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RESEARCH ARTICLE

Study on growth, yield and radiation interception in finger millet varieties under different dates of sowing

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Abstract

Finger millet yields remain low in rainfed situations due to lack of context regarding optimal sowing time and suitable varieties under the changing climatic conditions. This study addresses the gap by evaluating the performance of finger millet genotypes under varied sowing dates in rainfed conditions. A field experiment was conducted at University of Agricultural Sciences, Bangalore during *kharif* (July to November) 2023 and 2024. The experiment was laid out in randomized block design with factorial concept having three varieties namely MR-6 (V_1), KMR-316 (V_2) and KMR-630 (V_3) and three dates of sowing like, D_1- July first fortnight, D_2- July second fortnight and D_3- August first fortnight. Results revealed that among different varieties, significantly higher leaf area index and dry matter accumulation, grain yield and straw yield were recorded with MR-6 variety in both 2023 and 2024 seasons. While significantly lower growth and yield parameters were obtained with KMR-630. Among dates of sowing, July first fortnight achieved significantly higher grain and straw yield followed by July second fortnight and August first fortnight in pooled analysis. Significantly higher growth attributes were recorded with July first fortnight sowing when compared with other sowing dates in both seasons. Higher light absorption ratio and lower light transmission ratio was observed with MR-6 variety and July first fortnight sowing dates. Higher amount of photosynthetically active radiation was intercepted with MR-6 variety at first date of sowing. Higher amount of radiation was intercepted at flowering stage in all varieties. Intercepted radiation had a positive relationship with dry matter production and leaf area index.

Keywords: dry matter production; finger millet; leaf area index; photosynthetically active radiation

Introduction

Finger millet is a prominent cereal crop belonging to the family Poaceae. It is an annual, self-pollinating crop characterized by a digitate inflorescence having variable number of spikes arranged in bird's foot pattern. The caryopsis is smooth with seed colour varying from brown to white (1, 2). It is mostly rainfed crop grown predominantly in India and Africa. Finger millet being rich in nutrients, serve as a staple food in many countries thereby meeting nutritional demands of the people (3). Globally, finger millet is cultivated approximately in an area of 2.1 million hectares with an annual production of 3.7 million tonnes. Among different finger millet growing countries, India is the leading producer, followed by Ethiopia and Nepal (4). In India, finger millet is grown in an area of 1.21 million ha with a production of 1.67 million tonnes and with a productivity of 1375 kg ha^{-1} (5). It is grown majorly in states of Karnataka, Andhra Pradesh, Odisha, Tamil Nadu, Jharkhand, Uttarakhand and Maharashtra (6).

Climate change and rising human population are the chief determinants in assessing food security in the world (7). In developing nations like India with increasing food demand, climate change can adversely affect agrarian sector leading to severe food shortage. In order to achieve sustainability in food production, assessing the impact of climate change and devising suitable mitigation practices is need of the hour (8). Different crops have varied response for the ongoing climate change. Studying the impact of adverse climate conditions on various genotypes is required. Intricate nature of climate change accompanied by various weather extremities can be addressed with suitable agronomic practices such as selection of suitable varieties, adjustment of sowing windows and adoption of various resource management practices (9, 10). With the prevailing monsoon vagaries, optimizing sowing windows is essential to mitigate crop stress. Photosynthetically active radiation interception indicates the development of crop canopy, biomass accumulation and yield. Amount of photosynthetically active radiation absorbed by canopy access the growth and development of the crop thereby facilitating yield predictions. Intercepted PAR might be influenced by the season during which crop is grown, time during which observation is taken and the amount of cloud cover (11). Favourable conditions for crop growth leads to improved leaf area and biomass production which increases PAR interception. Different sowing windows significantly affect radiation interception and it also shows variation in transmitted and reflected PAR.

