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Research Paper

Agrometeorological evaluation of french bean (*Phaselus vulgaris*) genotypes in nilgiri hills

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ABSTRACT

A Field experiment was conducted at Horticulture Research Station (HRS) Ooty, to evaluate 11 French bean genotypes for yield and agrometeorological traits under high altitude of Nilgiri Hills. Analysis revealed significant variations among the genotypes in terms of yield and agrometeorological indices. Maximum plant height was recorded in IC 271,523, while EC 324,496 had highest pods/plant. The highest pod yield of 140.99 q/ha was obtained from EC 324,986 followed by IC 271,523 (125.19 q/ha). Days taken to first flowering phenophase phenophase (50 days after sowing, DAS) was lowest in case of genotypes EC 271,499. For 50% flowering and maturity, genotypes EC 324986 took least duration of 64 days and 119 days respectively. Among the genotypes the growing degree days were ignificantly varied for the days to first flowering, 50% flowering and maturity. The highest GDD of 475.7°C day recorded was with EC–271,564, 590.8°C day (EC—271,564) and 1106.1°C day (EC-324,986) at the phenophase of days to first flowering, 50% flowering and maturity respectively. There was significant difference recorded among the genotypes in terms of heliothermal unit except at maturity, heat use efficiency (HUE) and Photothermal unit. Heat use efficiency was found to be postiviey and highly correlated ($r=0.90^{**}$) with yield. The genotypes of EC 324986 and IC 271,523 can be used for develoing high yielding climate resilient French bean varieties for high altitude of NIlgiri hills of Tamil Nadu.

***Key words*: ** Crop phenology, Growing degree days, Helio-thermal unit, Heat use efficiency, French bean

French bean (*Phaseolus vulgaris*) is an important annual legume vegetable crop. It is cultivated for its tender pods, shelled beans, and dry beans. It is a rich source of protein, minerals and vitamins and hence considered as a food and nutrition crop (Noopur *et al.,* 2019) and hence cultivated worldwide for direct human consumption. French bean is a highly diversified crop of the Nilgiri Hills of Tamil Nadu**.** Earlier it was being grown on marginal land without much care and under low input production system (Noopur *et al.,* 2021), but recognizing its resilience to pests and diseases, along with superior nutritional and market value (Layek *et al.,* 2021), farmers have adopted French bean cultivation on mainland. Moreover, when grown on marginal land, proper nutrients and water management are being ensured for successful crop production.

French bean is short duration, quick growing high yielding crop (Layek *et al*., 2016) but the growth and productivity get affected by the environmental conditions mainly air temperature, sunlight, and rainfall (Kumar, 2022). The knowledge of agrometeorological indices will be helpful for improving French bean yield even under high hill altitude conditions. French bean, depending on agro-climatic conditions, can be grown round year in different regions of India (Pande *et al.,* 2024), however temperature play a significant role on its growth and yield of crops. Plant require specific temeprature conditions to reach successfully to various phenological stages (Mehta *et al.,* 2020). Hence, sowing of crop at optimal time ensures to favorable weather conditions which promotes proper growth, development (Basnet *et al.,* 2022) and finally yield.

The optimal temperature for cultivation is 15-25°C, the temperature below 10°C or above 35°C, cause flower drop, leading to yield reduction (Kumar, 2022). Variation in crop phenological stages from sowing to harvest is influenced by accumulation of heat or temperature above base temperature. The duration, growth and yield of a crop are determined by the thermal and photoperiod conditions, it encounters throughout its life cycle (Mehta *et al.,* 2020).

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Low temperature and low humidity stress prevailing in high hills may cause substantial yield reduction and prolong the growing period, necessitating the need to identify cultivar/genotypes suitable for high hills. Heat stress in French bean has primarily due to high night temperature during the reproductive phase.

