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Evaluation of Mungbean Genotypes for Phenophases and Morpho-physiological Traits during Heat and Water Stress Conditions for Optimizing Productivity

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was carried out to study the effect of phenophases, morpho-physiological parameters and yield attributing traits on mungbean under different dates of sowing 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. PDM139 (V_1) had an earliest attainment of all the phenophases and registered the lowest time for reproductive period (32.00 days) as well as span of seed filling period (18.66 days) and also recorded average highest LAI (0.723), LAD (7717.48 cm^2. days), CGR (0.00125 g cm^2 day^{-1}), RGR (0.03614 g g^{-1} day^{-1}), SLA (391.94 cm^2 g^{-1}) and carbon sequestration (58.93 g $plant^{-1}$). PDM139 (V_1) outyielded (5.78 g $plant^{-1}$ and 787.74 Kg ha^{-1}) others owing higher magnitudes of physiological parameters and mechanisms reflected in maximum yield

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components and subsequently yield. On the other hand D_2 (27th Feb.) took comparatively more time to achieve all the phenophase as compared to the former as well as average highest magnitudes of these parameters. Among sowing dates sowing carried out on 14th Mar (D_3) acquired the minimum time to attain all the phenophases. Among interactions, V_1D_2 (PDM139 sown on 27th Feb.) took comparatively more time to attain flower initiation (26.33 days) besides a short duration of reproductive span (31.00 days) and a comparatively low magnitudes of seed filling period (18.00 days) and as well as recorded average maximum magnitudes of LAI (Leaf Area Index), LAD (Leaf Area Duration, CGR (Crop Growth Rate), RGR (Relative Growth Rate), SLA (Specific Leaf Area), SLW (Specfic Leaf Weight) and carbon sequestration. Therefore, based on above results selection of genotypes could bring out desired improvement in yield and its attributing characters of mungbean cultivars.

Keywords: Mungbean; LAI; LAD; CGR; RGR; SLA; SLW; carbon sequestration.

ABBREVIATIONS

V1 : PDM139,
V2 : Pusa Ratna,
V3 : Pusa Vishal,
V4 : Pusa 1431
V5 : TJM3
D1 : First date of sowing (12th Feb),
D2 : Second date of sowing (27th Feb)
D3 : Third date of sowing (14th Mar)

1. INTRODUCTION

Mung bean [*Vigna radiata* (L.) Wilczek] is an important warm season grain legume with short duration, wide adaptability, high quality of protein, nitrogen fixation capability, ability to prevent soil erosion, and suitable for various cropping systems. . The irrigation is critical during pod-filling and flowering stages in mungbean plants mainly because of the higher leaf area index during these periods and consequently, the greater demand for water [1]. The correlation of LAD and grain yield is positive and so high and compared to the LAR has more correlation with grain yield since produced leaf area is important for the plant when it has capability to photosynthesize for a long time and a leaf which has no durability is not beneficial for the plant and a plant consumes more energy and photosynthesis assimilates for leaf production so the leaves which have longer life are more capable to compensate consumed photosynthesis assimilates for its production [2]. The plant dry matter production and accumulation can be analyzed through crop growth rate (CGR) [3]. The Relative growth rate represents the increment in biomass per unit of biomass present which may play a key role during a particular period of time in the crop productivity [4]. Hence, the present investigations are undertaken to optimize the appropriate sowing period and variety under prevailing conditions.

2. MATERIALS AND METHODS

An experiment is carried out to evaluate the effect of various dates of sowing on morpho-physiological parameters as well as yield and yield attributing characters in different varieties of summer mungbean under terminal heat and water stress conditions during *summer* seasons of 2017-18 and 2018-19 at the Research Farm, Department of Plant Physiology Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur (Madhya Pradesh) which was carried out in a 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.

The phenophases were recorded either at initiation or completion that stage. Weight of carbon dioxide sequestered in tree Scott de wald *et al*. [5]. The Physiological parameters like

a) Leaf Area Index [6]

$$LAI = \frac{\text{Leaf area}}{\text{Ground area}}$$

b) Leaf Area Duration [7]

$$LAD = (LA_2 + LA_1)/2 \quad x\ (t_2 - t_1)(cm^2.days)$$

Where LA_1 and LA_2 represents the leaf area at two successive time intervals (t_1 and t_2).

c) Crop Growth Rate [7]

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P} \text{ g cm}^{-2} \text{ d}^{-1}$$

Where,
W_1= Dry weight (g) of the plants at time t_1
W_2= Dry weight (g) of plants at time t_2
P = Unit land area occupied by the plant (cm^2)

d) Relative Growth Rate [7]

$$RGR = [(\ln W_2 - \ln W_1)/ (t_2-t_1)] \text{ (g g}^{-1} \text{ day}^{-1}\text{)}$$

e) Specific Leaf Area [6]

$$SLA = \frac{\text{Leaf area}}{\text{Leaf dry weight}} \text{ cm}^2 \text{ g}^{-1}$$

f) Specific Leaf Weight [8]

$$SLW = \frac{\text{Leaf dry weight}}{\text{Leaf area}} \text{ g cm}^{-2}$$

The seed and biological yield g $plant^{-1}$ and kg ha^{-1} was recorded after threshing, cleaning and drying the seeds.