Various studies across different crops have demonstrated the importance of optimizing sowing windows in combination with suitable genotypes for increasing crop yield. In maize, early sowing resulted in better crop growth, leading to increased productivity (12, 13). In basmati rice varieties, early transplanting significantly improved growth and yield attributes, whereas delayed transplanting resulted in decreased rice yield (14). Similarly, in wheat, optimum sowing time coupled with suitable genotype resulted in higher leaf area index, photosynthetically active radiation and yield, thereby minimizing the risk from extreme weather events (15). Early planting in sorghum has also been reported to enhance crop performance due to availability of longer crop duration along with favourable weather conditions (16).

Finger millet is chiefly a rainfed crop grown under suboptimal conditions without proper context for optimal sowing time and suitable varieties which improve productivity. In this regard, the present study is unique in evaluating various finger millet genotypes across different sowing windows under rainfed conditions, along with emphasis on analysing radiation interception across phenophases. This integrated approach, conducted over two growing seasons, provide valuable insights for optimizing finger millet productivity.

Keeping this in view, the objective was formulated to assess the impact of various sowing dates on growth, yield and radiation interception in different finger millet varieties under rainfed situation, thereby identifying optimal sowing date and suitable variety to improve productivity under the changing climatic conditions.

Materials and Methods

The field experiment was conducted at field unit, All India Coordinated Research Project on Agro-meteorology, University of Agricultural Sciences, Gandhi Krishi Vigyana Kendra, Bangalore, Karnataka during *kharif* (July to November) 2023 and 2024. The site is situated at 13.05 ^{0}N latitude and 77.34 ^{0}E longitude at 924 mean sea level. The soil at the experimental site was sandy loam in texture. Standard nutrient management practices were followed in all treatments. Recommended dose of fertilizer followed for finger millet crop was 50:40:37.5 kg ha^{-1} of N-P_2O_5-K_2O for rainfed situation. Nitrogen was applied in two splits, half of the dose as basal application and other half at 30 days after sowing. Phosphorus and potassium were applied entirely as basal dose at the time of sowing. The experiment was laid out in factorial Randomized Complete Block Design with two factors. First factor comprised of three varieties namely MR-6 (V_1), KMR-316 (V_2) and KMR-630 (V_3). The second factor included dates of sowing *viz.,* D_1- July first fortnight, D_2- July second fortnight and D_3- August first fortnight. In total there were nine treatment combinations which were replicated thrice. Experiment was conducted under rainfed condition. Crop spacing of 30 cm × 10 cm was followed. All the three varieties were sown accordingly in three sowing windows in both the seasons. In first season, total rainfall received from July to December was 558 mm with September month receiving higher amount of rainfall (Fig. 1). The average temperature prevailed during this period was 24.3 °C (Fig. 2A). In second season, October month received higher amount of rainfall and a total of 1067mm of rainfall was received for the entire crop duration. The average temperature prevailed during this season was 23.6 °C (Fig. 2B). For analysing the growth parameters *viz.,* dry matter production and leaf area index, five plants were selected randomly from net plot and used for analysis. Total dry

$$\text{Leaf Area Index} = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Land covered by plant (cm}^2\text{)}} \quad \text{(Eqn. 01)}$$

