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Photo thermal parameters and their responses on summer mungbean (*Vigna radiata* (L.) R. Wilczek) varieties under staggered dates of sowing

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Abstract
A field experiment was conducted to study the photo thermal requirements of mungbean varieties under different photo thermal environment during *summer* seasons of 2017-18 and 2018-19 at the Research area, Department of Plant Physiology, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (Madhya Pradesh). The experiment was laid out in a factorial randomized block design replicated thrice treatments consisted of three sowing environments *viz*., Feb 12th, Feb 27th and Mar 14th and five mungbean varieties *viz*., PDM 139, Pusa Ratna, Pusa Vishal, Pusa 1431 and TJM 3. Results revealed that duration to attain different phenophases and thermal units during sowing to maturity decreased with successive delay in sowing form November. Feb 27th sowing produced significantly higher total dry matter accumulation, higher seed yield and biological yield as compared to Feb 12th and Mar 14th. Among mungbean varieties, PDM 139 outyielded (730.42 Kg ha^{-1}) other genotypes. In interactions PDM 139 on 27th Feb (826.02 Kg ha^{-1}) revealed significantly higher total dry matter accumulation, higher seed yield and biological yield followed by other interactions.

Keywords: Mungbean, GDD, HTU, PTI and seed yield

Introduction

Green gram is a short duration crop and grown over wide range of environments in India. It is the main crop of *kharif* but nowadays farmers are frequently adopted this crop in *summer* season due to its short duration and well fitted in wheat-rice cropping system. At present scenario, temperature is going up day by day, which highly affect the crop at different phenophases, ultimately yield. Sunil and Sharma (2005) [11] stated that temperature is most influential factor, which affects the plants in terms of chemically, physiologically and biologically. Thus there is dire need to develop the heat tolerant varieties in this challenging era. Growing degree days (GDD), photo-thermal unit (PTU), helio-thermal unit (HTU), photo-thermal index (PTI) and heat use efficiency (HUE) have frequently been used as weather based parameters for assessing crop phenology. Every crop has definite temperature requirements for attaining certain phenological stages. A change in optimum temperature during different phenological stages of a crop adversely affects the initiation and duration of different phenophases and finally economic yield of any crop. It is therefore indispensable to harvest knowledge of exact duration of phenophases in a particular environment and their association with yield attributes for achieving high yields (Kumar *et al*., 2009) [5]. Influence of temperature on phenology and yield of crop plant can be studied under field conditions through accumulated heat unit system (Haider *et al*., 2003; Pandey *et al.*, 2010) [1, 6]. The temperature based agro-meteorological indices provide a reliable prediction for crop development and yield (Prakash *et al*., 2017) [7]. Thermal use efficiencies *i.e.* utilization of energy in terms of economic and biomass yield have a great practical application and these efficiencies of converting heat energy in to dry matter depends upon genetic factor, sowing time and genotypes (Kiran and Bains, 2007) [3]. Keeping in view of the above facts under consideration the investigations are undertaken on these aspects.

Material and Methods

A field experiment was conducted to investigate the effect of staggered dates of sowing on yield and yield attributing characters and dry matter partioning in different varieties of summer mungbean under terminal heat and water stress conditions during *summer* seasons of 2017-18 and 2018-19 at Research Farm, Department of Plant Physiology Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur (Madhya Pradesh).

The experiment was laid out in factorial randomized block design with three replications. Treatments comprised of three sowing environments *viz*., Feb 12th, Feb 27th and Mar 14th and five mungbean varieties *viz*., PDM139, Pusa Ratna, Pusa Vishal, Pusa1431 and TJM3.

Growing degree day was calculated by following formula and the heat unit or GDD concept was proposed to explain the relationship between growths occurred during the specific temperature. GDD, HTU and PTI as per the formula suggested by Rajput (1980) [8]:

Results and Discussion

Photo-thermal parameters

The results revealed that among treatments of factor A (genotypes) PDM 139 took significantly more period of GDD values from flower initiation (551.38 ^{0}C day) (Table no 1) till harvest (1427.86 ^{0}C day) (Table no 2), whereas Pusa 1431 indicated less GDD almost during entire growth stages, at harvest (1202.85 ^{0}C day) except at flower initiation (459.45 ^{0}C day).

Among treatments of factor B, sowing carried out on 27th Feb (Table no 1and 2) took significantly maximum GDD values to attain flower initiation (521.58 ^{0}C day) until harvesting stage (1357.13 ^{0}C day), while 14th Mar required significantly minimum period of GDD from flower initiation (487.61 ^{0}C day) upto harvesting stage (1292.22 ^{0}C day).