3. RESULTS AND DISCUSSION

3.1 Phenological Stages

The present study revealed (Table. 1) that among factor A (genotypes) PDM139 had an earliest attainment of all phenophases and registered the longest time for reproductive period (32.00 days) as well as span of seed filling period (18.66 days), whereas the Pusa1431 possessed the longest duration of reproductive span (36.17 days) as well as duration of seed filling (22.84 days). The higher duration of reproductive span and seed filling trait may be beneficially utilized in a breeding programme for enhancing the productivity. As earlier investigations showed their positive correlation with the economic productivity provided the grain filling rate is constantly higher [4].

Among treatments of factor B mungbean genotypes sown on 14th Mar. acquired the minimum time to attain all phenophases which clearly indicated that delayed sowing is associated with early attainment of all phenophases resulted in forced maturity. On the other hand, sowing carried out on 27th Feb. resulted in attaining more time to achieve all phenophases which clearly indicated that the span of reproductive phase was comparatively more. In late sown lines the flowering was initiated 4-5 days earlier *i.e.* 28-38 DAS [9]. The days to 50% flowering contributed maximum positive and direct effect on yield indicating that the trait should be given emphasis while selecting high yielding mungbean cultivars for irrigated conditions. It was very interesting to witness that the sowing carried out during 12th Feb. had the longest span of reproductive phase (36.34 days). However, it had shortest duration pod seed filling (19.34 days). This suggests that early sowing though initiated early flowering but could not prolong seed filling duration. Late sowing on 14th Mar. though had shortest span of reproductive phase (33.10 days) but had prolonged duration of seed filling (23.01 days).

Among interactions genotype PDM139 sown on 27th Feb. took comparative more time to attain flower initiation (26.33 days) besides a short duration of reproductive span (31.00 days) and a comparatively low magnitudes of seed filling period (18.00 days). On the other hand genotype Pusa Ratna sown during 27th Feb. had late appearance of flowers (32.33 days) as well as attainment of physical maturity (71.83 days). Besides, it registered a comparative higher span of reproductive phase (34.17 days) with comparatively higher duration of seed filling (21.17 days). TJM3 sown on 14th Mar. had earliest attainment of flower initiation stage though had the shortest duration of reproductive period (30.33 days). Pusa1431 sowing carried out during 14th Mar. recorded a comparatively higher duration of reproductive phase (35.50 days) besides higher duration of seed filling (25.50 days).

3.2 Leaf area Index (LAI)

In the present study, it was noted that a LAI had a continuous enhancement with the progressive advancement of the crop age upto 50 DAS, thereafter it declined during subsequent growth phases in all factors and treatment combinations. The decline of LAI in later growth phases was attributed to the reduction in quantum of assimilatory surface area as a result of drying and senescence of leaves. However, Rajput *et al.* [10] recorded the non-significant differences in LAI of mungbean genotypes examined. Among treatments of factor A, PDM139 possessed the average maximum (Table 2) LAI (0.723). On the other hand, Pusa1431 recorded the average lowest LAI (0.561). The higher LAI in PDM139 may be attributed to the genetic make-up of genotype. The higher LAI in genotype PDM139 is a beneficial trait for breeding aspects. The higher LAI is a beneficial trait as long as mutual shedding among leaves does not begin. The LAI is related to the biological and economic yields and increase in LAI caused higher yield [11].

Among treatments of factor B, sowing carried out during 27th Feb. resulted in average higher LAI (0.67) over other sowing dates which may be attributed to the optimum availability of growth factors which might have contributed in increasing quantum of assimilatory surface area. On the other hand, sowing carried out during 14th Mar. recorded the lowest (0.60).

In interactions, PDM139 sown on 27th Feb. resulted in maximum LAI (0.76), whereas genotype Pusa1431 sown on 14th Mar. registered the minimum (0.53).

Table 1. Various phenophases of summer mungbean genotypes under staggered dates of sowing

Factor A	Days to Flower Initiation	Days to 50% Flowering	Days to Pod Formation	Days to seed formation	Days to Physiological Maturity	Days to Harvest Maturity
V1	26.72	31.72	34.94	40.06	56.17	58.72
V2	31.11	36.11	39.28	44.44	64.39	67.22
V3	28.78	33.78	36.94	42.11	60.78	63.33
V4	31.39	36.39	39.56	44.72	64.67	67.56
V5	26.94	31.94	35.11	40.28	56.44	59.06
SEm±	0.216	0.219	0.22	0.216	0.352	0.008
C.D. (P=0.05)	0.629	0.646	0.63	0.0629	1.052	0.023
Factor B						
D1	31.63	37.63	41.63	48.63	64.60	67.97
D2	29.30	34.30	37.30	42.30	60.20	62.43
D3	26.03	30.33	32.53	36.03	56.67	59.13
SEm±	0.167	0.169	0.17	0.167	0.273	0.006
C.D. (P=0.05)	0.487	0.498	0.49	0.487	0.794	0.018