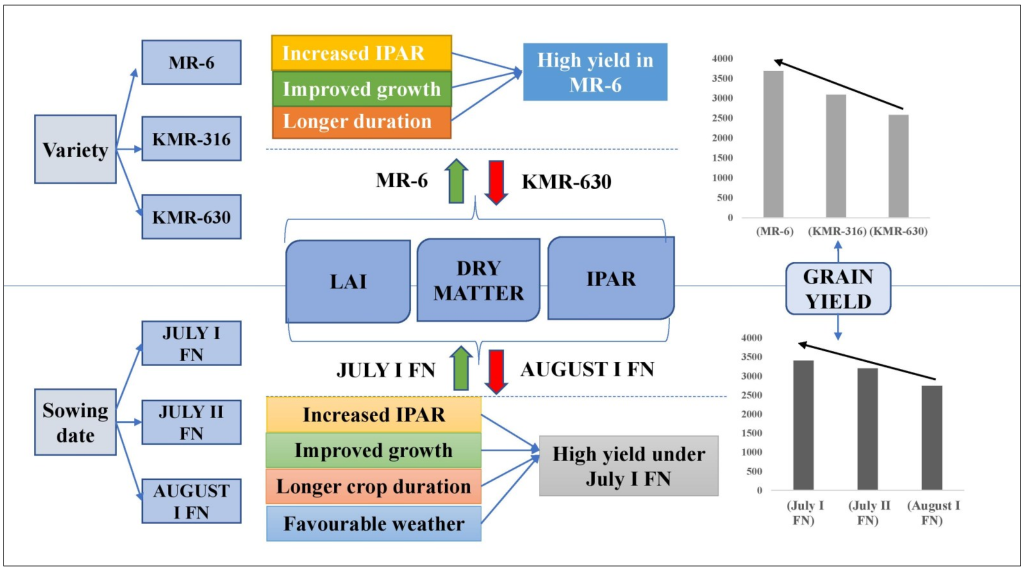

Fig. 1. Graphical representation: Effect of varieties and sowing dates on finger millet performance.

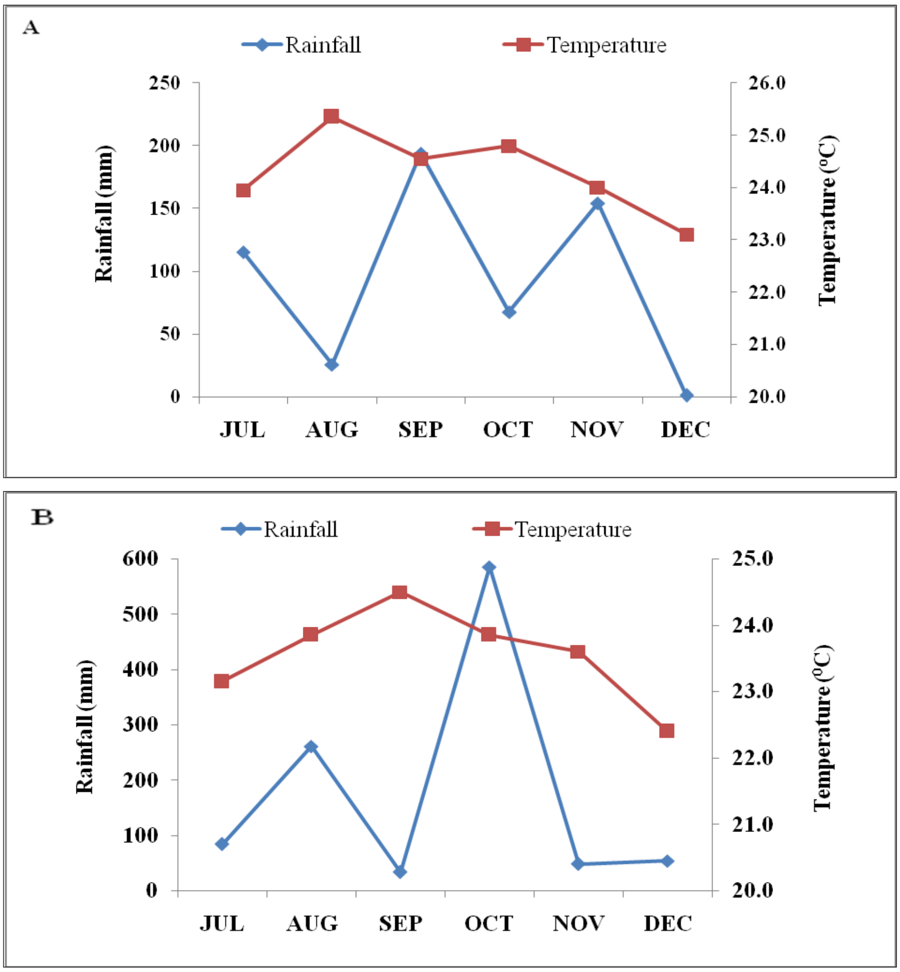

Fig. 2. Rainfall (mm) and temperature (°C) prevailed during the crop growing season in year 2023 (A) and 2024 (B).

