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Short communication

Thermal utilization of greengram (*Vigna radiata* L. Wilczek) under different sowing dates and nutrient managements

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Green gram (*Vigna radiata* L. Wilczek) locally called as moong belongs to the family *Fabaceae*, it fixes atmospheric nitrogen and improves soil fertility by adding 20-25 kg N ha^{-1} (Islam, 2015). The rate of plant growth and development is dependent upon the temperature surrounding the plant with a specific temperature range represented by a minimum, maximum, and optimum (Hatfield *et al.,* 2011). The location, nutrient availability, sowing date, and temperature are the main factors that affect how long it takes for a plant to mature. The number of days from planting to physiological maturity varies from year to year and from place to location, which makes it difficult to anticipate how a crop will grow. This is due to fluctuations in daily minimum and maximum temperatures. To explain variations in phenological behaviour and growth parameters, meteorological indices such as growing degree days (GDD), helio-thermal unit (HTU) and photo-thermal unit (PTU) are utilised (Hussain *et al.,* 2023; Kumar *et al.,* 2022). The temperature-based agrometeorological indices offer accurate crop development and production predictions. The onset and length of various phenophases, as well as the seed yield, are negatively impacted by temperature changes during a crop's phenophases. Therefore, to achieve a better yield, it is essential to understand the precise duration of phenophases in a certain environment and their relationship with yield qualities.

The research trial was conducted during the *rabi* (January to May) season of 2022 at Agricultural Research Station, Binjhagiri, Chhatabar, Faculty of Agricultural Sciences, Bhubaneswar, Odisha. The soil of the experimental field was sandy clay in texture with a pH of 5.8. The experiment was laid out in a split-plot design where in main plots were assigned to three sowing dates [D_1 - 22nd January 2022 (4th Standard Meteorological Week (SMW)), D_2 - 12th February 2022 (7th SMW) and D_3 - 5th March 2022 (10th SMW)] and sub-plots to eight combinations of major nutrients ($N_0P_0K_0$, $N_1P_0K_0$, $N_1P_1K_0$, $N_1P_1K_1$, $N_0P_1K_0$, $N_0P_1K_1$, $N_0P_0K_1$, $N_1P_0K_1$), and replicated thrice. Greengram variety Virat (IPM-205/7) was used for the experiment. The spacing between rows was 25 cm and between plants was 10 cm maintained with a recommended seed rate of 25 kg ha^{-1}. The recommended fertilizer dose of 20-40-20 kg of N, P_2O_5 and K_2O was applied using urea, SSP and MOP. The daily weather data like maximum, minimum temperature, and bright sunshine hours required to compute the thermal time was obtained from agro-metrological station OUAT, Bhubaneswar.

Different growth phases of greengram were identified following BBCH scale (Hack *et al.,* 1992). The scale helps to divide the phenological development of both mono and dicotyledonous plants from germination to senescence. Ten principal growth phases comprise this scale, further separated into secondary growth stages. Furthermore, these stages are identified by the first and second digits of the two-digit code, with ordinal values ranging from 0 to 9 (Meier *et al.,* 2009). The details of the phases are as the germination phase denotes with '0' followed by Principal Growth Stage (PGS) 1 i.e leaf development stage, PGS2 (formation of side shoot), PGS 3 (stem elongation), PGS5 (inflorescences emergence), PGS 6 (flowering), PGS 7 (development of fruit), PGS 8 (ripening) and PGS9 (senescence). Now following this scale details in this experiment for further analysis, the range of BBCH scale (0-9) has been clubbed into four major growth phases, such as Phase I- G_0 to P_3 (0-39 DAS), Phase II-P_5 & P_6 (50-69 DAS), Phase III -P_7 & P_8 (70-89) and Phase IV- P_9 (90-102)

The growing degree days (GDD) concept assumes that there is a direct and linear relationship between the growth and

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Table 1: Growing degree days (GDD), Helio-thermal Units (HTU) and Photo-thermal Units (PTU) at different stages of greengram