Table 1. Interactions

Treatment Combinations	Days to Flower Initiation	Days to 50% Flowering	Days to Pod Formation	Days to seed formation	Days to Physiological Maturity	Days to Harvest Maturity
V1D1	29.17	35.17	39.17	46.17	60.83	63.67
V1D2	26.33	31.33	34.33	39.33	55.00	57.33
V1D3	24.66	28.67	31.17	34.67	52.67	55.16
V2D1	33.67	39.67	43.67	50.67	67.67	71.83
V2D2	32.33	37.33	40.33	45.33	64.50	66.50
V2D3	27.33	31.33	33.83	37.33	61.00	63.33
V3D1	31.67	37.67	41.67	48.67	65.17	68.33
V3D2	29.33	34.33	37.33	42.33	61.33	63.17
V3D3	25.33	29.33	31.83	35.33	55.83	58.50
V4D1	34.17	40.17	44.17	51.17	67.83	72.00
V4D2	31.83	36.83	39.83	44.83	64.83	67.00
V4D3	28.17	32.17	34.67	38.17	61.33	63.67
V5D1	29.50	35.5	39.50	46.50	61.50	64.00
V5D2	26.67	31.67	34.67	39.67	55.33	58.17
V5D3	24.67	28.67	31.17	34.67	52.50	55.00
SEm±	0.374	0.37	0.375	0.37	0.61	0.013
C.D. (P=0.05)	1.089	1.09	1.091	1.089	1.776	0.039

Table 2. Leaf area index (LAI) and Leaf area duration (LAD cm². days) of summer mungbean genotypes under staggered dates of sowing during entire crop growth span

Factor A	Leaf Area Index (LAI)						Leaf Area Duration (LAD cm². days)				
	20 DAS	30 DAS	40 DAS	50 DAS	At Harvest	Mean	30 DAS	40 DAS	50 DAS	At Harvest	Mean
V1	0.175	0.339	0.638	1.403	1.059	0.723	3265.7	7587.9	11240.0	8776.3	7717.5
V2	0.152	0.287	0.559	1.318	0.974	0.658	3108.2	7430.4	11082.5	8618.8	7560.00
V3	0.11	0.221	0.477	1.237	0.896	0.588	2605.5	6927.7	10579.8	8116.1	7057.28
V4	0.104	0.198	0.443	1.203	0.857	0.561	2484.3	6806.5	10458.6	7994.9	6936.08
V5	0.129	0.246	0.507	1.279	0.934	0.619	3002.8	7325.0	10977.1	8513.4	7454.58
SEm±	0.009	0.009	0.013	0.018	0.018	0.011	45.98	120.55	194.21	142.63	124.84
C.D. (P=0.05)	0.027	0.027	0.037	0.053	0.051	0.033	136.10	359.23	572.91	422.18	367.02
FactorB											
D1	0.125	0.24	0.528	1.28	0.94	0.62	2856.85	7178.45	10831.2	8367.65	7308.53
D2	0.17	0.261	0.574	1.34	0.99	0.67	3075.45	7397.05	11049.8	8586.25	7527.13
D3	0.108	0.273	0.473	1.24	0.9	0.6	2656.95	6978.55	10631.3	8167.75	7108.63
SEm±	0.007	0.007	0.01	0.014	0.014	0.009	42.41	116.73	190.62	139.11	121.00
C.D. (P=0.05)	0.021	0.021	0.029	0.041	0.04	0.025	125.20	344.35	564.23	413.16	359.30

Table 2. Interactions

Treatment combinations	Leaf Area Index (LAI)						Leaf Area Duration (LAD cm². days)				
	20 DAS	30 DAS	40 DAS	50 DAS	At Harvest	Mean	30 DAS	40 DAS	50 DAS	At Harvest	Mean
V1D1	0.167	0.324	0.645	1.4	1.24	0.72	2942.15	7229.65	10880.9	8419.25	7367.98
V1D2	0.216	0.35	0.688	1.45	1.1	0.76	3233.85	7521.35	11172.6	8710.95	7659.68
V1D3	0.144	0.34	0.581	1.35	1.01	0.69	2768.55	7056.05	10707.3	8245.65	7194.38
V2D1	0.143	0.26	0.56	1.32	0.97	0.65	2854.45	7141.95	10793.2	8331.55	7280.28
V2D2	0.194	0.29	0.619	1.37	1.03	0.7	3078.25	7365.75	11017	8555.35	7504.08
V2D3	0.118	0.3	0.499	1.26	0.92	0.62	2704.95	6992.45	10643.7	8182.05	7130.78
V3D1	0.104	0.21	0.483	1.23	0.9	0.58	2506.05	6793.55	10444.8	7983.15	6931.88
V3D2	0.138	0.22	0.516	1.28	0.93	0.61	2567.45	6854.95	10506.2	8044.55	6993.28
V3D3	0.089	0.24	0.434	1.2	0.86	0.56	2413.15	6700.65	10351.9	7890.25	6838.98
V4D1	0.09	0.18	0.456	1.18	0.85	0.55	2358.85	6646.35	10297.6	7835.95	6784.68
V4D2	0.141	0.2	0.481	1.25	0.9	0.59	2463.25	6750.75	10402	7940.35	6889.08
V4D3	0.079	0.22	0.392	1.17	0.82	0.53	2333.35	6620.85	10272.1	7810.45	6759.18
V5D1	0.12	0.22	0.493	1.26	0.92	0.6	2735.55	7023.05	10674.3	8212.65	7161.38
V5D2	0.159	0.25	0.566	1.34	0.99	0.66	2939.65	7227.15	10878.4	8416.75	7365.48
V5D3	0.107	0.27	0.46	1.23	0.89	0.59	2637.95	6925.45	10576.7	8115.05	7063.78
SEm±	0.016	0.016	0.022	0.032	0.03	0.02	39.87	112.32	185.84	135.38	118.60
C.D.(P=0.005)	-	-	-	-	-	-	-	-	-	-	-

3.3 Leaf Area Duration (LAD) (cm^2. days)

The present study indicated (Table 2) that the LAD had an increasing trend with the progressive increase in life span of crop till 50 DAS followed by a subsequent decline in remaining phases of growth in all factors and their interactions. The decline was attributed to the reduction in the quantum of LAI. The decline in leaf area duration was significant at moisture stress given at flower initiation and pod initiation stages in summer mungbean genotypes (SML1082 and SML1168) [12].