Selection of improved genotypes for specific agro climatic conditions plays remarkable role in combating food and nutritional security (Panwar *et al*., 2019) through maximization French bean yield. The genotyepe should be climate resilient and responsive to agroclimate of the region. The heat unit requirement or growing degree days (GDD) is being used for characterizing the thermal response of French bean, while the quantification of heat use efficiency (HUE) is useful for determining yield potential of different cultivars grown in the same environment. The concept of heat unit has been linked to phenological development of a crop, helping to predict physiological maturity and yield (Mehta *et al*., 2020) and hence crop production with increased temperature is a challenge (Verma *et al*., 2020). Agro-meteorological indices based on temperature, such as GDD, can prove to be quite useful in predicting the growth and yield of French bean. The duration of growth stages is also directly relates to temperature, which can be calculated with the help of the daily air temperature (Kumar *et al*., 2017). Therefore, knowledge of different phenophase of French bean is important to understand the effect of growing environment and their impact on French bean yield. The work on micro-climate effect on French bean has not been much done especially for Nilgiri Hills of Tamil Nadu and hence it is difficult to guide farmers about agro-meteorological aspect of bean production. Secodnly, genotype evalautation for developinh high yielding, climate resilient and market preferred varieties to maximize productivity, economic viability and support sustainable vegetable production in high altitude areas is necessary. Keeping in view, the present study was planned to assess the influence of agrometeorological factors on their performance under high hill altitude conditions of Nilgiri Hills.

MATERIALS AND METHODS

A Field experiment was conducted at horticulture research station (HRS), TNAU, Ooty, Nilgiri Hills, during 2018 and 2019. The experimental site was located at latitude of 16.8°N and 81.5°E with an altitude of 2240 m above mean sea level. The maximum temperature during the course of experimentation was 24.6 °C on 18th, 23th and 28th April, 2018 and minimum temperature was 8.2°C was on 2nd March, 2018. The maximum sunshine hourse were observed during first (8.37 hours) and second fortnight of March and April (7.75 hours) month, respectively, while lowest were in the month of May month (Fig. 1). The annual average rainfall was around 1,236 mm. The maximum temperature during summer touches 27°C during June while lowest temperature was –4°C to –5°C in the month of January. The treatment consisted of 11 genotypes (Table 1) were tested in randomised block design with three replications. The field was thoroughly ploughed and applied FYM @ 10 t/ha. The seeds were treated with *Rhizobium* culture and sown on 14th March, 2018 with a spacing of 45 cm × 10 cm. At the time of sowing a recommended dose of N : P : K @ 15 : 60 : 40 was applied as

