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Phenological studies in rabi greengram (*Vigna radiata* L.) under seasonal climatic variations

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Abstract
Unfavourable environmental condition is the main cause of low greengram yield in Odisha. An experiment was conducted at Bhubaneswar to quantitatively establish the relationship of environment as varied with the dates of sowing (20 January, 30 January, 9 February and 19 February) with growth, phenology and yield of four greengram varieties [PDM-139(SAMRAT), IPM 205-7 (VIRAT), IPM 02-14 and OUM11-5]. Greengram yield was high with late sowing on 19 February (487 kg / ha) and it was the lowest with 20 January sowing (404 kg / ha). The decline in yield was mainly due to reduced number of pods plant-1 and seeds pod-1. The 1000 - seed weight, plant height and number of branches plant-1 did not vary much with sowing time. Among the varieties, OUM 11-5 was the high yielder (478 kg / ha) followed by PDM-139 (450 kg / ha) across the sowing dates. 20 January sowing took more number of days to reach flowering, pod initiation and maturity i.e. 38.6 days, 42.5 days and 57.0 days, respectively as compared to crops sown later.

Keywords: Environment, greengram, phenology, growth, yield

1. Introduction
Greengram [*Vigna radiata* (L.)], commonly known as mungbean, a pulse crop belonging to the family Leguminosae, is native to India and Central Asia. It is principally cultivated for its multipurpose uses such as vegetable, fodder and green manure crop. Greengram is a short duration crop and has been an important component of Indian agriculture. Mung bean provides 33-37 kg/ha of nitrogen (N) to the soil after harvest and thus helps in saving of about 25 per cent nitrogen for the succeeding crop enabling the land to restore fertility (Sekhon *et al*., 2007) [1]. Green gram is an important pulse crop of Odisha state. It is grown in kharif and summer season throughout the state, but also cultivated in rabi season mainly in coastal belt and as a post rainy season crop in south-western districts. The area under green gram is 8.25 Lakh ha with production of 4.1 lakh tonnes and productivity of 495 kg/ha (Odisha Agri. Statistics, 2019-20) [2]. The total area under rabi greengram in the state is 6.44 lakh ha with a productivity of 480 kg/ha as compared to national productivity of 640 kg/ha. Being a short duration and low-input crop, the growth and yield of greengram are greatly affected by climatic variability. Solar radiation, temperature, soil moisture, relative humidity and bright sunshine hours are the important weather elements that influence the crop life cycle during growing season (Makone *et al*., 2015) [3]. In light of the above points a field experiment was conducted to study the differential growth, development and yield response of greengram varieties to sowing time.

2. Materials and methods
The experiment was conducted at the Agrometeorology field research unit of Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, under All India Co-ordinated Research Project on Agrometeorology (AICRPAM) during *rabi* 2020-21. The test site falls under East and South Eastern Coastal Plain Agroclimatic Zone of Odisha. The soil of the test site was sandy loam in texture and acidic in reaction. It was medium in organic carbon (0.52%), low in N (196 kg/ha), very low in available P (2.5 kg/ha) and low in available K (58 kg/ha content. The climate of the place falls in moist hot group and is characterized by warm and moist climate with a hot and humid summer (March-June), hot and humid rainy (late June - mid-October) and mild winters (November - February). The experiment comprised of four varieties of greengram sown under four dates in a split plot design with date of sowing in main