Among treatments of factor A, PDM139 possessed highest LAD (7717.50 cm^2. days) which is beneficial trait which may be utilized in a breeding programme for enhancing LAD in mungbean which has been found to be highly associated with the economic productivity of crop [13]. Pusa1431 attained the minimum LAD (6936.08 cm^2. days).

Among treatments of factor B, sowing carried out during 27th Feb. recorded the highest LAD (7527.13 cm^2. days) which indicated suitability of sowing time for attaining maximum LAD which has a significant role in maintaining persistence and active period of leaf growth. On the other hand, sowing carried out on 14th Mar. exhibited the lowest LAD (7108.63 cm^2. days).

In interactions, PDM139 sown on 27th Feb. exhibited highest LAD (7659.68 cm^2. days), whereas Pusa1431 sown on 14th Mar. was found to be associated with the lowest magnitude (6759.18 cm^2. days).

3.4 Crop Growth Rate (CGR g cm^{-2} day^{-1})

The present study indicated that the CGR in mungbean showed an increasing trend from early growth period onwards reaching the peak at 50 DAS afterwards it declined. The decline was attributed to the reduction in magnitudes of LAI and LAD (Table 3). Mondal *et al*. [14] showed that CGR and RGR also decreased with moisture stress and an increase in values. The maximum CGR was observed during pod filling stage in all the varieties due to maximum leaf area (LA) development at this stage. Two plant characters such as LA and CGR contributed to the higher TDM production. Results indicated that high yielding mungbean varieties should possess larger LA, higher TDM production ability, superior CGR at all growth stages which would result in superior yield components.

Among treatments of factor A, PDM139 recorded the average maximum CGR (0.00125 g cm^{-2} day^{-1}) over other genotypes, whereas Pusa1431 exhibited the minimum (0.0008 g cm^{-2} day^{-1}). The CGR was ranged between 0.30 to 25.6 g m^{-2} day^{-1} [10]. In the treatments of factor B, sowing carried out during 27th Feb. significantly superseded other sowing dates for CGR (0.00125 g cm^{-2} day^{-1}) which was attributed to the resultant of enhancement in LAI and LAD. Sowing carried out on 14th Mar. recorded lowest CGR (0.00088 g cm^{-2} day^{-1}) due to increase in temperature threshold coupled with higher light intensities. In interactions, PDM139 sown on 27th Feb. exhibited average highest CGR (0.0014 g cm^{-2} day^{-1}), whereas Pusa1431 sown on 14th Mar. recorded the lowest (0.0004 g cm^{-2} day^{-1}).

3.5 Relative Growth Rate (RGR) (g g^{-1} day^{-1})

The Relative growth rate represents the increment in biomass per unit of biomass present which may play a key role during a particular period of time in the crop productivity [4]. The plant dry matter production and accumulation can be analyzed through crop growth rate (CGR) and relative growth rate (RGR) which are the most important growth indices [3].

The present investigations (Table 3) showed that there was enhancement in the magnitudes of RGR from early growth phase onwards till 40 DAS thereafter it declined during rest of the crop growth life span in all the factors and interactions as also reported by Shihabuddin *et al*. [15]. The RGR decreased with the moisture stress [12].

Among the treatments of factor A, PDM139 recorded an average maximum RGR (0.03614 g g^{-1} day^{-1}), whereas Pusa1431 exhibited the lowest values for this character (0.035174 g g^{-1} day^{-1}). The RGR was found to be in the range of 0.01 to 0.043 g m^{-2} day^{-1} [10]. The high yielding mungbean varieties should possess the highest relative growth rate which would result in superior yield components [14].

Among the treatments of factor B, sowing carried out during 27th Feb. recorded the average maximum (0.038255 g g^{-1} day^{-1}) RGR which was attributed to an increase in quantum of LAI, LAD and CGR. Sowing carried out on 14th Mar. was found to be associated with the lowest RGR (0.032643 g $g^{-1}$$day^{-1}$). In interactions, PDM139 sown on 27th Feb. exhibited highest RGR (0.0425 g g^{-1} day^{-1}), whereas Pusa1431 sown on 12th

Feb. possessed the average minimum RGR (0.0225 g g^{-1} day^{-1}).

3.6 Specific Leaf Area (SLA cm^2 g^{-1})

The specific leaf area represents relative proportion of mechanical, conductive and assimilatory tissues in the assimilatory apparatus which may be useful in dry matter production and its efficient mobilization to the developing sink and providing resistance against water loss [4].

The present study revealed (Table 4) that the SLA had the higher magnitudes during early growth periods upto 30 DAS thereafter it showed a continuous reduction till maturity in all the treatments of factors and interactions. The decline was attributed to the reduction of SLW during later growth span.