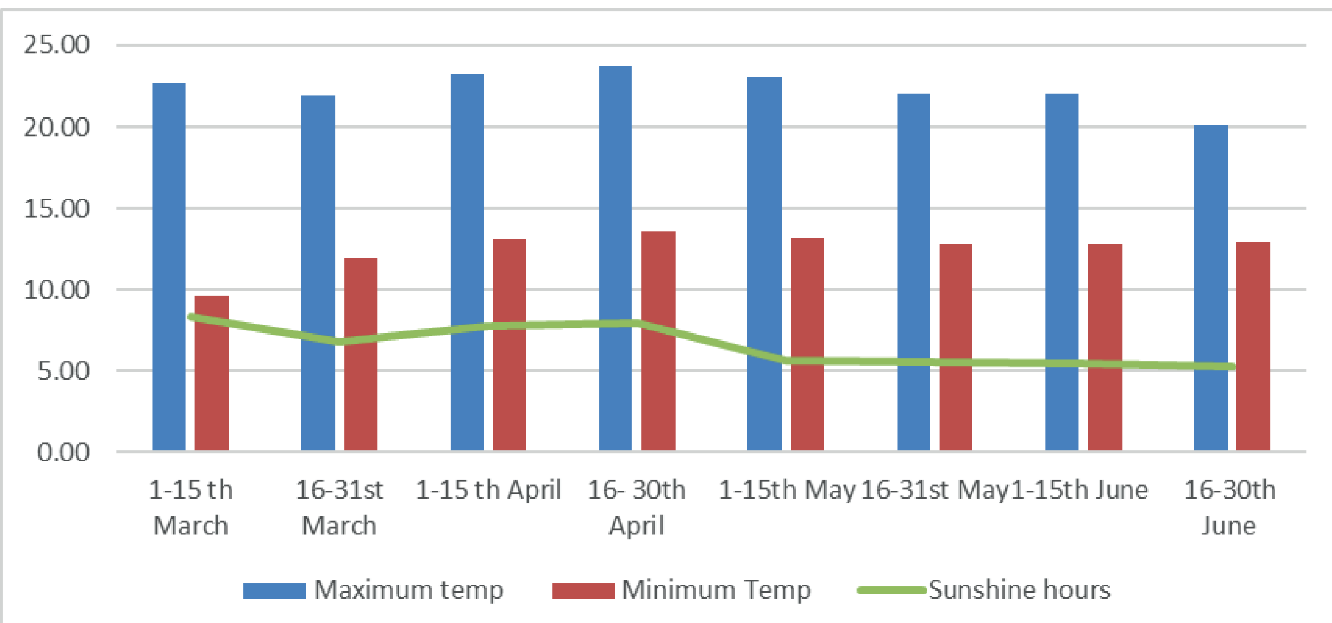

Fig 1. Monthly variations in temperature and sunshine hours

Table 1. Growth, yield attributes and yield of French bean genotypes

Genotypes	Plant Height (cm)	No of Pods/plant	Pod length (cm)	Single Pod weight (g)	Pod Yield (q/ha)
IC 311094	63.13	26.97	16.84	1.85	100.81
EC 284247	44.05	24.28	11.80	1.92	103.29
EC 271563	46.06	20.34	11.42	2.21	97.13
EC 271564	52.61	17.90	11.66	2.56	102.22
EC 271493	41.76	21.03	11.95	1.85	94.46
EC 271499	42.99	22.57	12.89	2.44	117.62
EC 271501	49.89	17.85	16.98	2.57	97.41
IC 271523	84.51	23.60	13.33	2.10	125.19
EC 398574	50.54	17.41	16.17	2.93	112.80
EC 324986	68.30	32.71	16.33	2.33	140.99
EC 755305	34.80	20.82	11.23	1.30	89.61
SEm±	1.45	1.76	1.07	0.19	8.91
CD (P=0.05)	3.05	3.70	2.24	0.39	18.72

basal in the form of urea, SSP and MOP, respectively. after 30 days of sowing, the field was spaded and earthing up operations was performed. This was followed by stacking to support the plant to climb on the sticks. One weeding was also perfomed at 45 days after sowing. Irrigation was provided as and when needed. The data with respect to yield attributes was recorded at harvest by selecting 5 plants in each replications, while for pod yield, the per plot yield was converted into yield q/ha. The observations were recorded by randomly selected five plants in all the plots at three phenophase i.e. days to first flowering, days to 50% flowering and days taken to harvest.

The metrological data was also recorded at Agrometeorological Observatory situated near the experimental area. Different thermal indices like growing degree days (GDD), heat use efficiency (HUE), heliothermal unit (HTU), and photothermal unit (PTU) were calculated using the following expressions as suggested by Singh *et al.* (2016):

$$\mathrm{GDD} = \sum \left\{\frac{\mathrm{Tmax} + \mathrm{Tmin}}{2}\right\} - \mathrm{Tbase}$$

Where, Tmax= Daily maximum temperature (ºC); Tmin= Daily minimum temperature (ºC); Tbase= Base temperature for French bean was taken as 8ºC.

The heat use efficiency (HUE) was calculated using the following expressions

$$\mathrm{HUE} = \frac{\text{Pod yield(kg/ha)}}{\text{AGDD(°C/day)}}$$

Where, HUE= Heat use efficiency (kg grains/ha ºC/day), AGDD (ºC/day) = Accumulated growing degree days

$$\mathrm{HTU} = \mathrm{GDD} \times \mathrm{DS}$$

Where, HTU= heliothermal unit (degree-days hours), GDD= growing degree days (degree-days) and DS= duration of Sunshine (Hrs)

$$\mathrm{PTU} = \mathrm{GDD} \times \text{Day length}$$

Where, PTU= Photothermal unit (degree-days hours), GDD= growing degree days (degree-days) and Day length=Duration of day (Hrs).

The recorded data was subjected to statistical analysis (ANOVA) as per standard procedures. The comparison of treatment was made by critical differences (CD) at P≥0.05 and correlation coefficients were calculated at significance level of 0.01 and 0.05.

RESULTS AND DISCUSSION

Growth and yield

Results showed maximum plant height of 84.51 cm with ‘IC 271523’ followed by ‘EC24986’ (68.30 cm) and the lowest was with ‘EC 755305’ (34.80 cm) might be due to genetic difference. The number of pods/plant were the highest in ‘EC 32496’ (32.71), while the lowest pods/plant (17.90) was with genotype EC 271564 suggest superior assimilate translocation and efficient resource utilization by the genotype. The single pod weight was maximum in ‘EC 398574’ (2.93 g) and ‘EC 271501’ (2.57 g), which were significantly at par with genotypes ‘EC 271499’ and ‘EC 324986’ contributing to higher yield (Table 1). Pod yield varied significantly being highest yielding genotypes with ‘EC 324986’ (140.99 q/ha), ‘IC 271523’ (125.19 q/ha) and ‘EC 271499’ (117.62 q/ha) and lowest was recorded with ‘EC 755305’ (89/61 q/ha). The balance between pod number, pod weight is the key determinant of yield and genotypes exhibiting optimal combinations of these traits need further evaluation for yield stability and adaptability under high hill altitude conditions.

