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Impact of modified microclimate on the performance of Green gram *(Vigna radiata* L.) under different planting systems in the Upper Brahmaputra Valley zone of Assam

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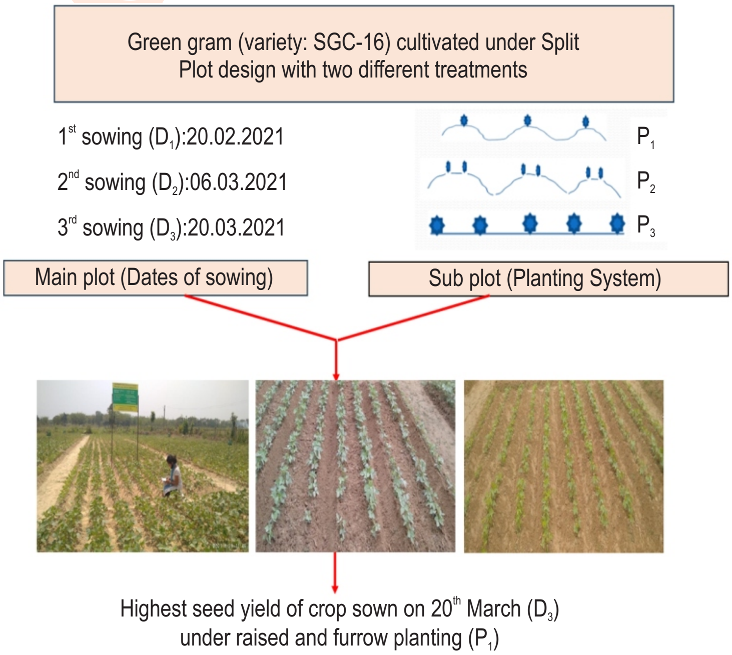
Abstract

Aim: To study the impact of modified crop microclimate on the performance of green gram in a representative district of the Upper Brahmaputra Valley zone of Assam.

Methodology: A field experiment was conducted during the *summer* of 2021 in the ICR Farm of Assam Agricultural University, Jorhat to study the impact of modified microclimates on the growth and yield of green gram under different planting systems. The variety SGC-16 was grown in a split-plot design with 3 dates of sowing at an interval of 15 days starting from 20th February (D_1) till 20th March (D_3) in main plots and three planting systems, *i.e.,* P_1- ridge and furrow, P_2 – raised bed with two rows in bed and P_3–flat bed in sub-plot treatment, with three replications following recommended agronomic practices.

Results: The average soil moisture content in the upper 30 cm soil profile was highest in D_3 (80.4±11.8 mm), followed by D_2 (75.0±7.8 mm) and D_1 (66.4±6.9 mm). Compared to P_3, the decrease in weekly evening soil temperatures under P_1 and P_2 was up to 2.1 and 1.4°C, respectively. Irrespective of sowing dates the mean maximum leaf area index (2.06) and higher pods per plant (16.7) were recorded under P_1. The seed yield under different sowing dates and planting systems ranged from 286.3 to 681.0 kg ha^{-1} with an overall mean of 509.8 kg ha^{-1}. Correlation studies between seed yield, LAI and soil moisture in the upper 30 cm soil profile confirmed the existence of a significant and positive correlation between them.



Interpretation: The yield of the crop planted on 20th March (D_3) under ridge and furrow planting (P_1) was maximum, facilitated by optimum weather conditions with improved soil hydrothermal regimes at various phenological stages of entire crop growing season.

Key words: Green gram, Microclimate, Moisture stress, Planting system, Seed yield

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Introduction

Green gram (*Vigna radiata* L.) commonly known as Mungbean is one of the most important pulse crops grown in India. India is the major pulse-growing country accounting for roughly one-third of the total world area under pulse cultivation and one-fourth of total world production (Jat *et al.,* 2020). Green gram is a short-duration crop which can be grown as a catch crop. Being a short-duration crop it can utilize limited available moisture more efficiently. The crop consumes less water as compared to other crops as the roots of the crop grow deeper into the soil profile to extract water from greater depths (Haqqani and Pandey, 1994). This crop can also be grown as a cover crop, as its foliage checks the erosion by smothering the soil. It fixes atmospheric nitrogen and improves soil fertility by adding 20-25 kg of N per ha of land (Bobade *et al.,* 2019). Moreover, the foliage of the crop leftover after picking mature pods can either be fed to livestock or it may be ploughed as green manure, to enrich the organic matter in the soil. The crop is considered to be a heat and drought-tolerant crop. It is typically a warm season crop requiring temperatures in the range of 27°C to 35°C with well-distributed rainfall of 81 to 100 mm during the cropping season for optimum growth and yield (Gupta and Pratap, 2016).