Among the treatments of factor A, PDM139 recorded average maximum (391.94 cm^2 g^{-1}) SLA as compared to other genotypes. This trait will facilitate the genotype in higher assimilate mobilization to the demanding sink besides providing mechanical strength to the assimilatory apparatus which might not wilt even at a low water potential values. Pusa1431 recorded the minimum (332.55 cm^2 g^{-1}). The specific leaf area of the genotype K851 showed less per cent reduction (57.8) in leaf area under drought conditions, which is due to less elongation and enlargement of cells [16].

Among the treatments of factor B, sowing carried out during 12th Feb. recorded the average maximum (392.07 cm^2 g^{-1}) SLA. On the other hand, sowing carried out during 27th Feb. recorded the lowest SLA (294.68 cm^2 g^{-1}). The higher magnitudes of SLA during early sowing period was attributed to higher performance of mechanical, conductive and assimilatory tissues in the assimilatory apparatus.

In interactions, PDM139 sown on 12th Feb. exhibited highest (437.27 cm^2 g^{-1}) SLA, whereas Pusa Ratna sown on 27th Feb. recorded the lowest magnitude (301.23 cm^2 g^{-1}) for this parameter.

3.7 Specific Leaf Weight (SLW g cm^{-2})

The SLW represents leaf thickness and gives an estimative of the proportion between the assimilatory surface and the veins that sustain those leaf tissues [17]. The specific leaf weight showed significant positive association with seed yield. Thus tall plants with more specific leaf weight with more relative water content are the major yield contributing characters for rainfed vertisols [18].

The present study indicated (Table 4) that SLW in treatments of factors and interactions was found to be enhanced from early growth span reaching the peak at 50 DAS followed by a decline in remaining growth phases. The decline in later growth phases was attributed to the per unit decrease in assimilatory power of assimilatory apparatus during this period.

In treatments of factor A, genotype Pusa1431 possessed average maximum SLW (0.0034 g cm^{-2}) as compared to other genotypes under investigations. On the other hand, PDM139 exhibited the lowest magnitude (0.0015 g cm^{-2}). In treatments of factor B, sowing carried out during 27th Feb. significantly superseded (0.0031 g cm^{-2}) other sowing dates. The higher magnitude during this period may be attributed to the maximum per unit area assimilate production in assimilatory apparatus. Sowing carried out during 12th Feb. and 14th Mar. was found to be associated to the average lowest (0.0020 g cm^{-2}). In interactions, Pusa1431 sown during 27th Feb. recorded the maximum (0.0033 g cm^{-2}), whereas PDM139 sown on 14th Mar. indicated the lowest magnitude (0.0014 g cm^{-2}) for the same trait.

3.8 Carbon Sequestration (CS g $plant^{-1}$)

Carbon sequestration, the long-term storage of carbon in plants, soils, geologic formations, and the ocean. Carbon sequestration occurs both naturally and as a result of anthropogenic activities and typically refers to the storage of carbon that has the immediate potential to become carbon dioxide gas. In response to growing concerns about climate change resulting from increased carbon dioxide concentrations in the atmosphere, considerable interest has been drawn to the possibility of increasing the rate of carbon sequestration through changes in land use and forestry and also through geo-engineering techniques such as carbon capture and storage [19]. Main Objective to include these parameter is to express its carbon storage capacity which influences the productivity.

Trees possess unique property of effective sequestration of carbon as they store it in their above ground and below ground biomass as product of photosynthesis [20].

Table 3. CGR (crop growth rate g cm^{-2} day^{-1}) and RGR (relative growth rate g g^{-1} day^{-1}) of summer mungbean genotypes under staggered dates of sowing

Factor A	CGR (Crop Growth Rate g cm^{-2} day^{-1})					RGR (Relative Growth Rate g g^{-1} day^{-1})				
	30 DAS	40 DAS	50 DAS	At Harvest	Mean	30 DAS	40 DAS	50 DAS	At Harvest	Mean
V1	0.00065	0.00085	0.0021	0.0014	0.00125	0.03246	0.06836	0.03439	0.00936	0.03614
V2	0.00054	0.00075	0.00195	0.00125	0.00113	0.03238	0.06847	0.03365	0.00926	0.03594
V3	0.00035	0.00055	0.0017	0.00105	0.00091	0.03219	0.06864	0.03105	0.00915	0.035255
V4	0.00027	0.00045	0.0015	0.001	0.0008	0.03204	0.0686	0.03098	0.00907	0.035174
V5	0.00046	0.00065	0.0018	0.00115	0.00101	0.03187	0.06824	0.03256	0.00917	0.035461
SEm±	0.0001	0.0001	0.0003	0.0003	0.0002	0.006	0.009	0.005	0.0007	0.008
C.D. (P=0.05)	0.0002	0.0003	0.0009	0.0008	0.0006	-	-	-	0.0021	-
FactorB										
D1	0.000495	0.00064	0.0018	0.0012	0.00103	0.02367	0.06855	0.03864	0.01777	0.037156
D2	0.000635	0.00077	0.00215	0.00145	0.00125	0.04248	0.07257	0.0296	0.00838	0.038255
D3	0.00038	0.00053	0.00155	0.00105	0.00088	0.03579	0.06648	0.02372	0.00458	0.032643
SEm±	0.0001	0.0001	0.0003	0.0003	0.0002	0.005	0.009	0.003	0.0007	0.006
C.D. (P=0.05)	0.0002	0.0002	0.0008	0.0007	0.0006	0.014	0.027	0.008	0.002	0.018