Crop phenology

Days to flowering, fruiting and crop maturity are important phenological events that affect productivity of crops. The phenological growth and productivity of crop plants are significantly influenced by temperature.

Among the genotypes, a significant variation in days to first flowering was observed (Table 2), ranging from 50 to 59 days. The earliest flowering was recorded in 'EC-271499' (50 DAS), which was at par with 'EC-324986' (52 DAS). The next group of early-flowering genotypes included 'IC-311094', 'EC-271563', 'IC-271523', 'EC-398574', 'EC-271523', and 'EC-755305', with flowering occurring between 54–55 DAS, while the remaining genotypes were at par with this group.

Among the genotypes, a significant variation in days to first flowering was observed (Table 2) which was ranged from 50 to 59 days. The significantly of earliest flowering of 50 DAS were recorded in 'EC-271499' and it was at par with 'EC-324986' (52 DAS). The next group of the early flowering genotypes were 'IC-311094', 'EC-271563', 'IC-271523', 'EC-398574', 'EC-271523' and 'EC-755305' where days taken by the genotypes was in between 54–55 DAS, while theremining genotypes were at par with this group. The variation in days to flowering in beans might be due to photoperiodic response as reported by White and Laing (1989). Neupane *et al*. (2008) reported that the days to flowering in beans varied in different genotypes which was 40 to 84 days in the bean genotypes studied. Number of days taken to flowering was highly correlated with GDD and HTU up to appearance of flowering, but it was no way associated for the maturity period (Table 3).

Days to 50% flowering showed significant difference among the genotypes. Earliest days to 50% flowering was observed in 'EC-271523' (64 DAS), which was at par with 'IC-311094' and 'EC-271523'. Genotypes 'EC-284247', 'EC-271493' 'EC-271499', 'IC-271523', 'EC-398574', 'EC-271501' and 'EC-755305' took 67 to 69 days to attain the 50% flowering stage. However, genotypes 'EC-271564' and 'EC-324986' recorded the longest days to 50% flowering (70 DAS). Genotype and environment interaction in common bean for days to flowering and the length of flowering period was also reported by Wallace *et al*. (1991). It was ob-

Table 2. Crop phenophases and Agrometeorological indices of various genotypes of French bean

Genotypes	First Flowering				50% Flowering					At Harvest				
	Days taken	GDD	HTU	PTU	Days taken	GDD	HTU	HUE	PTU	Days taken	GDD	HTU	HUE	PTU
'IC-311094'	53.7	427.3	3494.9	8.0	65.3	540.4	4368.8	4.2	8.3	127.0	1090.5	7068.9	2.1	8.6
'EC-284247'	55.7	447.0	3647.4	8.0	68.7	573.4	4624.4	2.0	8.4	121.0	1048.7	7056.7	1.1	8.7
'EC-271563'	54.7	437.0	3574.1	8.0	66.3	550.3	4450.1	3.3	8.3	124.3	1073.0	7067.3	1.7	8.6
'EC-271564'	58.7	475.7	3879.9	8.1	70.3	590.8	4756.8	2.3	8.4	124.7	1074.7	7042.0	1.3	8.6
'EC-271493'	57.3	463.3	3777.4	8.1	68.3	570.6	4597.4	2.2	8.4	122.3	1058.5	7033.8	1.2	8.7
'EC-271499'	50.3	394.3	3224.2	7.8	68.0	567.0	4568.7	2.6	8.3	122.7	1060.9	7036.6	1.4	8.7
'IC-271523'	54.7	437.0	3573.7	8.0	67.3	560.9	4522.8	3.1	8.3	127.3	1091.9	7034.3	1.6	8.6
'EC-398574'	54.7	437.0	3575.4	8.0	69.7	583.7	4704.6	2.6	8.4	121.0	1048.7	7056.7	1.4	8.7
'EC-271501'	56.7	456.3	3722.2	8.0	67.3	560.2	4513.8	1.9	8.3	120.7	1046.4	7028.3	1.0	8.7
'EC-271523'	54.7	437.0	3575.4	8.0	64.0	527.3	4277.6	4.7	8.2	119.0	1034.1	7044.4	2.4	8.7
'EC-324986'	52.0	410.7	3363.3	7.9	70.0	587.6	4732.5	1.7	8.4	129.0	1106.1	7102.7	0.9	8.6
'EC-755305'	55.0	440.3	3602.5	8.0	68.0	567.8	4583.5	2.5	8.3	127.0	1091.8	7075.7	1.3	8.6
SEm±	0.9	8.77	67.23	0.02	0.96	9.46	74.27	0.2	0.02	1.51	10.63	28.85	0.11	0.01
CD (P=0.05)	2.65	25.88	198.47	0.08	2.83	27.95	219.23	0.6	0.06	4.47	31.4	N/A	0.33	0.05
SE(d)	1.27	12.4	95.09	0.03	1.35	13.39	105.03	0.29	0.03	2.14	15.04	40.8	0.16	0.02
C.V.	2.84	3.46	3.24	0.59	2.45	2.90	2.12	12.96	0.46	2.12	1.72	0.70	13.63	0.38

