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ASSESSMENT OF THERMAL SENSITIVITY OF GARDEN PEA (*Pisum sativum* L.) TOWARDS PRODUCTIVITY CONSTRAINTS UNDER VARIOUS FIELD MANAGEMENT PRACTICES

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ABSTRACT

A heat-unit system involving the sum of daily mean temperatures above a given base temperature is used to assess the thermal sensitivity of garden pea towards productivity constraints under various field management practices. Pea varieties, V_1 (Azad pea-3) and V_2 (PSM-3), were sown under three rows spacing, viz. S_1=40×15 cm, S_2=35×10 cm, S_3= 30×5 cm and two irrigation levels, I_1 (irrigation at flowering and pod filling stages) and I_2 (irrigation at ten days intervals). Plant height, number of branches, number of seeds per pod and pod yield was more in case of V_1 than V_2. With increasing plant density, number of branches per plant, number of seeds per pod and pod yield decreased. Total Green pod yield was 9.03 t ha^{-1} for S_1 spacing, whereas S_3 provided only 8.75 t ha^{-1}. Number of seeds per pod was maximum in case of I_2 (7.08) than I_1 (6.57), and green pod yield was higher in case of I_2 (9.11 t ha^{-1}) than I_1 (8.67 t ha^{-1}). Number of days and cumulative heat units required for seed germination, 1st and 5th leaf initiation, flowering and pod picking are calculated separately. Relationships were computed between accumulated growing degree days (GDDs) and yield components of garden pea (Number of green seeds per pod and pod yield).

KEYWORDS: Garden pea, Growing degree days (GDDs), Microclimate, Phenology, Yield

Citation

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Garden pea (*Pisum sativum* L.) is an imperative, highly productive, and nutritionally rich coolseason legume crop grown worldwide and consumed as food, feed, and fodder [1]. The scientific cultivation practices of garden pea, like proper spacing management, variety selection, timely irrigation facilities, manuring and fertilization etc., have become an integral part of increasing productivity. Temperature significantly impacts the growth, development and quality of pods [2]. Pea yields are sensitive to environmental conditions, especially temperature extremes and water deficit [3]. However, adequate data to measure the effect of plant species, spacing, irrigation and heat units on the biometric, phenological character and yield of garden pea are limited. In view of this fact, this study aims to investigate the effect of modified microclimate and heat units on the biometric, phenological characters and yield component of garden pea.

MATERIALS AND METHODS

The field experiment was conducted during the rabi (winter) season, 2017-18 and 2018-19 at the Instructional Farm, Jaguli, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal (Latitude: 22˚56' N, Longitude: 88º32' E and Altitude: 9.75 m above mean sea level). Meteorological pooled data for 2017-18 & 2018-19 were recorded during the experimental period. The average weekly maximum temperature ranges from 20.61℃ to 28.5℃. The average weekly minimum temperature ranges from 8.04℃ to 14.48℃ during the crop growth period. The average weekly rainfall ranges from a minimum of 0.4 mm to 3.42 mm, with an average of 0.29 mm. The experiment was laid out in a Factorial Randomized Block Design with two replications. Two varieties, Azad pea-3 (V_1) and PSM-3 (V_2), were cultivated with three spacing levels of 40×15 cm (S_1), 35×10 cm (S_2) and 30×5 cm (S_3), with two irrigation levels, one applied only at critical stages (I_1) (flowering and pod filling stage) and other applied during ten days interval (I_2). Each Plot size was 3 × 2 m. The seed rate was 80 kg/ha, and the fertiliser dose was N_2: P_2O_5:K_2O=25:50:50 each year. Plant height (cm.) and the number of branches per plant from the tagged plants were recorded at 15 days intervals starting from 30 days after sowing. The number of days required to reach different phenophases like germination, 1st leaf and subsequent 5th leaf initiation, along with the 1st flower initiation and 1st pod picking from the date of sowing on each tagged plant, were calculated the average values. Crop heat unit is an energy term calculated for each day and accumulated from sowing to the harvest date. The growth depends on the total amount of heat required to complete crop lifecycle. The cumulative GDD required for reaching emergence, 1st leaf initiation, 5th leaf initiation, flowering and pod picking were calculated for all treatments and in combination with a base temperature (T_{base}) of 4.5℃ was often reported to be the most satisfactory for green pea [4].