Table 3. Treatment Combinations

Treatment combinations	CGR (Crop Growth Rate g cm^{-2} day^{-1})					RGR (Relative Growth Rate g g^{-1} day^{-1})				
	30 DAS	40 DAS	50 DAS	At Harvest	Mean	30 DAS	40 DAS	50 DAS	At Harvest	Mean
V1D1	0.0005	0.0007	0.0020	0.0013	0.0011	0.0244	0.0682	0.0384	0.0173	0.0244
V1D2	0.0007	0.0009	0.0023	0.0016	0.0014	0.0425	0.0712	0.0295	0.0075	0.0425
V1D3	0.0003	0.0004	0.0012	0.0008	0.0006	0.0337	0.0661	0.0223	0.0044	0.0337
V2D1	0.0004	0.0006	0.0018	0.0012	0.0010	0.0243	0.0684	0.0384	0.0183	0.0243
V2D2	0.0006	0.0008	0.0022	0.0015	0.0013	0.0424	0.0738	0.0295	0.0073	0.0424
V2D3	0.0002	0.0004	0.0011	0.0007	0.0006	0.0330	0.0664	0.0234	0.0043	0.0330
V3D1	0.0003	0.0004	0.0014	0.0010	0.0008	0.0233	0.0695	0.0374	0.0172	0.0233
V3D2	0.0004	0.0006	0.0018	0.0013	0.0010	0.0421	0.0748	0.0293	0.0071	0.0421
V3D3	0.0002	0.0003	0.0008	0.0005	0.0004	0.0302	0.0665	0.0234	0.0040	0.0302
V4D1	0.0002	0.0004	0.0013	0.0009	0.0007	0.0225	0.0693	0.0373	0.0171	0.0225
V4D2	0.0004	0.0006	0.0017	0.0012	0.0009	0.0420	0.0737	0.0292	0.0071	0.0420
V4D3	0.0002	0.0003	0.0007	0.0004	0.0004	0.0300	0.0664	0.0232	0.0040	0.0300
V5D1	0.0003	0.0005	0.0016	0.0011	0.0009	0.0242	0.0682	0.0382	0.0172	0.0242
V5D2	0.0005	0.0007	0.0021	0.0014	0.0012	0.0423	0.0717	0.0293	0.0092	0.0423
V5D3	0.0002	0.0004	0.0009	0.0006	0.0005	0.0312	0.0662	0.0227	0.0041	0.0312
SEm±	0.00005	0.00008	0.0003	0.0002	0.0001	0.0010	0.0050	0.0009	0.0004	0.0010
C.D.(P=0.005)	0.00014	0.00023	0.0008	0.0005	0.0003	-	-	-	0.0012	-

Table 4. SLA (specific leaf area cm² g^{-1}) and SLW (specific leaf weight g cm^{-2}) at different growth stages in summer mungbean genotypes under staggered dates of sowing

Factor A	SLA (Specific Leaf Area cm² g^{-1})						SLW (Specific Leaf Weight g cm^{-2})					
	20 DAS	30 DAS	40 DAS	50 DAS	At Harvest	Mean	20 DAS	30 DAS	40 DAS	50 DAS	At Harvest	Mean
V1	509.61	562.76	300.09	306.17	281.62	391.94	0.0010	0.0011	0.0017	0.0021	0.0019	0.0015
V2	465.31	504.82	281.90	297.52	271.58	364.22	0.0010	0.0021	0.0024	0.0029	0.0024	0.0022
V3	407.82	457.74	276.53	304.47	274.90	344.30	0.0020	0.0032	0.0034	0.0040	0.0031	0.0031
V4	394.55	427.15	268.11	301.93	271.04	332.55	0.0021	0.0033	0.0039	0.0042	0.0033	0.0034
V5	444.16	483.38	278.28	301.46	275.24	356.51	0.0009	0.0021	0.0025	0.0027	0.0028	0.0022
SEm±	33.93	38.78	20.00	22.83	18.89	27.30	0.0001	0.0002	0.0002	0.0003	0.0002	0.0001
C.D. (P=0.05)	-	-	59.00	-	-	80.53	-	0.00048	0.0005	-	-	-
FactorB												
D1	430.83	600.39	330.13	306.90	292.08	392.07	0.0010	0.0013	0.0027	0.0034	0.0016	0.0020
D2	468.35	324.74	224.76	235.73	219.85	294.68	0.0015	0.0032	0.0039	0.0042	0.0028	0.0031
D3	433.69	536.39	288.06	364.30	312.70	386.96	0.0021	0.0021	0.0018	0.0021	0.0020	0.0020
SEm±	30.12	36.53	17.74	20.66	17.08	25.31	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002
C.D. (P=0.05)	-	107.39	52.15	61.15	50.39	74.66	-	-	0.0005	0.0006	0.00049	0.00056