GDD= Growing degree days, HTU= Heliothermal unit, HUE= Heat use efficiency and PTU= Photothermal Unit

Table 3. Correlation coefficients of grain yield of various genotypes of French bean with days taken to various phenopahses and Agrometeorological indices

		Appearance of first flowering			50 % flowering			Maturity					
		Days taken	GDD	HTU	Days taken	GDD	HTU	Days taken	GDD	HTU	PTU	HUE	Grain Yield
Appearance	Days taken	1.00	1.00**	0.99**	0.42*	0.43**	0.43**	0.33	0.32	0.12	-0.21	-0.04	0.03
of first .	GDD	1.00**	1.00	0.99**	0.42*	0.42**	0.43**	0.32	0.32	0.12	-0.21	-0.05	0.03
Flowering	HTU	0.99**	.99**	1.00	0.42**	.43**	0.43**	0.33*	0.33	0.13	-0.21	-0.03	0.04
50 %	Days taken	0.43*	0.42*	0.42**	1.00	1.0**	0.99**	0.51**	0.51**	0.23	-0.24	-0.26	-0.22
flowering	GDD	0.43**	0.43**	0.43**	1.0**	1.00	0.99**	0.52**	0.52**	0.24	-0.26	-0.26	-0.22
	HTU	0.43**	0.43**	0.43**	0.99**	0.99**	1.00	0.52**	0.52**	0.24	-0.25	-0.24	-0.21
Maturity	Days taken	0.33	0.32	0.33*	0.51**	0.52**	0.52**	1.00	1.0**	0.57**	-0.73	0.07	0.15
	GDD	0.32	0.32	0.33	0.51**	0.53**	.52**	1.0**	1.00	0.58**	-0.72	0.06	0.14
	HTU	0.12	0.12	0.13	0.23	0.24	0.24	.58**	0.58**	1.00	-0.59	-0.06	0.05
	PTI	-0.21	-0.21	-0.21	-0.24	-0.26	-0.25	-0.73	-0.72	-0.59	1.00	-0.16	-0.18
	HUE	-0.04	-0.05	-0.03	-0.26	-0.26	-0.24	0.07	0.06	-0.06	-0.16	1.00	0.90**
	Grain Yield	0.03	0.03	0.04	-0.22	-0.22	-0.21	0.15	0.14	0.05	-0.18	.90**	1.00

GDD= Growing degree days, HTU= Heliothermal unit, PTU= Photothermal Unit and HUE= Heat use efficiency
**. Correlation is significant at the 0.01 level.
*. Correlation is significant at the 0.05 level.

served that days taken to 50% flowering was significantly correlated with GDD, HTU of both phenophases i.e., appearance of flowering and 50% of flowering. It was also correlated significantly with the days taken to maturity and GDD at maturity. However, other indices such as HTU, PTI, HUE of maturity and grain yield were not significantly correlated.

