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.

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 (V₁) 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 cm² days), CGR (0.00125 g cm⁻² day⁻¹), RGR (0.03614 g g⁻¹ day⁻¹), SLA (391.94 cm² g⁻¹) and carbon sequestration (58.93 g plant⁻¹). PDM139 (V₁) 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.
components and subsequently yield. On the other hand D2 (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 (D3) acquired the minimum time to attain all the phenophases. Among interactions, V1D2 (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 (Specific 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 morphophysiological 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]

\[ \text{LAI} = \frac{\text{Leaf area}}{\text{Ground area}} \]

b) Leaf Area Duration [7]

\[ \text{LAD} = \frac{(LA_2 + LA_1)}{2} \times (t_2 - t_1) (cm^2 \text{days}) \]

Where LA1 and LA2 represents the leaf area at two successive time intervals (t1 and t2).
c) Crop Growth Rate [7]
\[
\text{CGR} = \frac{W_2 - W_1}{P (t_2 - t_1)} \quad \text{g cm}^{-2} \text{d}^{-1}
\]

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 (cm²)

d) Relative Growth Rate [7]
\[
\text{RGR} = [(\ln W_2 - \ln W_1)/ (t_2-t_1)] (\text{g g}^{-1}\text{ day}^{-1})
\]

e) Specific Leaf Area [6]
\[
\text{SLA} = \frac{\text{Leaf area}}{\text{Leaf dry weight}} \quad \text{cm}^2 \text{g}^{-1}
\]

f) Specific Leaf Weight [8]
\[
\text{SLW} = \frac{\text{Leaf dry weight}}{\text{Leaf area}} \quad \text{g cm}^{-2}
\]

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 comparatively 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 | 10825.0 | 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 | 10971.1 | 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 |

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      | 0.723 | 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 | 10560.2 | 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     | 6838.99 |
| 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) (cm² 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 cm² 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 cm² days).

Among treatments of factor B, sowing carried out during 27th Feb. recorded the highest LAD (7527.13 cm² 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 cm² days).

In interactions, PDM139 sown on 27th Feb. exhibited highest LAD (7659.68 cm² days), whereas Pusa1431 sown on 14th Mar. was found to be associated with the lowest magnitude (6759.18 cm² 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 (0.0008 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.
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 12\(^{th}\) Feb. recorded the average maximum (392.07 cm\(^{2}\) g\(^{-1}\)) SLA. On the other hand, sowing carried out during 27\(^{th}\) 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 12\(^{th}\) Feb. exhibited highest (437.27 cm\(^{2}\) g\(^{-1}\)) SLA, whereas Pusa Ratna sown on 27\(^{th}\) 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 27\(^{th}\) 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 12\(^{th}\) Feb. and 14\(^{th}\) Mar. was found to be associated to the average lowest (0.0020 g cm\(^{-2}\)). In interactions, Pusa1431 sown during 27\(^{th}\) Feb. recorded the maximum (0.0033 g cm\(^{-2}\)), whereas PDM139 sown on 14\(^{th}\) 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 |
| Factor B | | | | | | | | | | |
| 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 | 0.002 | 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 | 0.0006 | 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 | 0.0101 | 0.005 | 0.0009 | 0.0004 | 0.010 |
| 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  | -       | -       | -         | -     |

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    | 329.32 | 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                            |

| Factor B | D1     | D2     | D3     | SEm±   | C.D. (P=0.05) |
|----------|--------|--------|--------|--------|---------------|
| D1       | 3.51   | 6.05   | 29.24  | 0.92   | 2.00          |
| D2       | 5.42   | 14.31  | 71.64  | 0.78   | 1.71          |
| D3       | 3.33   | 6.45   | 29.97  | 0.78   | 1.71          |
| SEm±     | 0.68   | 0.92   | 3.84   | 0.64   | 0.364         |
| C.D. (P=0.05) | 2.00   | 2.71   | 11.30  | 3.80   | 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 | 20 DAS | 30 DAS | 40 DAS | 50 DAS | At Harvest | Mean | 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 27\(^{th}\) Feb. was found to be associated with average highest (79.74 g plant\(^{-1}\)) magnitudes for carbon sequestration, whereas sowing carried out during 12\(^{th}\) Feb. indicated minimum (29.01 g plant\(^{-1}\)) carbon sequestration. The higher carbon sequestration during 27\(^{th}\) Feb. was attributed to higher photosynthetic rate of the genotypes during this period. In interactions, PDM139 own on 27\(^{th}\) Feb. exhibited the average highest (95.43 g plant\(^{-1}\)) carbon sequestration, whereas Pusa1431 sown on 14\(^{th}\) 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 27\(^{th}\) 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 15\(^{th}\) March over sowing of green gram on 5\(^{th}\) and 15\(^{th}\) April (987 and 793 kg ha\(^{-1}\)), but it was found at par with sowing of green gram on 25\(^{th}\) 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 27\(^{th}\) Feb. recorded the significantly maximum (6.36 g plant\(^{-1}\) and 826.02 Kg ha\(^{-1}\)) seed yield, while the Pusa1431 sown on 14\(^{th}\) 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 27\(^{th}\) 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 14\(^{th}\) 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 27\(^{th}\) 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 14\(^{th}\) 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 27\(^{th}\) 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 (14\(^{th}\) Mar.) due to leaf senescence and mobilization of photosynthates decline in sinks. Among interactions V\(_1\)D\(_2\) (PDM139 sown
on 27th Feb.) noted highest seed yield (6.79 g plant⁻¹ and 880.10 Kg ha⁻¹).

ACKNOWLEDGEMENT/FUNDING

The Author is thankful to department of Plant Physiology JNKVV, Jabalpur (M.P.) for providing necessary assistance for conduct of research.

The authors would like to acknowledge EPCO (Environmental Planning and Coordination Organisation), Bhopal for providing funds during the entire period of my research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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