In interactions, PDM 139 on 27th Feb (Table no 1 and 2) took significantly more time period of GDD (573.60 ^{0}C day) to attain the flower initiation to harvesting stage (1480.05 ^{0}C day). Pusa 1431 on 14th Mar took significantly minimum GDD from flower initiation (440.05 ^{0}C day) till at harvesting stage (1178.70 ^{0}C day).

The investigations showed that among treatments of factor A (genotypes) PDM 139 took significantly more period of HTU magnitudes from flower initiation (4626.28 ^{0}C day) (Table no 1) till harvest (12285.33 ^{0}C day) (Table no 2), whereas Pusa 1431indicated less HTU during entire growth stages, at flower initiation (9343.49 ^{0}C day) to harvesting stage (3860.57 ^{0}C day).

Among treatments of factor B, sowing on 27th Feb (Table no 1and 2) took significantly maximum HTU values to attain flower initiation (4441.90 ^{0}C day) until harvesting stage (11215.64 ^{0}C day), while 14th Mar required significantly minimum period of HTU values from flower initiation (4084.40 ^{0}C day) upto harvesting stage (10882.82 ^{0}C day)

In interactions, PDM 139 on 27th Feb (Table no 1 and 2) took significantly more time period HTU values (4886.60 ^{0}C day) to attain the flower initiation to harvesting stage (12860.00 ^{0}C day). Pusa 1431 on 14th Mar took significantly minimum HTU magnitudes from flower initiation (3573.75 ^{0}C day) till at harvesting stage (9729.29 ^{0}C day).

The experiment exhibited that among treatments of factors PDM 139 took significantly more period of PTI values from flower initiation (6519.17 ^{0}C day) (Table no 1) till harvest (17460.26 ^{0}C day) (Table no 2), whereas Pusa 1431 recorded the less PTI values from flower initiation (5406.77 ^{0}C day) till harvesting stage (14574.51 ^{0}C day).

Among treatments of factor B, 27th Feb (Table no 1and 2) took significantly maximum PTI values to attain flower initiation (6327.21 ^{0}C day) until harvesting stage (16912.74 ^{0}C day), while 14th Mar required significantly minimum period of PTI from flower initiation (5561.93 ^{0}C day) upto harvesting stage (15394.89 0C day).

In interactions, PDM 139 on 27th Feb (Table no 1 and 2) sowing took significantly more time period of PTI (6968.65 ^{0}C day) to attain the flower initiation to harvesting stage (18527.73 ^{0}C day). Pusa 1431 on 14th Mar took significantly minimum PTI from flower initiation (5184.75 ^{0}C day) till at harvesting stage (14127.72 ^{0}C day).

The present investigations concluded that GDD, HTU and PTI values increased from flowering to harvesting stage. PDM 139 exhibited more values of GDD, HTU and PTI which revealed that it accumulates more dry matter during its entire growth stages and having high seed and biological yield (Table no 3). Among dates of sowing normal sowing 27th Feb recorded higher magnitudes of photo-thermal parameters as compared to early and late sowing and revealed high seed and biological yields (Table no 3). In treatment combinations PDM139 sown at 27th Feb possessed the more values of heat units as compared to remaining interactions and had more seed and biological yielding (Table no 3). Kumar *et al*. (2017) [4] also concluded that seed yield showed significant and positive association with days to maturity, growing degree days. Based on variability, association and path analysis; maturity, photo thermal index and growing degree days were found most contributing indices/ traits and should be considered as selection criteria for discrimination of outstanding green gram genotypes under heat stress conditions.

Table 1: GDD, HTU PTI at different phenological stages of summer mungbean genotypes under staggered dates of sowing

Factor A	At flower initiation			At pod formation		
	GDD (^{0}C day)	HTU (^{0}C day)	PTI (^{0}C day)	GDD (^{0}C day)	HTU (^{0}C day)	PTI (^{0}C day)
V1	551.38	4626.28	6519.17	730.32	6177.45	8710.63
V2	540.86	4543.30	6391.65	719.05	6073.45	8571.63
V3	494.33	4155.12	5825.53	670.57	5673.63	7975.17
V4	459.45	3860.57	5406.77	623.63	5252.75	7401.00
V5	460.78	3870.93	5425.35	631.25	5312.83	7494.23
SEm±	0.135	0.441	1.80	0.03	0.46	1.544
C.D. (P=0.05)	0.392	1.285	5.24	0.086	1.33	4.50
Factor B						
D1	494.90	4107.39	5851.93	667.44	5643.66	7961.30
D2	521.58	4441.90	6327.21	690.00	5864.92	8409.60
D3	487.61	4084.40	5561.93	667.45	5585.49	7720.70
SEm±	0.104	0.342	1.39	0.023	0.354	1.196
C.D. (P=0.05)	0.303	0.995	4.06	0.067	1.031	3.48

