula applied for calculation of heat unit is $(T_{max} + T_{min}) / 2 - T_{base}$ (Monteith, 1984; Rai *et al.*, 2002). The heat units for different phenological phases were recorded. The different parameters for flowering and fruiting characteristics were recorded as per the standard methodology. The bio-chemical parameters were determined following Ranganna (1986) and A.O.A. C. (1984). For statistical analysis the mean separation for different parameter were performed using Least Significant Difference (LSD) test ($Pd^{0.05}$). Normality of residuals under the assumption of ANOVA was tested using Kolmogorov-Smirnov, Shapiro-Wilk, Cramer-Von Mises and Anderson Darling procedure using Proc-Univariate procedure of SAS (version 9.3).

RESULTS AND DISCUSSION

Response of heat unit requirement on flowering of litchi

The heat unit requirement of different phenological phases in litchi cultivars were recorded (Table-1). The heat unit requirement for bud break to panicle appearance was maximum in cv. China (144.03°C), which was statistically at par with cvs. Bombai, Calcuttia, Shahi and lowest in Elaichi (94.58°C). Subsequently, it was observed (Table-2a) that cv. Bombai required maximum number of days (17.83 days) for bud break to panicle emergence, statistically at par with cv. China (17.27 days), while the cv. Elaichi recorded the minimum number of days (12.47 days). For panicle appearance to

flowering, the heat unit requirement was maximum in cv. Bombai (400.16°C) which was statistically at par with cvs. Elaichi (371.31°C), Bedana (340.20°C), Muzaffarpur (335.26°C) and Calcuttia (329.24°C), whereas, cv. Shahi required lowest (312.38°C) heat unit (Table-1). However, the duration of panicle emergence was not significant among the different cultivars (Table-2a) but maximum number of days (35.10 days) was required in cv. Elaichi and lowest (29.52 days) in cv. Shahi. There was no significant variation observed during flowering to fruit set stage for heat unit requirement, however, it was recorded maximum in cv. Muzaffarpur (347.78°C) and minimum (326.83°C) in cv. Calcuttia. The duration of flowering to fruit set was recorded maximum in cv. Muzaffarpur (28.98 days) which was statistically at par with all other cultivars except for cv. Bombai (23.95 days). The litchi varieties exhibited significant variation for heat units requirement during fruit set to harvesting stages and cv. Bedana registered the maximum heat unit requirement (1133.80°C) which was at par with cv. China (1076.33°C), whereas, the cv. Shahi required the minimum (950.74°C).

Flowering parameters

It is believed that litchi needs a period of vegetative dormancy to initiate floral buds (Das *et al.*, 2004). The maximum length of panicle (19.00 cm) was observed in cv. Muzaffarpur, while the minimum length (16.16 cm) was recorded in cv. Bedana. The flowering duration was statistically similar for different cultivars and cv. Muzaffarpur exhibited the maximum flowering duration (25.83 days). The maximum number of flowers per panicle was produced by the cv. Shahi (593.87) while it was minimum for cv. Bombai (422.80). Number of hermaphrodite flowers as functional male showed significant variation and ranged from 59.19% (Bombai) to 67.18 % (Muzaffarpur). The highest percentage of hermaphrodite flowers as functional female (21.26%) was recorded in the cv. Bombai while China recorded the lowest percentage (17.94%) of hermaphrodite flowers as functional female. Bedana recorded the highest percentage of male flowers (19.60%) and Muzaffarpur registered the lowest percentage of male flowers (14.46%) (Table 2b).

Table 1. Heat unit requirement by different litchi cultivars

Treatments	Bud break to panicle appearance (°C)	Panicle appearance to flowering (°C)	Flowering to fruit set (°C)	Fruit set to harvesting (°C)
T ₁ (Calcuttia)	128.72 ^{abc}	329.24 ^{ab}	326.83 ^a	1012.48 ^b
T ₂ (Elaichi)	94.58 ^c	371.31 ^{ab}	329.67 ^a	957.37 ^b
T ₃ (Bedana)	104.50 ^{bc}	340.20 ^{ab}	334.68 ^a	1133.80 ^a
T ₄ (Bombai)	136.85 ^{ab}	400.16 ^a	336.35 ^a	1010.06 ^b
T ₅ (China)	144.03 ^a	322.33 ^b	347.08 ^a	1076.33 ^a
T ₆ (Shahi)	121.44 ^{abc}	312.38 ^c	347.72 ^a	950.74 ^b
T ₇ (Muzaffarpur)	100.24 ^c	335.26 ^{ab}	347.78 ^a	962.54 ^b
S.Em. (±)	11.80	23.94	10.54	20.41
L.S.D (Pd ^{0.05})	36.35	73.77	NS	62.90