The crop can also tolerate higher temperatures and thus can be successfully grown during *summer* season when temperature rises beyond 35°C. Pulse crops need proper drainage, as they are very sensitive to water logging, however, the same crop requires life-saving irrigation, especially at critical growth stages due to uneven distribution of rainfall (Sharma *et al.,* 2005). In such situations, the raised beds and ridge and furrow cultivation have been inspired and suggested in many crops, which not only improves drainage but also improves soil moisture conservation due to better capture and use of rainfall. Several reports suggest a significantly better performance of different pulse crops under raised bed planting (Pooniya *et al.,* 2015). Raised beds can drain away water effectively by facilitating good drainage. Furthermore, it can enhance crop establishment with reduction in possibilities for disease incidence by breaching congenial microenvironment. In Assam, the optimum time for sowing green gram is mid-February to mid-March and mid-August to mid-September when sown as Summer and Kharif season crop, respectively.

The state receives a normal seasonal rainfall of 501 mm and 1177 mm (1988-2017) during pre-monsoon and monsoon seasons, respectively corresponding to the growing season of green gram in both seasons. Thus, cultivation of black gram and green gram is risky, as the area receives high rainfall during sowing time of kharif green gram (August and September) and the reproductive stage of *summer* green gram (April-May). On the contrary, the later growth stages of kharif green gram are often subjected to low soil moisture due to decrease in rainfall activities during October-November, and a similar kind of situation arises during initial vegetative stage of *summer* green gram during the month of February-March. Overall, limitations associated with soil moisture regimes can be figured as the major constraints for higher productivity of pulse in Indian sub-tropics (Praharaj *et al.,* 2023).

The problem of deficit or excess moisture in the successful cultivation of green gram in Assam receiving high rainfall with uneven distribution patterns can be successfully addressed by modifying the microclimate in the crop fields by growing crops in different planting systems. Furthermore, modification of micro-meteorological parameters, such as soil moisture, soil temperature, etc., in crop fields through modification of planting system or sowing dates affect the growth, development, and crop yield. However, there is a considerable paucity of information on the advantage of modification of microclimates on the growth, development, and yield of green gram in Assam. Therefore, it is important not only to quantify the effect of sowing time but also to study the impact of modified crop micro-environments on the overall performance of green gram cultivated under different planting systems and sowing dates. To achieve this purpose, a field experiment was conducted to evaluate the effect of a modified microenvironment on the performance of green gram and therefore, an attempt was made to identify the solution to problems related to the cultivation of green gram in the humid sub-tropical climate of Assam, North-East India.

Materials and Methods

The study was carried out in the Instructional-Cum-Research (ICR) Farm of Assam Agricultural University, Jorhat located in the Upper Brahmaputra Valley Zone of Assam, during the summer season of 2021. The experimental site is located at 26°47' N latitude, and 94°12' E longitude, 87 m above mean sea level. To carry out this investigation, green gram variety SGC-16 was sown in a split plot design with three sowing dates starting from 20th February (D_1) at 15 days intervals under main plots and three planting systems with ridge and furrow (P_1), raised bed with two rows in bed (P_2) and flatbed (P_3) under sub-plot treatment with three replications.During the experimentation period (from 20th February 2021 to 12th June 2021), the daily maximum and minimum temperatures ranged from 26 to 35.2°C and 12.4 to 24.8°C, as recorded in the Agrometeorological Observatory of Assam Agricultural University, Jorhat. A total rainfall of 404.6 mm was received during a period of 50 days corresponding to the crop growing period.

The maximum weekly total rainfall of 62.6 mm from 4 rainy days was recorded on the 23rd Standard Meteorological Week (SMW). The weekly mean morning and afternoon relative humidity varied from 82 to 97% and 40 to 86%, respectively during the crop growing period (Fig. 1). The soil of the experimental site was alluvium derived with the mean percentage of sand, silt, and clay in the experimental site as 57.0%, 16.9% and 24.9%, respectively, with 0.64% of organic carbon. The bulk density of the soil varied from 1.47 (at 0-5 cm depth) to 1.54 (30-45 cm depth). During initial land preparation, $CaCO_3$ in the form of dolomitic lime @ 490 kg ha^{-1} was applied 15 days before seeding and incorporated in the soil. After land preparation, FYM @ 4.0 t ha^{-1}