Treatments	GDD				HTU				PTU			
	G_0-P_3	P_5-P_6	P_7-P_8	P_9	G_0-P_3	P_5-P_6	P_7-P_8	P_9	G_0-P_3	P_5-P_6	P_7-P_8	P_9
Date of sowing												
D_1=22nd January, 2022	1708	514	372	168	11787	3697	3172	459	1636	2154	1675	672
D_2=12th February, 2022	2145	655	617	269	16831	5451	4347	782	2108	2591	2518	1072
D_3=5st March, 2022	2293	620	536	252	19226	5289	3941	729	2237	2546	2235	1058
SEm±	2.56	0.034	20.5	0.025	31.58	117.39	22.5	2.78	34.001	33.65	85.42	11.76
LSD (P=0.05)	7.13	0.097	57.19	0.7	87.53	325.94	62.32	7.72	94.89	93.49	237.18	32.86
Nutrient Management												
$N_0P_0K_0$	2051	554	5142	2010	15928	4509	3060	601	2026	2138	2094	862
$N_1P_0K_0$	2048	585	487	223	15983	4332	3600	638	2030	2337	1983	921
$N_1P_1K_0$	2015	580	515	216	15775	4714	4044	620	2005	2317	2102	967
$N_1P_1K_1$	2027	622	515	252	15686	5108	3978	711	1994	2493	2101	1022
$N_0P_1K_0$	2066	598	499	217	16129	4906	3832	618	2048	2457	2034	875
$N_0P_1K_1$	2055	613	503	252	16066	5003	3902	711	2041	2485	2053	1022
$N_0P_0K_1$	2071	601	510	231	16101	4900	3940	663	2047	2475	2361	872
$N_1P_0K_1$	2057	615	523	238	15919	5027	4217	689	2025	2741	2416	930
SEm±	13.54	0.056	33.41	0.08	51.48	191.71	238.28	6.53	69.24	59.20	91.32	15.45
LSD (P=0.05)	27.32	0.109	69.49	NS	103.9	386.88	480.86	13.71	138.60	119.48	184.31	NS
Interaction D × F												
SEm±	23.45	0.0096	38.86	0.069	89.17	332.47	412.71	6.62	131.31	102.54	158.18	27.62
LSD (P=0.05)	S	S	S	NS	S	S	S	S	S	S	S	NS

development of plants and temperature and the growth is dependent on the total amount of heat units to which it is subjected during its lifetime. The growing degree days was computed by using following formula,

$$GDD = \frac{T\ max + T\ min}{2} - T_{base}$$

The base temperature was taken as 10 °C for greengram.

A Helio-thermal unit (°C days hrs) is the product of the degree-days on any day and the corresponding actual bright sunshine hours. HTU were calculated using following expression.

HTU = GDD × Actual bright sunshine hours (°C days hrs)

The Photo thermal units (PTU) is the product of GDD and corresponding day length for that day were computed on daily basis

PTU = GDD × Day length (N) (°C days hrs)

Where, day length (N) refers to maximum possible sunshine hours.

Heat unit requirement as influenced by the treatments

Data on thermal units of greengram at varied crop growth stages under different sowing windows and nutrient management is presented in Table 1. It was observed that the highest numbers of growing degree days (GDD) were noticed on 3rd sowing date i.e 5th March. It indicated that the mean heat load was increased with delayed sowing crop. It indicated that early sowing did not favour plants in a low-temperature regime. The highest GDD (229.0 °C days) was recorded during G_0 to P_3 of 3rd (D_3) date of sowing followed by D_2 and D_1. During flowering to senescence, the highest GDD was obtained in (D_2 – 655 °C days during P_5-P_9, 617 °C days at fruit development and 269.9 °C days at senescence) followed by D_3 & D_1. This could be a result of the fact that the photoperiod, which primarily affects sowing time, dictates the amount of time available for the vegetative phase before the start of flowering. The helio-thermal units were higher on 3rd date of sowing from phenophase G_0 – P_3 i.e. 19226˚C days hours in D_3. The lowest HTU was observed in D_1 i.e. 11787 ˚C days hours. But in later phases i.e , P_5 to P_9 under 2nd date of sowing more HTU were accumulated as compared to the other two sowing dates which are due to the variation of atmospheric temperature and BSS. This might be due to the crop accumulating more heat units to reach maturity and better-growing conditions such as temperature, light and relative humidity to complete the biological development of the crop (Bahar *et al.,* 2015). The photo-thermal units were higher on the third date of sowing from phenophases P_5 to P_6 i.e. 2546 ˚C days hours and the lowest PTU were observed in D_1 i.e. 672 ˚C days hours during senescence i.e P_9. This is due to the difference in atmospheric temperature and day length hour. It could be as a result of the crop accumulating greater photoperiod, temperature, and relative humidity to fully utilise the crop's potential to mature (Pandey *et al.,* 2010).