Means followed by same alphabet are not significantly different

Table 2a. Flowering parameters of different litchi cultivars

Treatments	Days taken for bud break to panicle emergence	Duration of panicle emergence (days)	Length of panicle (cm)	Duration of flowering (days)
T ₁ (Calcuttia)	12.67 ^c	29.55 ^a	17.42 ^{bc}	24.48 ^a
T ₂ (Elaichi)	12.47 ^c	35.10 ^a	16.69 ^{cd}	24.12 ^a
T ₃ (Bedana)	14.83 ^{bc}	30.20 ^a	16.16 ^d	23.58 ^a
T ₄ (Bombai)	17.83 ^a	31.47 ^a	17.99 ^{ab}	22.90 ^a
T ₅ (China)	17.27 ^{ab}	29.55 ^a	16.39 ^{cd}	24.13 ^a
T ₆ (Shahi)	13.95 ^c	29.52 ^a	17.32 ^{bcd}	25.38 ^a
T ₇ (Muzaffarpur)	13.65 ^c	30.02 ^a	19.00 ^a	25.83 ^a
S.Em.(±)	0.84	2.41	0.40	1.21
L.S.D (Pd ^{0.05})	2.59	NS	1.23	NS

Means followed by same alphabet are not significantly different

Table 2b. Flowering parameters of different litchi cultivars

Treatments	Total no of flowers per panicle	Hermaphrodite male (%)	Hermaphrodite female (%)	Male (%)
T ₁ (Calcuttia)	476.52 ^{cd}	64.41 ^a	19.67(4.43) ^{ab}	15.84(3.98) ^{bcd}
T ₂ (Elaichi)	457.35 ^{de}	65.70 ^a	18.33(4.28) ^{ab}	17.20(4.15) ^{abcd}
T ₃ (Bedana)	518.92 ^{bc}	59.64 ^b	20.09(4.47) ^{ab}	19.60(4.42) ^a
T ₄ (Bombai)	422.80 ^e	59.19 ^b	21.26(4.61) ^a	18.11(4.24) ^{abc}
T ₅ (China)	528.83 ^b	63.67 ^a	17.94(4.23) ^b	18.96(4.35) ^{ab}
T ₆ (Shahi)	593.87 ^a	64.83 ^a	19.52(4.42) ^{ab}	15.56(3.93) ^{cd}
T ₇ (Muzaffarpur)	593.83 ^a	67.18 ^a	18.48(4.30) ^{ab}	14.46(3.80) ^d
S.Em.(±)	16.97	1.30	0.12	0.12
L.S.D (Pd ^{0.05})	52.03	4.01	0.36	0.38

Means followed by same alphabet are not significantly different (Value in parenthesis is the square root transformed value)

Fruiting characteristics

Duration of fruit set, fruit set percentage and fruits per panicle was statistically similar for all the cultivars under study. Calcuttia variety showed the maximum duration (11.97 days) for fruit set and was observed minimum in cv. Bombai (10.68 days). The fruit set percentage varied from 3.41% (Muzaffarpur) to 4.79% (Bombai), whereas, number of fruits per panicle was observed from 18.08 (Bedana) to 23.22 (Shahi). Physio-chemical properties of fruits were significantly varied among the different cultivars studied under this experiment. Higher fruit weight (17.88g), fruit diameter (3.01cm) and fruit volume (18.70ml) were observed in cv. Bedana. Small fruit of litchi was observed in cv. China (11.23g). The maximum fruit length (3.17 cm) was observed in cv. Bombai; however, the higher peel content (29.94%) and seed content (27.90%) makes the variety with high waste index (1.51). The fruit pulp content was highest in cv. Muzaffarpur (62.09%) and it was statistically at par with cvs. Calcuttia, Elaichi, Bedana and Shahi. Seed content was lowest in cv. Bedana (10.84%). The seed size (30.65%) and peel content (28.50%) were higher in cv. China resulting maximum waste index (1.66g) among the different varieties studied under this experiment. The minimum fruit length (2.71 cm) was recorded in Bedana. The data on

fruit diameter showed that the maximum fruit diameter (3.01 cm) was recorded in Bedana, whereas, Muzaffarpur recorded the minimum fruit diameter (2.33 cm). The maximum specific gravity (1.07) was observed in Elaichi while the minimum specific gravity (0.84) was recorded in Shahi. Highest pulp content (62.09%), and lowest waste index (0.64g) was recorded in Muzaffarpur. China recorded the maximum waste index (1.66g), seed content (30.65%). Percentage of juice was maximum (55.08%) in Shahi while maximum peel (29.94%), minimum juice (30.03%) and was recorded in Bombai (Table 4b).