Treatment combinations

Treatment combinations	At flower initiation			At Pod formation		
	GDD (^{0}C day)	HTU (^{0}C day)	PTI (^{0}C day)	GDD (^{0}C day)	HTU (^{0}C day)	PTI (^{0}C day)
V1D1	443.25	3786.25	5041.90	619.90	5148.00	7144.00
V1D2	573.60	4886.60	6968.65	745.40	6307.35	9097.60
V1D3	499.05	4252.80	6049.40	648.40	5535.95	7893.40
V2D1	523.55	4374.40	5986.25	704.95	5933.35	8175.95
V2D2	549.60	4585.05	6517.90	730.20	6186.20	8732.15
V2D3	549.45	4670.30	6670.75	722.00	6100.80	8806.80
V3D1	487.25	4105.25	5554.10	667.90	5583.50	7725.50
V3D2	496.70	4107.30	5873.10	670.35	5681.75	7996.10
V3D3	499.05	4252.80	6049.40	673.45	5755.65	8203.90
V4D1	532.45	4410.10	6089.70	714.10	6023.25	8287.25
V4D2	548.10	4582.15	6499.15	731.45	6201.75	8747.05
V4D3	440.05	3573.75	5184.75	602.60	5074.30	7165.60
V5D1	451.55	3860.95	5237.70	630.40	5239.35	7270.80
V5D2	442.15	3578.45	5194.75	604.60	5078.30	7169.60
V5D3	486.75	4147.00	5897.85	660.75	5624.85	8046.30
SEm±	0.233	0.764	3.11	0.051	0.79	2.67
C.D. (P=0.05)	0.679	2.22	9.07	0.149	2.31	7.79

Table 2: GDD, HTU PTI at different phenological stages of summer mungbean genotypes under staggered dates of sowing

Factor A	At seed formation			At physiological maturity			At harvest		
	GDD (^{0}C day)	HTU (^{0}C day)	PTI (^{0}C day)	GDD (^{0}C day)	HTU (^{0}C day)	PTI (^{0}C day)	GDD (^{0}C day)	HTU (^{0}C day)	PTI (^{0}C day)
V1	842.43	7151.30	10090.10	1320.22	11637.17	16115.05	1427.86	12285.33	17460.26
V2	831.50	7043.18	9954.94	1323.82	11678.57	16160.00	1418.61	12222.59	17339.34
V3	748.13	6358.28	8918.97	1149.17	9861.20	13762.78	1209.68	10220.42	14664.08
V4	740.22	6268.10	8830.62	1123.14	9766.27	13605.10	1202.45	9343.49	14574.51
V5	782.63	6642.97	9351.27	1225.70	10723.65	14897.20	1321.39	11324.56	16082.81
SEm±	0.126	1.74	2.47	0.25	2.12	0.47	0.166	3.43	1.60
C.D. (P=0.05)	0.367	5.06	7.19	0.74	6.18	1.37	0.482	10.11	4.65
Factor B									
D1	788.76	6689.26	9454.52	1207.87	10549.01	14681.34	1298.64	11139.37	15764.96
D2	809.83	6894.30	9455.13	1270.08	11436.65	15783.23	1357.13	11215.64	16912.74
D3	763.56	6452.74	9323.63	1191.67	10154.45	14163.51	1292.22	10882.82	15394.89
SEm±	0.098	1.346	1.92	0.20	1.64	0.37	0.128	2.82	1.24
C.D. (P=0.05)	0.284	3.92	5.57	0.57	4.79	1.06	0.373	8.32	3.60