Table 4. Treatment Combinations

Treatment combinations	SLA (Specific Leaf Area cm² g^{-1})						SLW (Specific Leaf Weight g cm^{-2})					
	20 DAS	30 DAS	40 DAS	50 DAS	At Harvest	Mean	20 DAS	30 DAS	40 DAS	50 DAS	At Harvest	Mean
V1D1	496.19	718.67	358.18	311.90	301.42	437.27	0.0012	0.0019	0.0021	0.0026	0.0021	0.0020
V1D2	524.96	366.20	232.42	236.51	221.60	316.34	0.0010	0.0032	0.0033	0.0035	0.0029	0.0028
V1D3	507.69	603.44	309.70	370.10	321.89	422.56	0.0004	0.0011	0.0016	0.0022	0.0018	0.0014
V2D1	446.90	619.04	329.17	300.43	287.35	396.58	0.0007	0.0010	0.0016	0.0023	0.0019	0.0015
V2D2	494.23	334.74	225.83	233.57	217.78	301.23	0.0010	0.0030	0.0031	0.0034	0.0028	0.0027
V2D3	454.82	560.70	290.86	358.56	309.63	394.91	0.0007	0.0020	0.0022	0.0027	0.0021	0.0019
V3D1	398.35	561.59	326.11	309.79	293.49	377.86	0.0008	0.0014	0.0017	0.0023	0.0020	0.0016
V3D2	429.85	306.56	221.93	238.63	220.08	351.73	0.0017	0.0029	0.0030	0.0033	0.0029	0.0028
V3D3	395.28	505.08	281.57	364.99	311.16	338.49	0.0017	0.0030	0.0032	0.0035	0.0030	0.0029
V4D1	367.80	505.57	313.19	301.56	284.70	334.67	0.0018	0.0010	0.0017	0.0023	0.0018	0.0017
V4D2	442.22	296.27	218.65	237.94	219.13	340.01	0.0019	0.0035	0.0039	0.0041	0.0033	0.0033
V4D3	373.63	479.62	272.51	361.63	309.12	329.33	0.0017	0.0029	0.0033	0.0037	0.0031	0.0029
V5D1	444.93	597.09	324.18	310.84	293.45	338.77	0.0007	0.0009	0.0016	0.0024	0.0019	0.0015
V5D2	450.53	319.94	224.98	230.30	220.54	365.74	0.0008	0.0029	0.0032	0.0036	0.0030	0.0027
V5D3	437.05	533.15	285.69	363.25	311.74	347.76	0.0007	0.0020	0.0025	0.0030	0.0025	0.0021
SEm±	27.98	34.26	16.39	17.1	15.47	23.84	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002
C.D.(P=0.005)	-	-	-	-	-	-	-	-	-	-	-	-

Table 5. Carbon sequestration, Seed Yield and Biological yield (Kg ha^{-1}) of summer mungbean genotypes under staggered dates of sowing during entire crop growth period

Factor A	20 DAS	30 DAS	40 DAS	50 DAS	At Harvest	Avg. Mean	Seed Yield (Kg ha^{-1})	Biological Yield (Kg ha^{-1})
V1	4.78	10.51	51.15	101.62	126.60	58.93	730.42	2281.82
V2	4.08	8.98	43.63	87.08	108.85	50.52	700.85	2194.33
V3	3.82	8.31	40.71	80.79	100.21	46.77	585.48	2032.59
V4	3.43	7.47	36.60	72.71	90.11	42.06	532.37	1973.01
V5	4.31	9.42	46.00	91.20	116.60	53.50	625.68	2076.36
SEm±	0.79	1.16	4.58	12.27	14.89	6.44	0.161	0.18
C.D. (P=0.05)	2.33	3.42	13.51	36.19	43.92	18.99	0.469	0.524
FactorB								
D1	3.51	6.05	29.24	69.39	103.44	42.32	659.27	2092.54
D2	5.42	14.31	71.64	140.23	167.12	79.74	736.07	2321.24
D3	3.33	6.45	29.97	50.41	54.90	29.01	509.54	1921.08
SEm±	0.68	0.92	3.84	11.49	13.20	6.04	0.125	0.139
C.D. (P=0.05)	2.00	2.71	11.30	33.89	38.80	17.75	0.364	0.406

Table 5. Treatment Combinations

Treatment combinations	Carbon sequestration (g Plant^{-1})						Seed Yield (Kg ha^{-1})	Biological Yield (Kg ha^{-1})
	20 DAS	30 DAS	40 DAS	50 DAS	At Harvest	Mean		
V1D1	3.95	6.85	33.05	78.53	117.43	47.96	779.95	2252.26
V1D2	6.53	17.19	85.82	168.44	199.17	95.43	826.02	2473.09
V1D3	3.87	7.47	34.56	57.89	63.13	33.38	585.29	2120.10
V2D1	3.55	6.21	29.87	71.04	106.63	43.46	745.15	2187.17
V2D2	5.47	14.41	72.01	141.18	166.60	79.93	802.81	2398.35
V2D3	3.23	6.31	28.99	48.97	53.34	28.17	554.58	1997.46
V3D1	3.33	5.66	27.49	65.16	96.58	39.64	598.31	2015.52
V3D2	4.97	13.12	65.73	128.49	151.01	72.66	677.40	2249.93
V3D3	3.17	6.14	28.92	48.77	53.05	28.01	480.74	1832.33
V4D1	3.08	5.18	25.22	59.65	88.18	36.26	528.63	1956.19
V4D2	4.45	11.77	58.99	115.19	135.08	65.09	647.83	2200.72
V4D3	2.79	5.47	25.61	43.23	46.99	24.81	420.64	1762.11
V5D1	3.67	6.33	30.57	72.58	108.23	44.28	644.28	2051.57
V5D2	5.71	15.10	75.63	147.80	183.64	85.58	726.31	2284.10
V5D3	3.56	6.85	31.79	53.21	57.87	30.65	506.44	1893.41
SEm±	0.53	0.78	3.34	10.76	12.25	5.50	0.271	0.312
C.D.(P=0.005)	1.55	2.30	9.85	31.84	36.26	16.17	0.0813	0.907

The present study indicated (Table no. 5) a continuous increase in carbon sequestration in all the treatments of factors and their interactions from early growth period onwards till attainment of maturity which is attributed to the continuous increase in plant dry matter.