plots and varieties in subplot with three replications. The four varieties were PDM-139 (SAMRAT), IPM 205-7 (Virat), IPM 02-14 and OUM-11-5 and the four dates of sowing were January 20, January 30, February 09 and February 20. The greengram varieties PDM-139, IPM 205-7 popularly known Virat and IPM 02-14 have been released from the Indian institute of Pulses Research (IIPR), Kanpur and the greengram variety OUM-11-5 was released from Centre for Pulses Research, Berhampur, OUAT. All these varieties come under early maturity group and are suitable for cultivation in summer & spring season. Seeds were sown on the specific dates as mentioned above with a row spacing of 25 cm x 25 cm at a depth of about 3-5cm, using 20 kg seeds/ ha and adopting recommended package of practices. All the plots received uniform basal dose of 20 kg N, 40 kg P2O5 and 20 kg K2O/ha. The mean maximum and minimum temperatures were 34.8°C and 19.8°C, respectively. The mean weekly relative humidity (RH) at 7 am was 92.4% and in the afternoon was 92.4% for the crop season. Irrigation was applied to the crop as and when required. After two weeks of sowing, the plants were thinned so as to maintain a distance of 10 cm from plant to plant in the field for optimum population. Manual weeding was done timely to keep the crop free of weeds in all treatments. Timely crop protection measures were adopted as and when necessary. The data on number of pods per plant, number of seeds per pod, 100- seed weight (g) were taken from the 5 tagged plants from each plot. The greengram crop was harvested when the pods were fully ripened leaving one border row from each side, bundled separately and tagged. Harvested produce was left in the respected plots for three days to allow sun-drying. Weighing was done to record biological yield. Threshed seeds were sun-dried for 2-3 days to reduce the moisture content to 8% and then the seed yield per plot was recorded. Days taken by the plants for germination, development of branches, flowering, pod formation and physiological maturity were recorded. The thermal, photothermal and heliothermal units accumulated by the crop during different phenological stages along-with their use efficiencies were calculated by using the following formulae as given below:

Growing Degree Days **(**GDD) = $\sum$ [T max + T min]/2 -Tb

Where, T max is the daily maximum temperature (°C), T min is the daily minimum temperature (°C) and Tb is the base temperature (10 °C).

Photo Thermal Unit (PTU) = GDD * L

Where GDD is growing degree days and L is the maximum possible daylight hour.

Helio-Thermal Unit (HTU) = GDD * BSS

Where GDD growing degree days and BSS is the bright sunshine hours of the day

Heat Use Efficiency (HUE) = Total seed yield /Accumulated GDD

Heliothermal Use Efficiency (HTUE) = Total seed yield /Accumulated HTU

The statistical analysis of data recorded in pre- and post-harvest studies was done as per the formulae (Gomez and Gomez, 1984) [4] to interpret the result.

3. Results

3.1 Attainment of phenophases

The results of time (number of days) taken to reach germination, flowering, pod initiation and physiological maturity have been presented in Table 1. The four varieties took about the same time (4.9 to 5.1 days) for germination. However, the varieties differed in number of days taken to reach other phenological stages. PDM 139 took maximum number of days to reach flowering (35.2), pod initiation (39.7) and physiological maturity (53.0) followed by OUM-11-5 which took 34.9, 39.5 and 52.9 days to reach flowering, pod initiation and physiological maturity, respectively. The cultivar *Virat* reached the respective stages earlier than the other varieties across the four sowing dates. Actual number of days for germination, flowering, pod initiation and maturity varied with the variation in sowing date. In general when sown on 20 January, days taken to reach various stages were consistently higher than the other sowing dates. 20 January sowing took maximum days to reach different stages i.e. 38.6 (flowering), 42.5 (pod initiation) and 57.0 (physiological maturity) followed by 30 January sowing, which took 36.7, 41.6 and 55.7 days to reach flowering, pod initiation and physiological maturity, respectively. Delayed sowing decreased the actual number of days required for a particular stage.

Table 1: Effect of sowing time and variety on attainment of different phenophases (DAS) in *rabi* greengram

Treatments	Germination	Flowering	Pod initiation	Physiological maturity
Sowing dates (D)				
20.01.2021	5.1	38.6	42.5	57.0
30.01.2021	5.0	36.7	41.6	55.7
09.02.2021	6.0	34.0	39.2	50.5
19.02.2021	4.0	29.6	34.7	47.7
Varieties (V)				
PDM 139	5.1	35.2	39.7	53.0
VIRAT	5.0	34.4	39.0	52.5
IPM 02-14	4.9	34.7	39.2	52.7
OUM-11-5	5.1	34.9	39.5	52.9