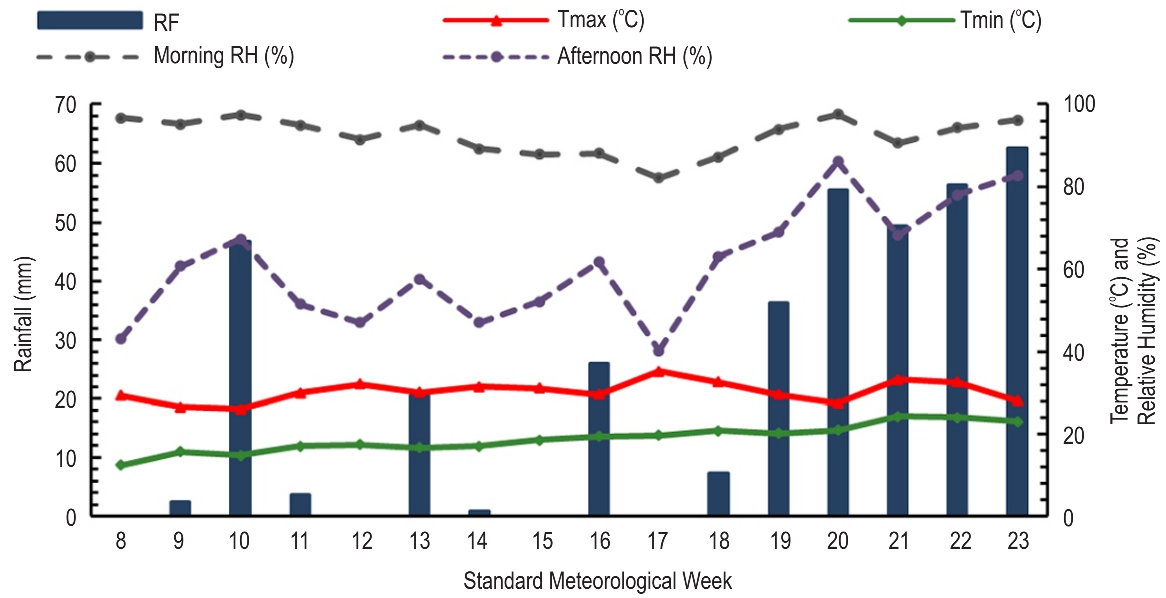

Fig. 1: Weekly variations in the mean maximum and minimum temperatures (°C), mean morning and afternoon Relative Humidity (%) and accumulated rainfall (mm) corresponding to summer green gram growing period during, 2021.

and $N:P_2O_5:K_2O$ fertilizer was applied in 10:35:15 ratio as per standard recommendations stated in the "Package of Practices for Rabi crops of Assam".

The ridges and furrows were maintained at a spacing of 40 cm between the two ridges. The raised beds of 50 cm were made in such a way that a row-to-row distance of 40 cm between two intra-and-inter raised bed rows was maintained. A distance of 40 cm between two rows was also kept in flat beds, which served as a control treatment. Before sowing, the seeds were moistened with clean water, and mixed with Rhizobium culture @ 50 g kg^{-1} green gram seeds and dried under shade. The daily soil temperature data were recorded with a soil thermometer placed at 10 cm depth of soil in 9 plots representing different treatment combinations. The soil temperature observations were recorded daily at 14.00 hours from sowing to physiological maturity. Soil samples from two depths, *viz*. 0 to 15 cm and 15 to 30 cm were collected using a screw auger at 7 days interval throughout the crop growing season which was weighed, oven dried at 105 °C and reweighed for estimating soil moisture percentage by gravimetric method and converted to the depth units by multiplying with bulk density (g cm^{-3}) (Black, 1965).

The observations on periodic leaf area index using Biovis PSM-Leaf V4.56, number of nodules per plant having diameter more than 1 cm, number of pods per plant, number of seeds per pod and seed yield at harvest were taken. The data on the leaf area index (LAI) of green gram were recorded in different phenological stages, *viz.,* trifoliate, bud formation, flowering, pod initiation and pod maturity stages under different dates of sowing and planting systems from which maximum leaf area index was computed. Seed yields and other yield-attributing characters were recorded from each plot. The average soil moisture retention (mm) in the upper 30 cm soil profile and soil temperatures at 10 cm soil depth under various treatment combinations of sowing dates and planting systems in the green gram cultivar SGC-16 were computed and correlated with crop growth parameters and seed yield. The standard statistical analysis *viz*., Analysis of Variance (ANOVA) for Split Plot Design, SE(d), CD (at 0.05), CV (%), mean, SD etc., were computed following Panse and Sukhatme (1967). In addition, treatment means were compared following Duncan's Multiple Range Test (DMRT) in IBM SPSS Statistics software.

Results and Discussion

During the crop growing season, the mean soil moisture depth in the upper 30 cm soil profile varied from 63.9 to 82.0 mm with a standard deviation of ±5.7 to ±12.7 mm under different sowing dates and planting systems. The average soil moisture depth throughout the growing season was highest on the third date of sowing (80.3 mm), followed by the second (75.0 mm), and least in the first (66.4 mm) dates of sowing (Fig. 2, 3). Fluctuation of soil moisture depth with one or two peaks in different dates of sowing was probably due to the occurrence of a good amount of rainfall during 10^{th} (46.6 mm) 19^{th} (36.3 mm), 20^{th} (55.3 mm) and 21^{st} (49.3 mm) SMW corresponding to crop growing season. Irrespective of planting systems, higher soil moisture retention in the upper 30 cm soil profile in delayed sown crop (D_3) was probably due to increasing rainfall activities from the 19^{th} SMW onwards till the end of the crop seasons. Thus, almost the entire crop growth period of the delayed sown crop (D_3) was exposed to