The growing degree days (GDD) accumulation was high from 50% flowering to the end of flowering in reproductive phase. HTU, PTU also showed a similar trend to GDD accumulation for the same phonological stages (P 5 to P 7). In early sowing 4th SMW, crop accumulated fewer heat units than 7th SMW and 10th SMW

Table 2: Seed yield of greengram under different sowing dates and nutrient

Treatments	Seed yield (kg ha^{-1})
Date of sowing	
D_1- 4th SMW	684.9
D_2- 7th SMW	878.1
D_3-10th SMW	805.9
Nutrient	
Control	548.8
Mean N	874.1
Mean P	850.8
Mean K	867.7

sowing which ultimately showed a drastic reduction in yield. 10th SMW and 7th SMW sowing crop absorbed a sufficient amount of heat units in less time as compared to 4th SMW and had taken a smaller number of days to mature. From sowing to germination heat unit requirement was low, but was maximum from flower bud development to maturity. Greengram also accumulated greater thermal units in the vegetative phase than the reproductive phase was might be due to the more crop growth and developed abundant foliage.

The seed yield of greengram varied significantly with different sowing dates (Table 2). The highest seed yield of 878.1 kg ha^{-1} was recorded when the crop was sown on 7th SMW (D_2-12th February). This treatment has a 17.5% and 28.20% yield increment over the seed yield of the other two sowing dates, producing seed yield of 805.9 kg ha^{-1} and 684.9 kg ha^{-1} respectively under treatment D_3 (2nd March -10th SMW) & D_1 (22nd January-4th SMW). This deviation in yield is due to the variation in temperature during the crop growth period. Generally, the mean temperature increases from February onwards in Odisha's east and south-eastern plains zone (Acharya *et al.,* 2020). When the crop was sown in late January it received relatively low night temperatures that led to delay in germination and slow initial vegetative growth. However, when the sowing was late i.e during 1st week of March, it got a favourable temperature for the first 30-40 days of its growth and development, afterwards with high day temperatures and low soil moisture the crop suffered. The anthers dried up fast leading to less fertilization and also the pods matured early, all these resulted in lower seed yield than sowing done on 7th SMW (12th February). Definitely when the crop receives either any one of the major nutrients it produces higher seed yield than control (Table 2). The highest seed yield of 874.1 kg ha^{-1} was recorded in the treatments received N. This was followed by the seed yield of 867.7 kg ha^{-1} and 850.8 kg ha^{-1} in the treatments received P and K respectively. In control, the lowest (548.8 kg ha^{-1}) seed yield was noted. A yield increment of 59.3%, 55.03% and 58.1% were noted with the use of either N, P and K respectively over control. Similar results have been reported by Kumar *et al.,* (2022) in mustard crop in Haryana.

It can be concluded that the sowing of greengram during 10th SMW showed better performance due to accumulation of optimal heat thermal indices compared to other sowing periods like 4th and 7th SMW. Sowing of greengram during the 7th SMW with NPK dose produced good crop yield in Odisha's east and south-eastern plains zone. This study also showed that each phenological stage reflects the varying in the cumulative heat accumulation brought on during different planting period.

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