The maturity period of a crop is very important factor considered in the choice of planting material (Dewitt and Rosaland, 2009). Perusal of data for maturity classified genotypes into three groups ranged between 119 DAS to 129 DAS. Genotypes 'EC-284247', 'EC-271493', 'EC-271499', 'EC-398574', 'EC-271501' and 'EC-271523' were found to be early maturing genotypes (115-120 days), the genotypes of 'IC-311094', 'EC-271563', 'EC-271564', 'IC-271523' and 'EC-755305' were found to be in medium maturing genotypes (120–125 days) while, 'EC-324986' was found to be the long duration genotype (>125 days). Dhakal *et al*. (2020) recorded the variability in the genotypes viz. semi light long and long green bean and trishuli under Mid–Hills of Nepal. They concluded that the flowering and fruiting days were influenced by genotypes, day length and temperature.Days taken to maturity was significantly correlated with HTU for the period of appearance of flowering, days taken to 50% flowering, GDD and HTU of 50% flowering, days taken to maturity, GDD and HTU up to maturity.

Agrometeorological indices

Growing degree days (GDD)

Growing degree days indicates growth and development of plants during the growing season. Crop weather interaction studies can be used effectively as an aid to crop management because there is a significant possibility to increase productivity under unusual weather conditions with enhanced management. GDD is extensively used to determine the best genotype for a given region, the best time to plant and to describe the biological phases of plants (McMaster and Wilhelm, 1997). Significantly lowest growing degree days (GDD) was required to attain the reproductive phase i.e., first flowering days in 'EC-271499' (394.3° days) and was at par with 'EC-324986'. The subsequent group was formed by genotypes, viz. 'IC-311094', 'EC-271563', 'IC-271523', 'EC-398574', 'EC-271523', and 'EC-755305' where it was ranged between 427.3° days to 440.3° days. The third group included genotypes namely 'EC-271501' and 'EC-271493' requiring 456.3° days to 463.3° days for first flowering phenophase whereas, genotype 'EC-271564' was found to be highest requirement of 475.7 º days to reach the reproductive phase of crop.

Accumulated GDD requirements for genotype to attain 50% flowering were significantly varied from genotype to genotype. Significantly the lowest growing degree days (GDD) was required to attain the 50% flowering phase i.e. 527.3 º days by the 'EC-271523' and it was at par with IC-311094 and EC-271563. The second group of genotypes constituted of genotypes 'EC-284247', 'EC-271493', 'EC-271499', 'IC-271523', 'EC-271501' and 'EC-755305' where it ranged between 560.2 to 573.4ºdays. Genotypes such as 'EC-271564', 'EC-398574' and 'EC-324986' constituted third group requiring 583.7º days to 590.8º days for 50% flowering phenophase. However, some of the genotypes falls under middle group and were statistically at par with some of the genotypes under early and late group of genotypes (Table 2). At maturity the GDD varied from 1034.1ºC day to 1106.1ºC day from genotype to genotype and three distinct group of genotype were recorded. Genotypes like 'EC-284247', 'EC-271493', 'EC-271499', 'EC-398574', 'EC-271501' and 'EC-271523' accumulated significantly the lowest GDD (1034.1 ºC day to 1060.3 ºC day) while 'IC-311094', 'EC-271563', 'EC-271564', 'IC-271523' and 'EC-755305' accumulated GDD of 1090.5 to 1091.9ºC day. Genotype 'EC-755305' accumulated the highest GDD (1106.1) for maturity among all the genotypes studied. GDD was significantly correlated with all the agromet indices undertaken in study during first flower appearance and 50% flowering but it was not associated with the any indices developed for maturity phenophase except HTU and GDD calculated for maturity (Table 3).

Heliothermal unit (HTU)