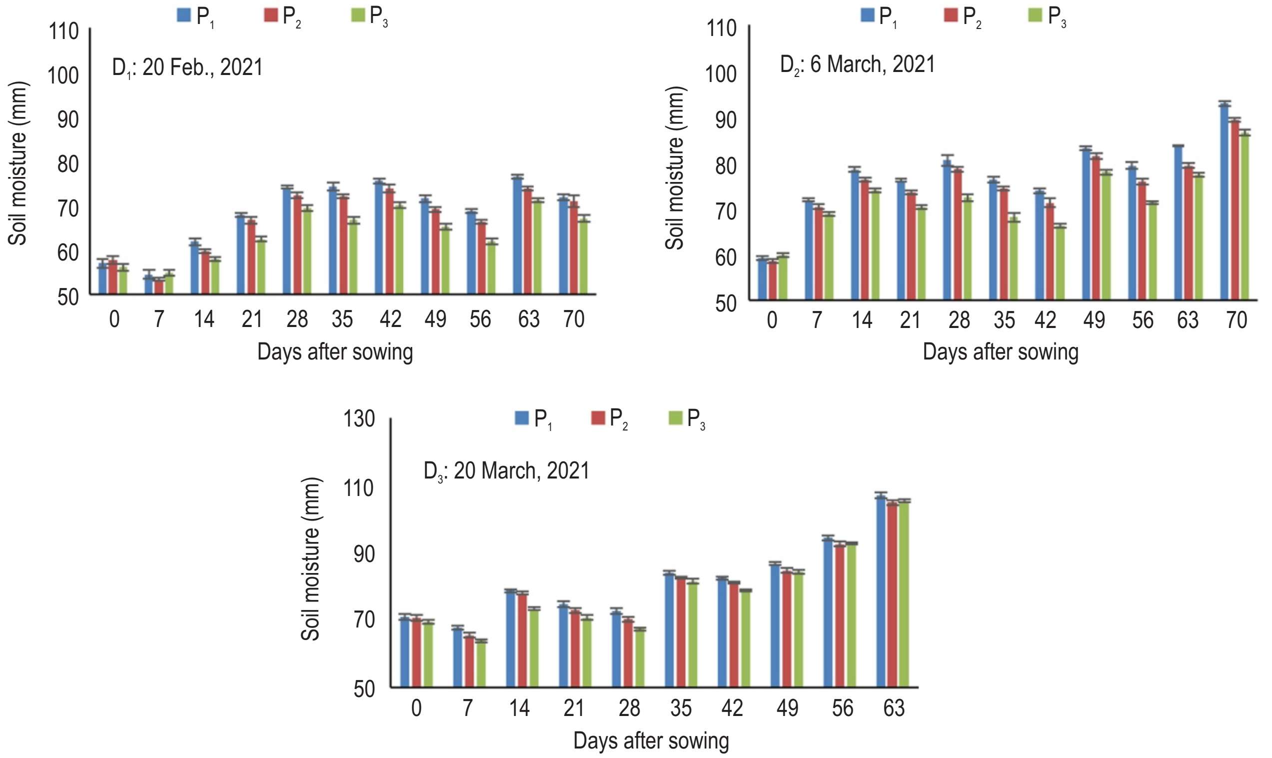

Fig. 2: Weekly variation of total soil moisture (mm) in upper 30 cm layer of soil profile under different dates of sowing and planting systems in green gram var. SGC-16 during summer, 2021.

the highest amount of rainfall (252 mm) with the highest number of rainy days (29 days). On the other hand, the lowest soil moisture retention in the case of first date of sowing (20th February) was attributed to the lowest amount of rainfall (99 mm) received during 19 rainy days. Overall, the average soil moisture retention in the upper 30 cm soil profile during the crop growth period of green gram was maximum under ridge and furrow planting system (76.1 mm), followed by raised bed planting system (74.2 mm) and least in flat-bed system (71.6 mm) in all dates of sowing. Sustainably higher soil moisture retention in the upper 30 cm soil profile throughout the growing season under the ridge and furrow system (P_1) was probably because the rainwater drains out from the surface soil and collects into furrows which rather minimizes the runoff from the plot and also increases soil moisture conservation within the crop root zone as compared to the flatbed system. A similar condition was observed in raised bed planting as compared to the flatbed system where an increase in the soil moisture retention was found in the ridge and furrow and raised bed as compared to the flatbed system (Fig. 3). Ram *et al*. (2018) in his study reported that mungbean likely to perform even better in fine textured soils under the raised bed planting, which generally yields poorly on conventional flatbed layouts, especially due to water logging when sown during the monsoon season in North-western India. Furthermore, in case of ramie, fibre yield was 14 percent higher in ridge planting over flat planting, which might be possibly due to better *in-situ* conservation of moisture in furrows as well as in the root zone, and better drainage of excess water during the wet period (Mitra *et al*., 2018). The weekly mean evening soil temperature ranged between 23.5 to 36.2°C with a mean of 30.3°C, regardless of the dates of sowing and planting systems. Under the ridge and furrow system, the weekly mean evening soil temperatures varied from 23.5°C to 34.3°C, with a mean value of 29.5°C, which was lowest among the planting systems (Fig. 4). It was observed that the evening soil temperature increased gradually from the beginning to the end of the crop season due to seasonal transition from winter to summer. The average evening soil temperature was observed to be highest when sown on 20th March (D_3), which decreased gradually with the successive advance in sowing.