3.2 Accumulation of thermal, heliothermal and photo thermal units

Thermal units required by the greengram crop from sowing to germination, 50% flowering, pod initiation and physiological maturity have been presented in Table 2. From the result it was observed that the accumulated growing degree days (GDD) required for completion of the crop growth period from sowing to physiological maturity were 904, 957, 968

and 970 at 1st, 2nd, 3rd and 4th date of sowing respectively. Similarly for varieties PDM 139, VIRAT, IPM 02-14 and OUM-11-5, the GDD for completion of the crop growth were 958, 947, 952 and 942, respectively. The 4th date of sowing (19.02.2021) accumulated highest HTU value (6431degree day hours) to attain maturity followed by 9th February sowing (6178 degree day hours). Variety OUM-11-5 accumulated highest HTU value (6117 degree day hours) to attain maturity followed by variety VIRAT (6107 degree day hours). The result revealed that 19th February sowing accumulated highest PTU value (11364 degree day hours) to attain maturity followed by 30th January sowing (11141 degree day hours). Variety OUM-11-5 accumulated highest PTU value (10964 degree day hours) to attain maturity followed by variety PDM 139 (10851 degree day hours).

Table 2: Effect of sowing dates and variety on GDD (degrre days), HTU (degree day hours) & PTU (degree day hours) requirement for attainment of different phenophases in *rabi* greengram

Treatments	Germination			50% Flowering			Pod Initiation			Physiological Maturity		
	GDD	HTU	PTU	GDD	HTU	PTU	GDD	HTU	PTU	GDD	HTU	PTU
Sowing dates (D)												
20.01.2021	85	366	975	558	3250	6313	660	3994	7478	904	5676	10491
30.01.2021	68	317	755	571	4269	6478	665	4413	7557	957	6043	11141
09.02.2021	94	318	1045	595	4093	6791	703	4721	8108	968	6178	11127
19.02.2021	70	307	799	572	3776	6655	676	4267	7994	970	6431	11364
Varieties (V)												
PDM 139	80	434	906	581	3936	6656	682	4374	7874	958	6075	10851
VIRAT	76	406	858	566	3722	6507	678	4344	7810	947	6107	10721
IPM 02-14	80	434	904	567	3805	6419	662	4290	7598	952	6029	10786
OUM-11-5	80	434	906	581	3926	6656	683	4387	7857	942	6117	10964

3.3 Yield attributes and yield

The yield attributes and yield of different cultivars of greengram as affected by sowing dates have been presented in Table 3. The number of pods per plant did not vary with date of sowing. However, among the varieties, OUM-11-5 recorded the highest number pods per plant (14.9) followed by IPM 02-14, which recorded 14.4 numbers of pods per plant. The number of seeds per pod was significantly influenced by the sowing date and varieties. The highest number of seeds per pod (10.7) was attained in the 4th date of sowing (19.02.2021) followed by 2nd, 3rd and 1st date of sowing which recorded 10.5, 9.6 and 9.3 numbers of seeds per pod, respectively. Among the varieties the highest number of seeds per pod (10.5) was recorded in variety OUM-11-5 followed by cultivars IPM 02-14 and PDM 139.

The 1000-seed weight 9 (test weight) did not vary with date of sowing. However, among the varieties, variety OUM-11-5 recorded the highest test weight (37.9 g) followed by varieties IPM 02-14 (37.3 g), Virat (36.9 g) and PDM 139 (34.8 g) respectively. Date of sowing significantly influenced the grain yield of greengram crop. Greengram yields from 30 January sown crop was significantly higher than other two sowings on 20 January and 9 February. The difference between 2nd and 3rd sowing dates and between 2nd and 4th sowing dates were not significant. Sowing of greengram on 19 February recorded the highest grain yield of 481 kg / ha and 20 January sowing recorded the lowest grain yield (404 kg / ha). The four varieties did not differ for grain yield significantly. The harvest index of greengram crop was not influenced significantly by varying the sowing time (Table 3). Among varieties, variety OUM-11-5 recorded the highest harvest index (34%) followed by PDM 139 (33%), Virat (32%) and IPM 02-14 (31%) respectively.

Table 3: Effect of sowing dates and variety on yield attributes and yield of *rabi* greengram.