Growing Degree Day (GDD) $=\Sigma (T_{max}+ T_{min}) \times 0.5 - T_{base}$

T_{max}: Maximum temperature of the day; T_{min}: Minimum temperature of the day; T_{base}: Base temperature

The experiment was conducted in Factorial Randomised Block Design. The pooled data of 2017-18 and 2018-19 on different aspects of pea were subjected to statistical analysis using the analysis of variance (ANOVA) as suggested by [5]. The critical difference was calculated when differences among the treatments were found significant by the ‘F’ test.

RESULTS AND DISCUSSION

Bio physical attributes

Plant height (cm.) and Number of branches per plant:

Table 1 shows that plant height and number of branches per plant for variety Azad pea-3 was more than PSM-3 throughout the growing period. Different varieties had a significant effect on plant height and branch number at every stage of plant growth, with the maximum critical difference at 75 DAS (0.78 and 0.54 for plant height and branch number, respectively). Different responses to plant height and number of branches of different varieties might be due to different phenotypic character of the different pea cultivars, and the same result also reported by [6]. Among all three spacing levels, S_3 obtained maximum plant height, followed by S_2 and S_1 at all the growth stages. It is also noted that there was a significant effect of different spacing on plant height at every stage of crop growth. Treatment difference was maximum at 75 DAS, followed by 30, 45 & 60 DAS. So, with decreasing spacing, plant height also increases; this might be due to close row spacing, the space for plant spreading was less and hence plant height increased significantly. The same result was obtained by [7], who indicated that a denser plant population of pea increased plant height due to competition among plants. The number of branches was also significantly influenced by different levels of spacing at every stage. Among all three spacing levels, it was observed that maximum branches at spacing S_1 and minimum branches at spacing S_3, CD values at 5% significance was maximum at 75 DAS (0.66). It is observed that with increasing plant density, the number of branches per plant decreases; this might be due to plants in high density having less space for spreading. The same results reported by [8], said a higher number of branches in pea was observed at wider row spacing. Among different irrigation levels, plants which were irrigated ten days intervals (I_2) showed more plant height and number of branches than those which were irrigated only at critical stages (I_1). Significant variation was observed at 5% significance level at each stage, where the maximum was at 75 DAS (0.78 for plant height and 0.53 for the number of branches). It is also noted that the number of irrigations increased plant height and branch numbers; this might be due to water availability more in I_2 than I_1. Plants show no stress effect with increasing irrigation levels, which is why increasing nodes. Same result also obtained by [9], reported that adequate moisture availability during the vegetative period under irrigated conditions significantly increased the plant height and number of branches of garden pea.

Table 1: Influenced of different varieties, spacing & irrigation on plant height (cm) and number of branches of garden pea (pooling over the year of 2017-18 & 2018-19)

Treatments	Plant Height (cm)				Number of branches			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
V_1	19.88	31.45	40.03	49.87	6.08	8.50	10.67	12.50
V_2	19.15	30.72	39.58	47.10	5.58	7.83	10.16	11.75
Sem(±)	0.10	0.08	0.06	0.26	0.12	0.10	0.10	0.18
CD at 5%	0.29	0.25	0.19	0.78	0.36	0.31	0.29	0.54
S_1	18.47	29.33	38.82	47.01	6.75	8.75	11.75	12.87
S_2	19.45	31.56	39.65	48.15	6.25	8.50	10.00	12.25
S_3	20.66	32.36	40.95	50.31	4.50	7.25	9.50	11.25

Sem(±)	0.13	0.10	0.07	0.32	0.15	0.13	0.12	0.22
CD at 5%	0.36	0.30	0.23	0.96	0.44	0.38	0.36	0.66
I_1	15.85	25.40	32.45	39.30	4.75	6.75	8.75	10.00
I_2	20.03	31.50	40.54	49.65	6.08	8.41	10.66	12.50
Sem(±)	0.10	0.08	0.06	0.27	0.12	0.10	0.10	0.18
CD at 5%	0.39	0.25	0.19	0.78	0.36	0.31	0.29	0.53

Duration to attain different phenological phases of garden pea

Number of days required to seed germination:

Table no. 2 shows that the PSM-3 variety took more days (5.75) to germinate than the Azad Pea-3 (4.33) variety. Two varieties had a significant effect on number of days for seed germination. Different responses to seed germination of different varieties might be due to different genotypes and adaptability to a particular environment. The same result was also reported by [10], who mentioned that variations in germination among the varieties might be attributed to a climatic factor, viz., temperature, rainfall, and relative humidity, which can enhance seed germination. Among the three different spacing, S_3 took more days (5.25) for germination, followed by S_2 (5.00) and S_1 (4.88). But there is no significant difference between spacing and the number of days for germination. There should be no significant variance between irrigation and the number of days to seed germination as one pre-sowing irrigation has been applied to experiment for all treatments.

No. of days required to 1st leaf initiation

Number of days required for initiation of the 1st leaf from days after sowing had significant variance with variety. Variety PSM-3 took more days (7.25) to initiate the 1st leaf than variety Azad pea-3 (6.08). The critical difference observed at 5% level was 0.43. Among different levels of spacings, S_3 took 7.38 days for initiation of the 1st leaf, whereas S_2 and S_1 took 6.63 and 6.00 days, respectively. Significant variation between spacing and 1st leaf initiation was 0.52. Irrigation has significant variance on 1st leaf initiation. For 1st leaf initiation, I_2 took less time (6.08) to leaf initiation than I_1 (7.25).

No. of days required to 5th leaf initiation

Number of days required for initiation of the 5th leaf from days after sowing had significant variance with variety. PSM-3 (V_2) variety took more days from the sowing date to the 5th leaf initiation. The significant variance between varieties and the number of days to 5th leaf initiation was 0.57. Table no.2 showed that for the 5th leaf initiation, S_3 took maximum days (13.25), followed by S_2 (12.75) and S_1 (12.13), and the critical difference at 5% level was 0.70. Irrigation has significant variance in 5th leaf initiation. For 5th leaf initiation, I_2 took less number of days than I_1.

Days to 1st flowering

It has been observed that the days to 1st flowering from the date of sowing for the PSM-3 variety (50.50) is more than the variety Azad pea-3 (45.92). Table 2 shows a significant difference between variety and days to 1st flowering. The same result also reported by [11] on garden pea. It is noted that among different levels of spacing, S_3 took maximum days to 1st flowering (49.50), followed by S_2 (48.13) and S_1 (47.00). I_1 takes more days (51.25) to reach the flowering stage than I_2 (45.17).

Table 3 shows that the difference between irrigation and the number of days to 1st flowering was highly significant and the critical difference value at 5% significance level was 1.28.

Days to 1st pod picking

The recorded data (table no.2) for days to 1st pod picking from the date of sowing was significantly influenced by varietal character. PSM-3 took more days (72.42) to 1st pod picking than Azad Pea-3 (68.00). Among three spacing levels, S_3 took more days to 1st pod picking (71.50), followed by S_2 (70.25) and S_1 (68.88). I_2 takes less number of days than I_1 to reach different phenological stages. The critical difference value at 5 % level was 1.34, which showed that the difference between irrigation levels was highly significant for days to 1st pod picking.

Table 2: Influence of different varieties, spacing & irrigation on number of days required to attain various phenological phases of garden pea (pooling over the year of 2017-18 & 2018-19)

Treatments	Number of days required to attain different phenological stages from days after sowing				
	Germination	**1st leaf initiation**	**5th leaf initiation**	**1st flowering**	**1st pod picking**
V_1	4.33	6.08	12.00	45.92	68.00
V_2	5.75	7.25	13.42	50.50	72.42
Sem(±)	0.20	0.14	0.18	0.41	0.43
CD at 5%	0.63	0.43	0.57	1.28	1.34
S_1	4.88	6.00	12.13	47.00	68.88
S_2	5.00	6.63	12.75	48.13	70.25
S_3	5.25	7.38	13.25	49.50	71.50
Sem(±)	0.25	0.17	0.23	0.51	0.53
CD at 5%	NS	0.52	0.70	1.57	1.64
I_1	5.08	7.25	13.25	51.25	74.42
I_2	5.00	6.08	12.17	45.17	66.00
Sem(±)	0.20	0.14	0.18	0.41	0.43
CD at 5%	NS	0.43	0.57	1.28	1.34