It can be summarized that weekly evening soil temperature under flat-bed system (P_3) was always higher as compared to other two planting systems (Fig. 4). Irrespective of the sowing dates, weekly evening soil temperature under ridge and furrow planting (P_1) and raised bed planting (P_2) were lowered by 0.1 to 3.8 °C and 0.1 to 2.6 °C with a mean of 1.7 °C and 1.1 °C, respectively, when compared with flat-bed (P_3) system (Fig. 5). The observed lowest evening soil temperature under ridge and furrow system (P_1) might be due to retention of highest soil

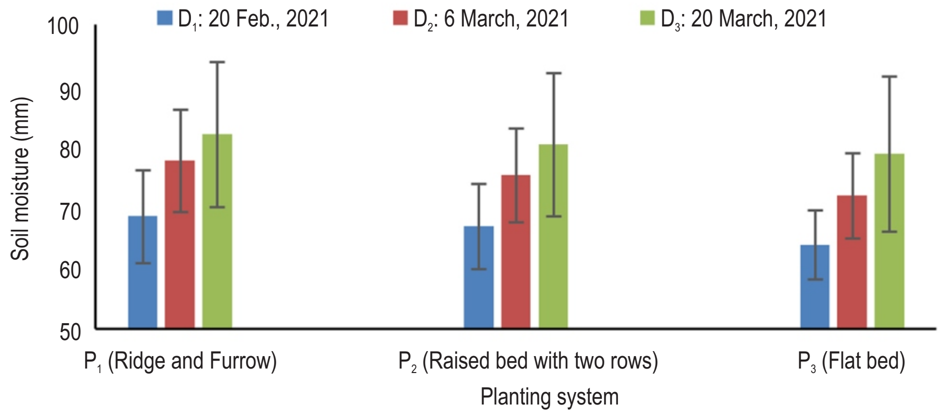

Fig. 3: Overall mean soil moisture (mm) at upper 30 cm layer of soil profile under different dates of sowing and planting systems in green gram var. SGC-16 during summer, 2021.

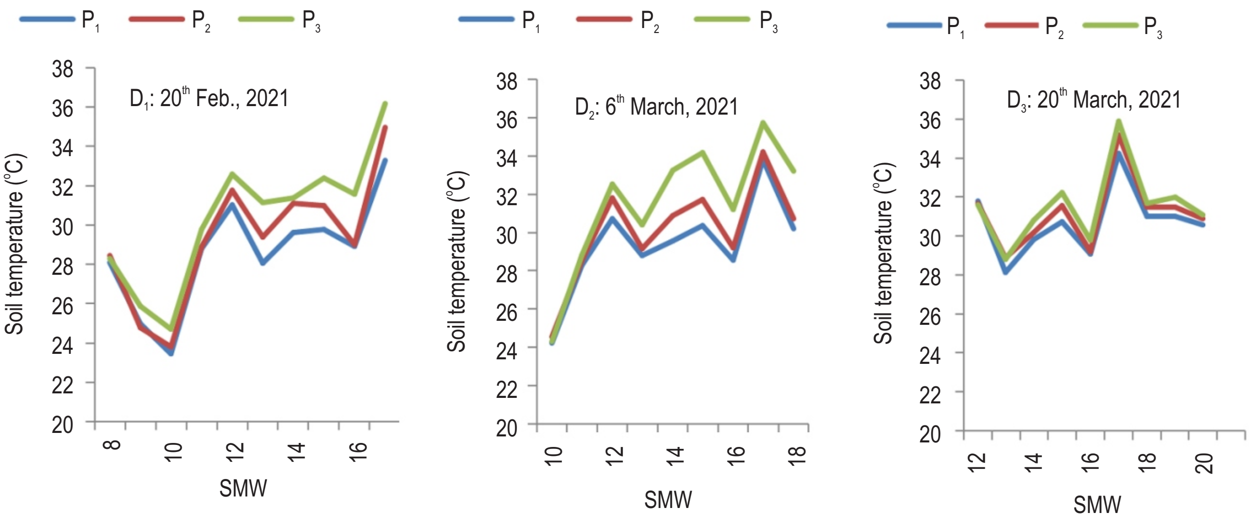

Fig. 4: Weekly variation of soil temperature under different dates of sowing and planting systems in green gram var.SGC-16 during summer, 2021.

moisture in the upper 30 cm soil profile under that treatment, while the highest soil temperature recorded under flat-bed was probably due to retention of lowest soil moisture. The specific heat capacity of water was higher than other soil components; and therefore, the heat storage capacity of the soil increased with increase in the soil moisture content. Moreover, with the increase of soil moisture, the rate of heat dissipation down the soil profile also increased,which can be attributed to low soil temperature (Ochsner *et al.,* 2001). The results corroborate with the findings of Hanks and Ashcroft (1986), who reported that the thermal properties were strongly dependent on the variations in soil water content and encouraged faster flow of heat to the lower soil layer. The crop sown on 20th February (D_1) was exposed to relatively cooler conditions with a mean air temperature of 22.6°C than the crop sown on 6th and 20th March with a mean air temperature of 23.6°C and 24.8°C, respectively, and was found to decrease the growth rate during vegetative stages of the crop when sown early. The lowest leaf area index under D_1 especially during bud formation (0.55) and pod initiation (1.55), irrespective of planting systems was probably due to exposure of the crop to acute soil moisture stress during early growth stages (Table 2).