Treatment combinations

Treatment combinations	At seed formation			At physiological maturity			At harvest		
	GDD (^{0}C day)	HTU (^{0}C day)	PTI (^{0}C day)	GDD (^{0}C day)	HTU (^{0}C day)	PTI (^{0}C day)	GDD (^{0}C day)	HTU (^{0}C day)	PTI (^{0}C day)
V1D1	856.50	7262.80	10128.15	1322.25	11743.20	16128.45	1418.40	12212.29	17298.92
V1D2	864.85	7391.35	10290.20	1382.25	12516.40	17251.60	1480.05	12860.00	18527.70
V1D3	791.34	6745.99	9547.36	1256.15	11651.90	15965.10	1385.13	11783.73	16554.12
V2D1	853.35	7292.45	9987.60	1266.95	11776.10	15799.95	1385.13	11783.73	16554.12
V2D2	856.15	7268.15	10286.55	1322.25	11743.20	16128.45	1404.90	12069.85	17123.70
V2D3	785.00	6568.95	9590.65	1192.25	12316.40	17051.60	1425.80	12814.19	18340.20
V3D1	780.00	6518.95	9450.65	1205.70	10266.10	14336.00	1297.05	10850.30	15453.20
V3D2	794.25	6738.05	9521.35	1262.25	11443.40	15981.60	1335.80	12234.19	17270.60
V3D3	745.40	6307.35	9097.60	1200.15	11023.35	15290.10	1323.13	11707.85	16625.28
V4D1	736.05	6280.30	8981.60	1108.60	9494.65	13131.80	1190.55	10257.35	16069.98
V4D2	756.80	6408.30	8807.00	1166.75	10461.50	14431.50	1247.08	9952.48	15468.69
V4D3	718.45	6088.65	8587.25	1081.80	9238.55	13092.15	1178.70	9729.29	14127.72
V5D1	789.45	6621.83	9615.78	1231.25	10781.55	14965.50	1324.00	11315.51	16069.98
V5D2	808.25	6883.50	9434.85	1275.00	11632.11	15543.89	1382.32	11721.90	16547.35
V5D3	745.40	6307.35	9097.60	1209.00	11065.60	15391.35	1349.60	11866.91	15711.81
SEm±	0.218	3.01	4.28	0.44	3.68	0.81	0.287	3.85	2.76
C.D. (P=0.05)	0.635	8.77	12.45	1.28	10.71	2.38	0.835	11.34	8.05

Table 3: Yield and yield components of summer mungbean genotypes under staggered dates of sowing

Factor A	Seed yield (g plant^{-1})	Seed Yield (Kg ha^{-1})	Biological yield (g plant^{-1})	Biological yield (Kg ha^{-1})
V1	5.47	730.42	14.89	2281.82
V2	5.28	700.85	13.93	2194.33
V3	4.55	585.48	11.52	2032.59
V4	4.28	532.37	11.12	1973.01
V5	4.86	625.68	12.34	2076.36
SEm±	0.001	0.161	0.31	0.18
C.D. (P=0.05)	0.003	0.469	0.904	0.524
Factor B				
D1	4.89	659.27	12.24	2092.54
D2	5.64	736.07	13.71	2321.24
D3	4.13	509.54	12.33	1921.08
SEm±	0.001	0.125	0.24	0.139
C.D. (P=0.05)	0.002	0.364	0.7	0.406

Treatment Combinations

Treatment combinations	Seed yield (g plant^{-1})	Seed Yield (Kg ha^{-1})	Biological yield (g plant^{-1})	Biological yield (Kg ha^{-1})
V1D1	5.43	779.95	13.87	2252.26
V1D2	6.36	826.02	16.92	2473.09
V1D3	4.63	585.29	13.88	2120.10
V2D1	5.30	745.15	13.48	2187.17
V2D2	6.01	802.81	15.12	2398.35
V2D3	4.53	554.58	13.17	1997.46
V3D1	4.61	598.31	11.06	2015.52
V3D2	5.31	677.40	11.99	2249.93
V3D3	3.73	480.74	11.51	1832.33
V4D1	4.37	528.63	10.86	1956.19
V4D2	4.90	647.83	11.52	2200.72
V4D3	3.57	420.64	10.56	1762.11
V5D1	4.75	644.28	11.91	2051.57
V5D2	5.63	726.31	13.03	2284.10
V5D3	4.21	506.44	12.09	1893.41
SEm±	0.002	0.271	0.538	0.312
C.D. (P=0.05)	0.005	0.0813	-	0.907

Singh and Singh (2015) [10] had also reported that early sown crop required highest thermal indices to achieve maturity and with each successive delay in sowing comparatively lower thermal indices were needed by mungbean crop.

Kiran and Chimmad (2018) [2] also reported that delayed sown conditions in chickpea significantly reduced all the morphological traits and reduced phenological stages which varies the thermal indices. The genotypes performed better in D2 (sowing dates) temperature regime with respect to morpho-phenological traits which showed higher plant height, number of primary branches and number of secondary branches which also took more number of days and accumulates optimum heat units for days to flowering, days to fifty per cent flowering, days to pod initiation, days to seed formation and days to maturity and also showed decreasing trend in phenol-thermal index (PTI) with yield was recorded in D2 temperature regime.

The detrimental effect of temperature at later stage of crop development in early and delayed sowing had an adverse effect on seed yield. Normal sown crop produced more dry matter and also resulted in higher seed yield as they availed more GDD which shortening of the duration of various growth phases might be the probable reason in the late sown crop for the reduction in the total biomass (Silawat *et al*., 2015) [9].

Conclusions

On the basis of present study it concluded that sowing of PDM 139 on 27th Feb (6.79 g plant^{-1} and 880.10 Kg ha^{-1}) exhibited significantly higher growth and yield due to optimal conditions for growth and development of mungbean crop and higher accumulation of photo-thermal parameters. The yield of mungbean varieties decreased with delay in sowing.

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