Computation of thermal sensitivity

Total heat units required to reach different phenological stages influenced by different varieties, spacing and irrigation

Table no.3 shows that V_1 took less heat units to germinate, 1st leaf initiation, 5th leaf initiation, flowering, and pod picking than V_2. Critical difference value at 5% significance was maximum (17.73) at flowering stage. Among three spacings, S_1 took less heat units to reach different phenological stages, followed by S_2 and S_3. Critical difference value due to different spacing levels was maximum (21.72) at flowering stage. Two different irrigation levels had a significant effect on heat unit accumulation to reach different phenological stages. It has been observed that plants which were got irrigation at ten days intervals (I_2) took less heat units to reach different phenological stages than I_1 and critical difference value was maximum (17.73) at flowering stage. Critical difference levels showed that the difference between variety, spacing and irrigation levels were highly significant for days to 1st flowering and pod picking.

Table 3: Accumulated heat units (°C day) required to reach different phenological stages influenced by different varieties, spacing and irrigation (pooling over the year of 2017-18 and 2018-19)

Treatments	Cumulative heat unit's requirement for different phenological stages				
	Germination	**1st leaf initiation**	**5th leaf initiation**	**1st flowering**	**1st pod picking**
V_1	70.32	97.09	186.27	664.34	947.89
V_2	87.72	114.43	207.83	723.28	1006.07
Sem(±)	1.89	2.43	2.79	5.70	5.56
CD at 5%	5.88	7.55	8.68	17.73	17.31
S_1	76.08	95.08	188.33	677.56	959.16
S_2	76.88	107.20	197.83	693.10	977.91
S_3	84.11	115.00	205.00	710.76	993.88
Sem(±)	2.31	2.97	3.41	6.98	6.81
CD at 5%	NS	9.25	10.63	21.72	21.21
I_1	81.16	113.08	205.45	733.38	1033.68
I_2	76.88	98.43	188.65	654.23	920.28
Sem(±)	1.89	2.43	2.79	5.70	5.56
CD at 5%	NS	7.55	8.68	17.73	17.31

Productivity components

Number of green seeds per pod

Analysis of variance showed that the number of seeds was more in the case of V_1 (7.24) than V_2 (6.41). The rate of acclimatization of genotypes may be considered the possible cause of this variation. Same result also found by [12], reported that this variation might be due to the genetic variability of different genotypes. Different Spacing levels were significantly influenced the number of seeds per pod. Table no. 4 shows a slight difference in the number of seeds per pod as 7.01, 6.83, and 6.64, respectively, at S_1, S_2, and S_3. Same result also found by [8], reported that a higher number of branches, pods per plant, and seeds per pod in pea at wider row spacing. Different irrigation levels also significantly differ in the number of seeds per pod. I_2 shows a better response than the I_1 level of irrigation regarding the number of seeds per pod. Same result also reported by [13], that the numbers of pods per plant and peas per pod, analysed as the main effect, were increased by irrigation. Two irrigation levels show a critical difference value of 0.07 between them.

Green pod yield (t ha^{-1})

Table no 4 shows that there has been significant variance between varieties and green pod yield. Azad pea-3 (V_1) produced more pod yield than PSM-3 (V_2), i.e., 9.31 t ha^{-1} and 8.47 t ha^{-1}. CD value at 5% significations was 0.08. Concerning green pod yield, it was significantly influenced due to different levels of spacing where S_1 produced maximum green pod yield (9.03 t ha^{-1}) followed by S_2 (8.89 t ha^{-1}) and S_3 (8.75 t ha^{-1}). Green pod yield increases with decreasing plant density; the critical difference value at 5% significance was 0.10. As the number of pods per plant increased with decreasing plant population, green pod yield also increased. The same result was also found by [14], who reported that the number of green pods plant^{-1} had the highest positive direct effect on green pod yield in pea. Different irrigation levels showed significant variation with green seed yield. Plants that got irrigation at ten days intervals produced more yield (9.11 t ha^{-1}) than plants that got irrigation only in critical stages (8.67 t ha^{-1}). The critical difference at 5% level was 0.08. Same result also supported by [15], reported that all yield components are usually increased by irrigation, which support the result.