On the other hand, the availability of adequate soil moisture along with the prevailing optimum air temperatures during early growth stages of the crop sown on 20th March (D_3) resulted in higher leaf area expansion with higher number of leaves resulting in the highest leaf area index under D_3, *i.e.,* 0.69 and 2.29, 2.28, respectively during bud formation and pod initiation (Table 2). Likewise, a higher leaf area index during bud formation (0.67) and pod initiation (2.10) under the ridge and

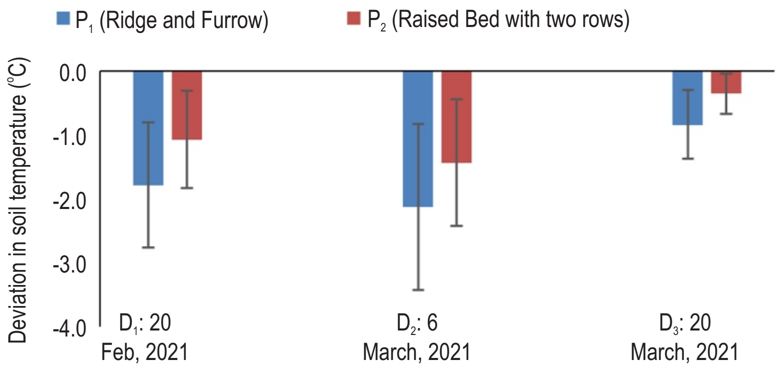

Fig. 5: Deviation in mean soil temperature under different sowing dates and planting systems in comparison to flatbed planting system (P_3) of summer green gram during, 2021.

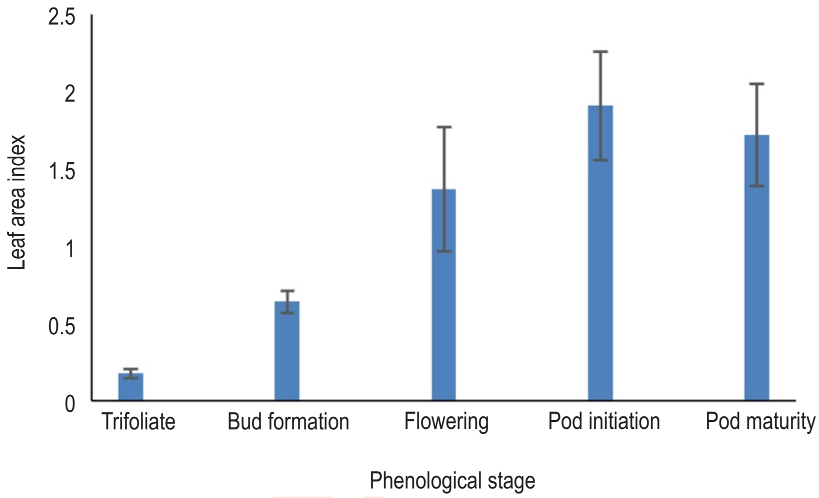

Fig. 6: Phase wise variations in leaf area index of green gram var SGC-16 irrespective of sowing dates and planting system during summer, 2021.

furrow (P_1) system can be attributed to higher retention of soil moisture under P_1 relative to P_2 and P_3; facilitating better growth, leaf area expansion and number of leaves per plant (Fig. 6). The leaf area index in the present study was found within the range reported by Saha *et al.* (2019), where the leaf area index of green gram varied within the range of 0.46 to 1.42 in different growth stages.

The number of nodules per plant at physiological maturity irrespective of sowing dates and planting systems varied from 18.5 to 34.1 with an overall mean of 25.4. The number of nodules per plant was maximum under ridge and furrow planting system (P_1), ranging from 20.2 to 34.1 with a mean value of 27.6. Significantly ($p \leq 0.05$), a higher number of nodules per plant in the case of crop sown on 20th March (31.0) as well as ridge and furrow planting system (27.6) (Table 1, 2) might be due to higher retention of soil moisture under these treatments, as nodulation and nodule activity in legume are inversely proportional to water stress (Gregersen *et al.,* 2020). As the activities of enzyme responsible for nodulation decreased rapidly with increase in the water stress (Figueiredo *et al.,* 1999), the number of nodules per plant decreased in early sown crop (D_1 and D_2) and declined under planting systems of P_2 and P_3, which might be due to retention of comparatively lower soil moisture. The results are in confirmation with the findings of Kamble *et al.* (2018), who reported that the number of nodules per plant in black gram ranged from 19.6 to 25.8, when grown under different treatments with or without seed inoculation with *Rhizobium.*

The number of pods per plant irrespective of sowing dates and planting systems varied from 7.1 to 21.4 with an overall mean of 15.2, and found to be significantly ($p \leq 0.05$) varied amongst the treatment means (Table 1). Regardless of the sowing dates, the number of pods per plant was maximum under