Treatments	Pods / plant (number)	Seeds / pod (number)	Test weight (g)	Grain yield (kg/ha)	HI (%)
Sowing Dates (D)					
20.01.2021	13.6	9.3	36.4	404	31
30.01.2021	14.7	10.5	36.7	444	32
09.02.2021	14	9.6	37.3	438	32
19.02.2021	14.8	10.7	36.5	482	33
S.E. (m) ±	0.3	0.3	0.5	12	1
CD 5%	NS	0.9	NS	40	NS
Varieties (V)					
PDM 139	14.2	9.9	34.8	450	33
VIRAT	13.7	9.7	36.9	413	32
IPM 02-14	14.4	9.9	37.3	428	31
OUM 11-5	14.9	10.5	37.9	478	34
S.E. (m) ±	0.2	0.1	0.4	20	1.3
CD 5%	0.7	0.4	1.3	NS	NS
D WITHIN V					
S.E. (m) ±	0.5	0.4	0.9	36.7	2.5
CD 5%	1.6	1.1	2.8	109.2	7.5
V WITHIN D					
S.E. (m) ±	0.5	0.3	0.9	40.2	2.7
CD 5%	1.4	0.9	2.6	117.4	7.7

The interaction between date of sowing and variety was significant for grain yield of greengram crop (Table 3a). Sowing of cultivar IPM 02-14 on 19 February recorded highest grain yield i.e., 579 kg/ ha followed by OUM 11-5 sown on 20 January (527 kg/ ha).

Table 3a: Interaction effect of date of sowing and varieties on grain yield of rabi greengram.

Treatments	Varieties (V)				
Sowing dates (D)	PDM 139	VIRAT	IPM 02-14	OUM-11-5	Mean
20.01.2021	510	278	300	527	404
30.01.2021	510	421	352	494	444
09.02.2021	392	428	479	454	438
19.02.2021	388	524	579	437	482
Mean	450	413	428	478	442
	S.E(m) ±	CD 5%			
D within V	36.7	109			
V within D	40.2	117			

4. Discussion

Attainment of phenophases with proper growth in each phase is an important determinant for the grain yield. In the present investigation, the earliest sown greengram on 20th January took more number of days to attain flowering, pod initiation and maturity than crops sown on later dates to reach corresponding phases (Table 1). It is attributed to less thermal and photothermal units accumulated by the early sown plants per day as compared to the late sown crops. The process of development was accelerated due to occurrence of higher maximum and minimum temperature during late sown crop (20th February) and as a result number of days taken for 50% flowering as well as physiological maturity was shortened. The present result fall in line with the findings of Patra *et al*., 2000 [5] and Singh *et al*., 2010 [6]. Accumulation of GDD, PTU & HTU was higher under late sown condition (19th February) as compared to earlier sown crops (Table 2). This is attributed to prevalence of higher temperature and Bright Sunshine Hours (BSH) during growth stages of late sown crops. Optimum accumulation of thermal and photo thermal units was also reflected in higher yield of delayed sown crops in 3rd week of February.

Data on yield components showed that the four varieties differed in the number of pods /plant, seeds /pod and seed yield (Table 3). The results are in line with the findings of Tekale *et al*., 2011 [7] who found that sowing of greengram on 20th February produced significantly higher number of pods per plant and higher grain yield as compared to that sown either on 5th February or 7th March in Navasari, Gujarat. This is due to favourable temperature conditions that prevailed during the growth period for the 20th February crop which returned optimum thermal and photothermal regimes for the crop. Increase in grain yield between 3rd week of February and 1st week of March have been reported by Chovatia *et al*, 1993 [8]. Harvest index followed the same pattern of seed yield indicating better growth of plants under favourable temperature conditions. The interaction between date of sowing and variety was significant for grain yield of greengram crop (Table 3a). The cultivars PDM 139 performed better under early sown conditions (sowing on 20 and 30 January) where as the cultivars IPM 02-14 and *Virat* performed better under late sown conditions (sowing on 9 and 19 February). However, the cultivar OUM 11-5 performed consistently well across the sowing dates.

On the basis of result of investigation it can be concluded that early sowing around 3rd week of January adversely influenced the growth, development and yield of greengram. The result indicates for higher yield, sowing should be done around 2nd and 3rd week of February. Among the four varieties OUM-11-5 performed better w.r.t. yield and yield attributes followed by PDM 139.

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