Table 4: Influence of different varieties, spacing & irrigation on green seed per pod and green pod yield (t ha^{-1}) of garden pea (pooling over the years of 2017-18 & 2018-19)

Treatments	**Green seed pod^{-1}**	**Green pod yield (t ha^{-1})**
V_1	7.24	9.31
V_2	6.41	8.47
Sem(±)	0.02	0.02
CD at 5%	0.07	0.08
S_1	7.01	9.03
S_2	6.83	8.89
S_3	6.64	8.75
Sem(±)	0.03	0.03
CD at 5%	0.08	0.10
I_1	6.57	8.67
I_2	7.08	9.11
Sem(±)	0.02	0.02
CD at 5%	0.07	0.08

Relationships among the thermal requirement for phasic changes of pea with productivity component

Relationships between accumulated degree days and yield components of garden pea

Growing degree days played a crucial role in effecting crop growth and development. Results have confirmed that accumulated growing degree days directly influenced the yield and its components. Figure 1 shows that the regression coefficient showed a negative correlation between the number of green seeds per pod and accumulated GDD at various phenological stages. Values of R^2 are 0.5492, 0.5693, and 0.6975 at 1st leaf initiation, flowering, and pod picking stages, respectively. The regression coefficient (fig.2) showed a negative correlation between pod yield and accumulated growing degree days at different phenological stages. Values of R^2 are 0.2147, 0.6724, 0.3597, 0.6185and 0.6001 at germination, 1st leaf initiation, 5th leaf initiation, flowering, and pod picking stage, respectively.

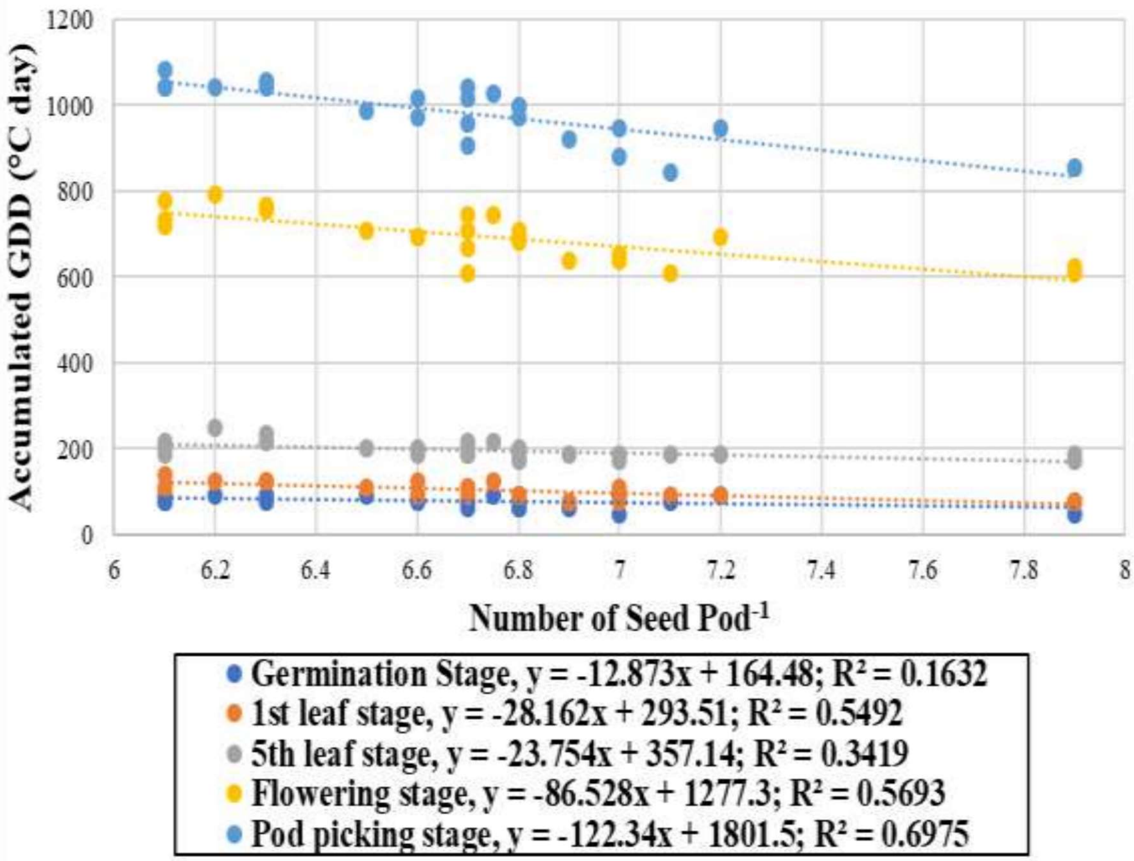

Fig.1: Relationship between number of seeds per pod and Accumulated growing degree days (°C day) at different phenological stages