Table 1: Variations in the number of nodules and number of pods per plant, number of seeds per pod and overall seed yield of green gram var. SGC-16 as affected by sowing dates and planting system

Treatments	Number of nodules per plant	Number of pods per plant	Number of seeds per pod	Yield (kg ha^{-1})
P_1D_1	20.2^{b}	11.3^{b}	11.3^{a}	442.7^{c}
P_2D_1	19.4^{ab}	10.5^{b}	11.1^{a}	405.0^{b}
P_3D_1	18.5^{a}	7.1^{a}	11.1^{a}	286.3^{a}
P_1D_2	28.6^{e}	17.5^{de}	11.2^{a}	557.0^{f}
P_2D_2	25.3^{d}	16.5^{d}	10.9^{a}	518.3^{e}
P_3D_2	23.4^{c}	14.6^{c}	10.8^{a}	495.0^{d}
P_1D_3	34.1^{f}	21.4^{f}	12.5^{b}	681.0^{h}
P_2D_3	33.6^{f}	20.4^{f}	11.2^{a}	647.7^{g}
P_3D_3	25.4^{d}	18.0^{d}	10.7^{a}	555.7^{f}
Mean	25.3	15.2	11.1	509.9
Std. Error mean	1.07	0.88	0.12	22.56
CV (%)	22.8	31.4	4.7	23.9

Where, P_1, P_2 and P_3 are Systems of planting and D_1, D_2 and D_3 are the of sowing

Table 2: Effect of date of sowing and planting systems on yield attributes and seed yield of green gram during summer, 2021

Treatments	LAI at bud formation	LAI at pod initiation	Number of nodules per plant	Number of pods per plant	Number of seeds per pod	Yield (kg ha^{-1})
D_1	0.55	1.55	19.4	9.6	11.2	378.0
D_2	0.67	1.96	25.8	16.2	11.0	523.4
D_3	0.69	2.29	31.0	19.9	11.5	628.1
SE (d)	0.003	0.070	1.3	0.5	0.2	18.2
CD (at 5%)	0.010	0.193	3.7	1.5	NS	50.5
Planting system						
P_1	0.67	2.10	27.6	16.7	11.7	560.2
P_2	0.64	1.92	26.1	15.8	11.1	523.7
P_3	0.61	1.76	22.4	13.2	10.9	445.7
SE (d)	0.006	0.052	1.6	0.4	0.3	18.9
CD (at 5%)	0.013	0.115	3.5	0.9	NS	41.2
Interaction (D X P)						
SE (d)	0.010	0.091	2.8	5.4	0.6	32.7
CD (at 5%)	0.024	NS	NS	NS	NS	NS

Where, P_1, P_2 and P_3 are the Systems of planting and D_1, D_2 and D_3 are the Date of sowing; LAI=Leaf area index

ridge and furrow (P_1), which varied from 11.3 to 21.4 with a mean value of 16.7. On the other hand, the lowest number of pods per plant was recorded in the crop grown in flatbed planting system (P_3), which varied from 7.1 to 18.0 with a mean value of 13.2. The recording of higher number of pods per plant (Table 1) under D_3 with a mean value of 19.9 was attributed to higher leaf area index and subsequently, more translocation of biomass from source to sink. A decrease in the number of pods per plant in green gram due to drought stress has been reported by Monneveux *et al.* (2006). Poehlman (1991) opined that high air temperatures accompanied by heavy rainfall caused flower shedding and pod damage, which resulted in reduced seed yield. The mean number of seeds per pod was found highest on the third date of sowing, *i.e.,* 20th March (11.5), followed by first sowing, *i.e.,* 20th February (11.2), and least in second sowing, *i.e.,* 6th March (11.0) during the year 2021 (Table 2). Similarly, the number of seeds per pod under ridge and furrow (P_1) was maximum, and ranged between 11.2 to 12.5 with a mean value of 11.7. On the other hand, seeds per pod varied from 10.7 to 11.1, with a mean of 10.8 under a flatbed planting system (P_3). Higher number of seeds per pod under third date of sowing (D_3) might be due to highest leaf area index and biomass production compared to other dates of sowing (D_1, and D_2). However, all treatment means, except P_1 D_3, were found at-par ($p \leq 0.05$) (Table 1). Non-significant difference in seeds per

Table 3: Correlation of maximum Leaf Area Index and seed yield of green gram with average soil moisture retention (mm) in upper 30 cm of soil profile during summer, 2021.

Variables	Average soil moisture retention (mm) in upper 30 cm soil profile		
	Sowing to bud formation	Bud formation to maturity	Entire crop season
Leaf area index	0.64	0.96**	0.88**
Seed yield	0.91**	0.94**	0.97**

pod in summer green gram sown on different dates has been reported earlier (Palsaniya *et al.,* 2016; Bag *et al.,* 2020). Neupane *et al.* (2023) also found that seed sown on 30th March, 2019 produced more leaves, the highest plant height, and the highest amount of above-ground dry matter as compared to seed sown on 13th February, 2019.