Among the treatments of factor A, PDM139 possessed average maximum carbon sequestration (58.93 g plant^{-1}) which is a beneficial trait correlated with the economic productivity, while Pusa1431 exhibited the lowest (42.06 g plant^{-1}). In the treatments of factor B, sowing carried out during 27th Feb. was found to be associated with average highest (79.74 g plant^{-1}) magnitudes for carbon sequestration, whereas sowing carried out during 12th Feb. indicated minimum (29.01 g plant^{-1}) carbon sequestration. The higher carbon sequestration during 27th Feb. was attributed to higher photosynthetic rate of the genotypes during this period. In interactions, PDM139 own on 27th Feb. exhibited the average highest (95.43 g plant^{-1}) carbon sequestration, whereas Pusa1431 sown on 14th Mar. was found to be associated with the lowest (24.81 g plant^{-1}) value for this character.

3.9 Seed Yield (g plant^{-1} and Kg ha^{-1})

The present study indicated (Table no. 5) that PDM139 significantly outyielded (5.47 g plant^{-1} and 730.42 Kg ha^{-1}) other genotypes owing to higher magnitudes of most of the yield components. On the other hand, Pusa1431 was found to be associated with the minimum (4.28 g plant^{-1} and 532.37 Kg ha^{-1}) seed yield.

Among treatments of factor B, sowing carried out during 27th Feb. recorded significantly highest (5.64 g plant^{-1} and 736.07 Kg ha^{-1}) as compared to other sowing dates. The different sowing dates significantly influenced growth parameters, yield attributes and seed yield of green gram. The higher yield was obtained in timely sowing, due to favourable temperature and humidity during their growth period and nodulation formation stage resulting in better growth. The maximum seed yield (1268 kg ha^{-1}) was recorded under sowing of green gram on 15th March over sowing of green gram on 5th and 15th April (987 and 793 kg ha^{-1}), but it was found at par with sowing of green gram on 25th March seed yield (1194 kg ha^{-1}) in the pooled analysis [21]. The significant reduction in seed yield was recorded in late sowing date [22].

In interactions, PDM139 sown on 27th Feb. recorded the significantly maximum (6.36 g plant^{-1} and 826.02 Kg ha^{-1}) seed yield, while the Pusa1431 sown on 14th Mar. recorded the minimum (3.57 g plant^{-1} and 420.64 Kg ha^{-1}) seed yield.

3.10 Biological Yield (g plant^{-1} and Kg ha^{-1})

The present study indicated (Table no.5) that among the treatments of factor A, genotype PDM139 significantly superseded (14.89 g plant^{-1} and 2281.82 Kg ha^{-1}) others for biological yield. On the other hand, Pusa1431 recorded the minimum (11.12 g plant^{-1} and 1973.01 Kg ha^{-1}). Khan *et al*. [23] found in fourteen mung bean genotypes maximum biological yield for NM92 (13111.1 kg ha^{-1}).

The study pertaining to factor B indicated that sowing carried out during 27th Feb. possessed significantly maximum (13.71 g plant^{-1} and 2321.24 Kg ha^{-1}) biological yield. On the other hand, sowing carried out during 14th Mar. recorded the minimum (12.24 g plant^{-1} and 1921.08 Kg ha^{-1}). The drought and temperature stresses might be the factor affecting the biological yield. There was a significant reduction in biological yield (20-40 %) on per plant basis due to heat stress in LS plants [24].

In interactions, PDM139 sown on 27th Feb. recorded the maximum (16.92 g plant^{-1} and 2473.09 Kg ha^{-1}) biological yield, whereas the minimum was noted in (10.56 g plant^{-1} and 1762.11 Kg ha^{-1}) Pusa1431 sown on 14th Mar.

4. CONCLUSIONS

Among varieties PDM139 (V_1) outyielded (5.78 g plant^{-1} and 787.74 Kg ha^{-1}) other owing to its contribution from morpho-physiological parameters, carbon sequestration and biological yield (16.16 g plant^{-1} and 2421.79 Kg ha^{-1}) which in turn had resulted in highest yield. However, lowest yield (4.65 g plant^{-1} and 571.62 Kg ha^{-1}) was noticed in Pusa 1431 (V_4) due to poor performance of yield components which might be a result of decline in kinetics of physiological mechanisms and parameters. Sowing carried out on 27th Feb. (D_2) recorded the maximum economic yield (6.12 g plant^{-1} and 792.33 Kg ha^{-1}) due to higher performance of morpho-physiological traits. Higher temperatures have been reported to reduce the yields in late sown conditions (14th Mar.) due to leaf senescence and mobilization of photosynthates decline in sinks. Among interactions V_1D_2 (PDM139 sown on 27^{th} Feb.) noted highest seed yield (6.79 g $plant^{-1}$ and 880.10 Kg ha^{-1}).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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