Helio thermal units represent the product of GDD, bright sun shine hours and directly or indirectly affect growth, development and yield of French bean. Higher HTU enhances photosynthesis, biomass production and pod filling and contributing towards yields. Perusal data of HTU required to cross the vegetative phase ranged from 3224.2 'EC-271499') to 3,879.9 'EC-271'564). Group of genotypes requiring the lowest HTU were 'EC-271499' and 'EC-324986' 3,224 and 3,363 respectively. Genotypes 'IC-311094', 'EC-271563', 'IC-271523', 'EC-398574' and 'EC-755305' were found to be the member of next to early group where HTU at first flowering ranged between 3,494.9 ('IC-311094') to 3,602.5 (EC-755305) while, genotypes 'EC-284247', 'EC-271493', and 'EC-271501' were found to be the representative member of penultimate group whereas genotype EC-271564 required the highest HTU (3879.9) among all genotypes undertaken for study. Second group of genotypes in accumulation of HTU at flowering phenophase was formed by 'EC-271501', 'IC-271523', 'EC-271499', 'EC-755305', 'EC-271493', 'EC-284247' and 'EC-398574' and range of accumulated HTU was 4,513.8 to 4,704.6. Genotype 'EC-271564' has accumulated significantly the highest HTU (4756.8) followed by 'EC-324986' (4732.5) which were at par with each other. At maturity, no significant difference in accumulation of HTU was recorded, however highest values of HTU was observed with 'IC 311094', 'EC 271564' 'EC 271493', and 'EC 324986' genotypes under study, leading to higher yield (Table 1) might be due to prolonged accumulation of assimilates and improved source-sink dynamics. These results are in accordance with the findings of Ram *et al.* (2012) in wheat crop in central Punjab

Heat use efficiency (HUE)

The heat use efficiency measured the plant's capacity to produce dry matter for every unit of heat used**.** In French bean, a higher HUE reflects better conversion of thermal energy harness the available nutrients in the soil and other resources such as light, soil moisture etc under a given set of weather condition (Kaur and Pannu, 2008). Here, all the genotypes were exposed to similar weather condition as all the genotypes sown on a single date. But the range of heat use efficiency (HUE) at the end of vegetative phase ranged between 2.4 kg/ha/ºC day 'EC-271523' to 0.9 kg/ha/ºC day 'EC-324986' showed their genetic potential to produce the photosynthates and accumulate the biomass after respirational loss. The group of genotypes namely 'EC-284247', 'EC-271564', 'EC-271493', 'EC-271501', 'EC-324986' and 'EC-755305' were observed to be least efficient in biomass accumulation per ºC day while genotypes like 'EC-27156'3, 'EC-271499', 'IC-271523' and 'EC-398574' were found more efficient to first one and ranged varied between 1.7 kg/ha/ºC day to 1.4 kg/ha/ºC day however some of them were at par of each other. Genotypes 'IC-311094' and 'EC-271523' were found to be the member of group having the significantly highest heat use efficiency. Heat use efficiency (HUE) significantly varied among the genotypes for 50% flowering, and it was ranged between 4.7 to 1.7 kg/ha/ºC day. The first group of genotypes represented by 'EC-284247', 'EC-271564', 'EC-271493', 'EC-271501' and 'EC-324986' were registered as the least efficient in biomass accumulation per ºC day while genotypes like EC-271523 and IC-311094 were found to be more efficient with the value of 4.7 kg/ha/ºC day and 4.2 kg/ha/ºC day over rest of the genotypes as it ensured efficient use of thermal resources, supporting higher yield in French bean.

Photothermal Unit (PTU)

Data pertaining to PTU was found to be 7.8 'EC-

271499' to 8.1 'EC-271493' and 'EC-271564'. Among the 12 different genotypes, two genotypes namely 'EC-324986' and 'EC-271499' had lowest PTU. Genotypes such as 'IC-311094', 'EC-284247', 'EC-271563', 'IC-271523', 'EC-398574', 'EC-271501', 'EC-271523' and 'EC-755305' formed the second group while genotypes like 'EC-271564' and 'EC-271493' formed the third group in terms of PTU. At 50% flowering, there were two distinct groups of genotypes in accumulation of PTU. Genotypes such as 'IC-311094', 'EC-271563', 'EC-271499', 'IC-271523', 'EC-271501', 'EC-271523', and 'EC-755305' (8.2 to 8.3) formed the group which was having fewer PTU compared to 2 'EC-284247', 'EC-271564', 'EC-271493', 'EC-398574' and 'EC-324986' (8.4). Likewise, PTU at predecessor phenophase, statistically, at maturity only two discrete group were recorded where the range was found between 8.6 to 8.7 (Table 1).

It may be concluded that genotypes 'EC-271499' and 'EC-324986' required less GDD and HTU indicated a shorter growth cycle while, 'EC-271523' recorded higher efficiency in biomass accumulation per unit of heat. Photothermal unit showed less variation at flowering. While highest yield of 140.99, 125.81 and 117.62 q/ha was observed with 'EC 324986', 'IC 311094' and 'EC 271499', respectively.

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