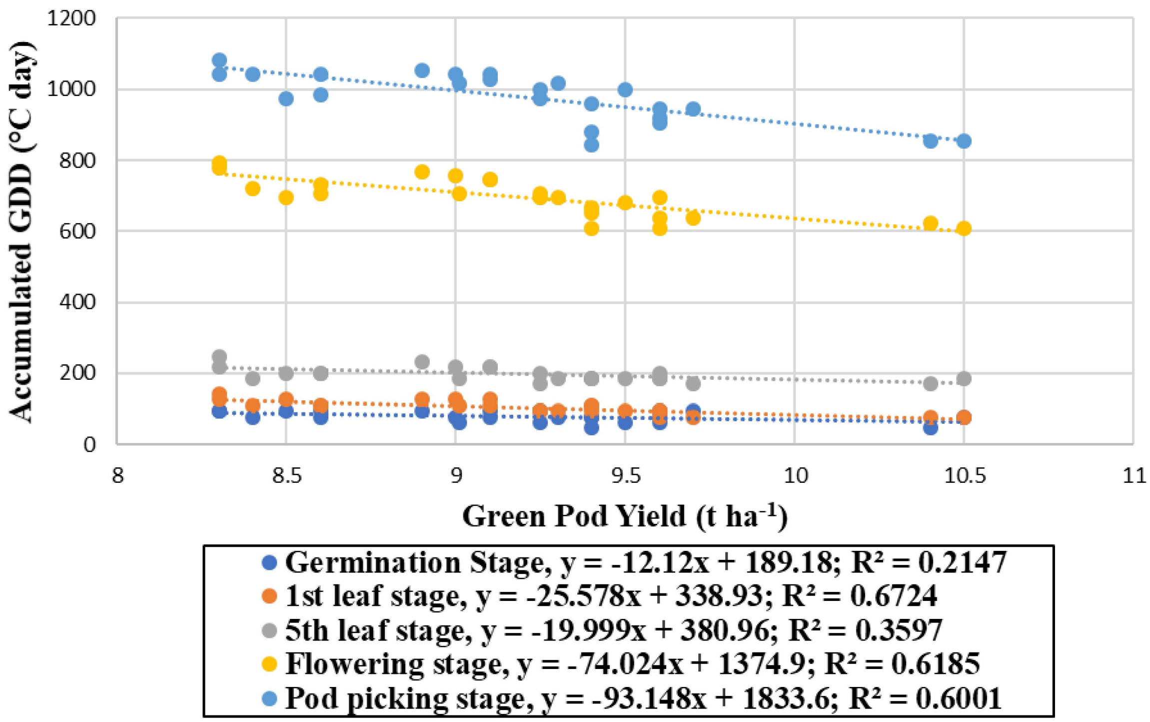

Fig.2: Relationship between Pod yield (t ha^{-1}) and Accumulated growing degree days (°C day) at different phenological stages

CONCLUSION

Plant biometric character and yield component of garden pea were significantly influenced by the treatment combinations, i.e., variety, spacing, and irrigation. Two different varieties significantly impacted the number of seeds per pod and pod yield. Among the two varieties, V_1 took less heat units to reach different phenological stages. Another interesting observation is that spacing (S_1) that took the lowest GDD among three spacings had shown a significantly higher yield (9.03 t ha^{-1}) followed by S_2 (8.89 t ha^{-1}) and S_3 (8.75 t ha^{-1}). Plants that took irrigation at ten days intervals (I_2) took less GDD and produced a higher yield. Conclusively, crop heat units can be used to predict crop growth stages of garden pea as its physiological responses depend on the accumulation of temperature.

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