Bio-chemical characteristics

Litchi cv. Bedana was recorded with maximum total soluble solids (TSS) content (15.87°Brix), total sugar content (15.96%), reducing sugar (12.61%) and ascorbic acid content (29.47 mg/100g), whereas, cvs. Elaichi, China, Muzaffarpur, and Shahi recorded with lowest amount of TSS (13.93° Brix) and total sugar (11.45%), reducing sugar (9.68%), and ascorbic acid (19.72 mg/100g) content, respectively (Table 5).

There was a variation among the litchi cultivars for different parameters studied under this experiment which indicates the genotypic differences. Higher heat unit requirement of cv. Bedana and China for fruit set to harvesting indicates it late maturity in

Table 3. Fruiting characteristics of different litchi cultivars

Treatments	Date of first fruit setting	Duration of flowering to fruit set (days)	Duration of fruit setting (days)	Percent fruit set (%)	Fruits per panicle
T ₁ (Calcuttia)	22 nd March	27.08 ^{ab}	11.97 ^a	4.25 (2.06) ^a	19.83 ^a
T ₂ (Elaichi)	22 nd March	26.77 ^{ab}	11.53 ^a	4.29 (2.06) ^a	19.03 ^a
T ₃ (Bedana)	26 th March	26.58 ^{ab}	11.02 ^a	3.56 (1.88) ^a	18.08 ^a
T ₄ (Bombai)	2 nd April	23.95 ^b	10.68 ^a	4.79 (2.18) ^a	19.83 ^a
T ₅ (China)	25 th March	27.55 ^{ab}	11.17 ^a	3.86 (1.97) ^a	20.27 ^a
T ₆ (Shahi)	23 rd March	28.90 ^a	11.57 ^a	3.85 (1.95) ^a	23.22 ^a
T ₇ (Muzaffarpur)	22 nd March	28.98 ^a	11.90 ^a	3.41 (1.85) ^a	19.75 ^a
S.Em.(±)	—	1.24	0.45	0.11	2.29
L.S.D (Pd ^{0.05})	—	3.83	N.S.	N.S.	N.S.

Means followed by same alphabet are not significantly different (Value in parenthesis is the square root transformed value)

Table 4a. Physical characteristics of fruits of different litchi cultivars

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit volume (ml)	Specific gravity
T ₁ (Calcuttia)	17.30 ^{ab}	3.14 ^{ab}	2.70 ^b	17.63 ^{ab}	0.99 ^{ab}
T ₂ (Elaichi)	13.85 ^{bc}	2.86 ^{bcd}	2.43 ^c	13.07 ^c	1.07 ^a
T ₃ (Bedana)	17.88 ^a	2.71 ^d	3.01 ^a	18.70 ^a	0.96 ^{abc}
T ₄ (Bombai)	13.32 ^c	3.17 ^a	2.48 ^{bc}	13.87 ^c	0.97 ^{abc}
T ₅ (China)	11.23 ^c	3.06 ^{ab}	2.35 ^c	13.30 ^c	0.87 ^{bc}
T ₆ (Shahi)	12.43 ^c	3.01 ^{abc}	2.47 ^{bc}	15.03 ^{bc}	0.84 ^c
T ₇ (Muzaffarpur)	11.78 ^c	2.78 ^{cd}	2.33 ^c	13.70 ^c	0.88 ^{bc}
S.Em.(±)	1.26	0.09	0.09	1.11	0.05
L.S.D (Pd ^{0.05})	3.89	0.27	0.26	3.43	0.14