As a whole, the seed yield of green gram cultivar SGC-16 under different sowing dates and planting systems varied from 286.3 to 681 kg ha^{-1} with an overall mean of 509.9kg ha^{-1}, and found to vary significantly ($p \leq 0.05$) amongst the treatment (Table 1). The highest seed yield was recorded under third date of sowing (D_3) with an average yield of 628.1 kg ha^{-1}, which was reduce a gradually by 16.7 and 39.8 percent under the second (D_2) and first (D_1) date of sowing, respectively (Table 2). Irrespective of sowing dates, the highest seed yield among the planting systems was observed under ridge and furrow (560.2 kg ha^{-1}), followed by raised bed planting (523.7kg ha^{-1}) and flat-bed system of planting (445.7kg ha^{-1}). The increase in seed yield under ridge and furrow was 25.7 percent, while it was 17.5 percent under the raised bed when compared with the flatbed system of planting. The highest yield recorded under D_3 could be attributed to prevailing favourable hydrothermal regime with maximum PAR interception and maximum crop growth in terms of leaf area index (2.29 during pod formation), number of nodules per plant (31.0), number of pods per plant (19.9) and number of seeds per pod (11.5) as compared to first as well as second dates of sowing (D_1, and D_2). In the case of first sowing (20th February), the crop growth was reduced substantially due to less soil moisture retention in the crop root zone, which attributed to comparatively lower seed yield.

The marginal decrease of seed yield in the second sowing (6th March) as compared third sowing (20th March) might also be attributed to the exposure of early crop growth stages to lower soil moisture as compared to third date of sowing. The lower value of leaf area index in crop sown on the first (20th February) and second date (6th March) ultimately reflected in lower biomass accumulation and partitioning, thereby lowering seed yield. In addition, the plants growing on the ridges, made more efficient use of resources like rainwater and sunshine, with a limited weed population due to inadequate moisture availability and quick development of canopy coverage of green gram (Dodwadiya and Sharma, 2012). The results were similar to those observed by Annie *et al.* (2019), who reported a yield range of 537 to 787 kg ha^{-1} in green gram varieties *viz.,* SG-16, SG-20 and IPBM-02-3 sown on three different dates at Jorhat. The adverse effect of weather parameters, particularly no or scanty rainfall during crop season on the growth, development, and yield of green gram was also reported by Bankar *et al.* (2020).Yadav *et al.* (2019) also reported that raised bed planting produces 10.5% and 10.8% higher seed yield of green gram as compared to conventional and zero till panting methods, respectively. Even water productivity under ridge planting of pulses enhanced to a tune of 22% compared to the conventional method, ensuring better natural nitrogen fixation for better soil health (Ray *et al.,* 2023). The average soil moisture retention in the upper 30 cm layer of soil profile showed a significant positive correlation with leaf area index (0.88**) and seed yield (0.97**) throughout the entire crop growth stages (Table 3). Though the leaf area index was not significantly correlated with average soil water retention during vegetative stage, it showed a significant positive correlation with the average soil moisture retention during bud formation to maturity stage of the crop (0.96**). Similarly, the maximum WUE under raised bed method (46.81kg ha^{-1}) and minimum under the flatbed method (38.87kg ha^{-1}) were also reported by Yadav and Singh (2014); which was mainly attributed to significantly higher plant height (54.76 cm), leaf area index (3.25) and yield (13.7 kg ha^{-1}) under raised bed method of planting relative to flatbed planting system.

The highest seed yield under 20th March (D_3) sown crop, could be attributed to favorable hydrothermal regime with a maximum growth of the crop in terms of leaf area index (2.28), number of nodules per plant (31.0), number of pods per plant (19.9) and number of seeds per pod (11.5) compared to first (D_1) as well as second (D_2) dates of sowing. In the case of the first sowing (20th February), the crop growth was reduced substantially due to less soil moisture retention in the crop root zone, which was attributed to comparatively lower seed yield. The maximum seed yield under ridge and furrow planting (P_1) as compared to raised bed (P_2) and flat-bed (P_3) systems was probably due to higher LAI (2.06) along with higher pods per plant (16.7) in that planting system. Though yield reduction under the raised bed planting system (P_2) was less than 5%, the reduction was 18.5% under the flatbed system (P_3), as compared to the ridge and furrow system (P_1). Thus, both raised bed and ridge-furrow systems proved significantly superior to flat-bed systems in terms of seed yield, as under these planting systems the moisture availability was highest for the crop as a result of low water loss through evaporation, percolation, and seepage and better soil environment as compared to the flatbed system.

In addition, more yield under ridge and furrow planting systems could be attributed to proper maintenance of soil-air-water equilibrium throughout the rhizosphere growth period, which gave more nitrogen fixation and favorable enhancement in growth attributes (Ray *et al.,* 2023).Therefore, sowing green gram seeds by mid-March, under the ridge and furrow system of planting may reduce the yield gap due to deficit and excess soil moisture regimes in summer green gram over the representative agro-climatic zone of Assam. However, field experiments comprising a holistic approach for crop-microclimate modifications study may enable researchers to generate more conclusive information on the role of weather parameters on the growth and development of green gram.

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