Means with the same letter are not significantly different

Table 4b. Physical composition and waste index of litchi fruits

Treatments	Juice (%)	Peel (%)	Pulp (%)	Seed (%)	Waste index (g)
T ₁ (Calcuttia)	46.12 ^{ab}	17.80 ^c	59.98 ^a	22.22 ^{bc}	0.79 ^{bc}
T ₂ (Elaichi)	44.48 ^b	22.16 ^c	58.73 ^a	19.11 ^c	0.92 ^{bc}
T ₃ (Bedana)	44.11 ^b	29.82 ^a	59.34 ^a	10.84 ^d	0.70 ^{bc}
T ₄ (Bombai)	30.03 ^c	29.94 ^a	42.16 ^b	27.90 ^{ab}	1.51 ^a
T ₅ (China)	37.44 ^{bc}	28.50 ^{ab}	40.85 ^b	30.65 ^a	1.66 ^a
T ₆ (Shahi)	55.08 ^a	23.14 ^{bc}	52.84 ^a	24.02 ^{bc}	1.19 ^{ab}
T ₇ (Muzaffarpur)	40.65 ^b	18.75 ^c	62.09 ^a	19.16 ^c	0.64 ^c
S.Em.(±)	3.41	1.81	3.43	2.08	0.18
L.S.D (Pd ^{0.05})	10.50	5.58	10.57	6.42	0.54

Means followed by same alphabet are not significantly different

Table 5. Biochemical properties of litchi fruits

Treatments	TSS (°Brix)	Total sugar (%)	Reducing sugar (%)	Acidity (%)	TSS:acid ratio	Ascorbic acid (mg/100g)
T ₁ (Calcuttia)	14.63 ^{bc}	13.15 ^{abc}	11.55 ^b	0.42 ^b	34.80 ^{bcd}	23.83 ^b
T ₂ (Elaichi)	13.93 ^d	14.71 ^{ab}	10.87 ^c	0.42 ^b	33.11 ^{cd}	28.82 ^a
T ₃ (Bedana)	15.87 ^a	15.96 ^a	12.61 ^a	0.54 ^a	29.86 ^d	29.47 ^a
T ₄ (Bombai)	15.20 ^b	12.60 ^{bcd}	12.41 ^a	0.40 ^b	38.36 ^{bc}	20.37 ^c
T ₅ (China)	14.37 ^{cd}	11.45 ^b	10.62 ^{cd}	0.52 ^a	27.89 ^d	23.62 ^b
T ₆ (Shahi)	14.87 ^{bc}	12.30 ^a	10.95 ^{cd}	0.32 ^c	47.41 ^a	19.72 ^c
T ₇ (Muzaffarpur)	14.80 ^{bc}	11.72 ^b	9.68 ^d	0.36 ^{bc}	41.34 ^{ab}	23.40 ^b
S.Em.(±)	0.21	0.17	1.02	0.03	2.50	0.40
L.S.D (Pd ^{0.05})	0.63	0.53	3.16	0.08	7.71	1.24

Means followed by same alphabet are not significantly different

this agro-climatic situation. The wide variation in heat unit may be due to the varied maturity period of different cultivars indicates that each genotype needs certain amounts of accumulation of heat units for completion of different phenophases which cause the variation in maturity period (Rai *et al.*, 2003). Flowering span might be differed in case of climatic condition, but flowering span of particular variety is over only when the required heat units are accumulated (Byrne and Bacon, 1992). The flowering parameters result shows similar trends as observed by Banerjee and Chaudhary (1944), Mustard *et al* (1953), Chadha and Rajpoot (1969), Pivovaro (1974) and Kumar (2000). The data indicated that the maximum titrable acidity (0.54%) was recorded in Bedana while the minimum titrable acidity content (0.32%) was recorded in Shahi. TSS:acid ratio was maximum (47.41) in Shahi and the minimum TSS:acid ratio (27.89) was recorded in China. The differences of fruit physiochemical properties indicate the relationship between cultivars and heat unit requirement.

CONCLUSION

There was a varietal difference regarding the heat unit requirements for different phenological phases resulting variation on flowering and fruiting characteristics. Bedana required maximum heat unit (1133.80°C) for attaining the harvesting stage from fruiting cultivar and it was lowest in cv. Shahi (950.74°C). Litchi cv. Bedana exhibited promising results in terms of flowering, fruiting and quality parameters with respect to high fruit weight (17.88g), fruit diameter (3.01cm), fruit volume (18.70 ml), TSS (15.87°Brix), total sugar content (15.96%), reducing sugar content (12.61%), ascorbic acid content (29.47 mg/100g) and may be recommended as promising cultivar in terms of better-quality characters under the sub-Himalayan Terai region of West Bengal condition.

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