matter production per plant was calculated by destructive sampling of plants from net plot followed by air drying and oven drying them at 65 °C until steady weight was achieved and expressed in g plant^{-1}. Leaf area index was determined with the help of leaf area meter as per the following formula (17).

Grain yield was obtained after threshing and cleaning operation and expressed in kg ha^{-1}. Similarly stalk yield was obtained after drying of straw and expressed in kg ha^{-1}. The data was statistically analysed using standard procedure (18).

Photosynthetically active radiation was measured using line quantum sensor (APOGEE model MQ-301X) which was placed above crop canopy to obtain the incident radiation. The sensor was then placed in reverse position to obtain reflected radiation. The sensor is placed below the crop canopy close to the ground to measure transmitted radiation. In this way incident, reflected and transmitted radiation was measured using line quantum sensor which aided in calculating interceped photosynthetically active radiation, light absorption ratio and light transmission ratio in finger millet canopy. Intercepted photosynthetically active radiation (% IPAR) was calculated as per the following formula (19).

$$\% \text{ IPAR} = \frac{\text{IPAR - TPAR - RPAR}}{\text{IPAR}} \times 100 \qquad \text{(Eqn. 02)}$$

$$\text{Light transmission ratio (\%)} = \frac{I}{I_0} \times 100 \qquad \text{(Eqn. 03)}$$

Where, IPAR indicates incident PAR, TPAR indicates transmitted PAR and RPAR indicates reflected PAR.

Light transmission ratio was obtained by dividing the light intensity measured below the canopy to that measured above the canopy (20).

$$\text{Light absorption ratio (\%)} = 100 - \text{Light transmission ratio (\%)} \qquad \text{(Eqn. 04)}$$

Where, I = light intensity at ground level and I_0 = light intensity above the canopy.

Results and Discussion

Grain yield

Significant difference was observed in grain yield among varieties and sowing dates (Table 1). Among varieties, MR-6 recorded significantly higher grain yield and KMR-630 produced lower yield. Reportedly, higher grain yield was observed in second season (4115 kg ha^{-1}) when compared with first season (3263 kg ha^{-1}). Similar trend in variation of grain yield was observed in pooled data analysis. Dates of sowing also had a significant impact on yield of finger millet varieties. In first season, July first fortnight recorded higher yield (3399 kg ha^{-1}) and August first fortnight produced lower yield (1663 kg ha^{-1}). Conversely, in second season, higher yield was obtained with August first fortnight (3833 kg ha^{-1}) and slightly lower yield was obtained with July first fortnight (3419 kg ha^{-1}). Pooled analysis revealed that July first fortnight recorded higher grain yield (3409 kg ha^{-1}), followed by July second fortnight and significantly lower

Table 1. Effect of varieties and dates of sowing on grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}) of finger millet

Treatment	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	2023	2024	Pooled	2023	2024	Pooled
Varieties						
V_1 (MR-6)	3263	4115	3689	6668	8934	7801
V_2 (KMR-316)	2417	3762	3090	5968	7820	6894
V_3 (KMR-630)	2196	2972	2584	5027	5520	5274
SEm (±)	107	107	84	280	531	303
CD (p=0.05)	324	324	252	846	1605	917
Dates of sowing						
D_1 (July I FN)	3399	3420	3409	7495	8325	7910
D_2 (July II FN)	2814	3595	3205	6286	7016	6651
D_3 (August I FN)	1663	3833	2748	3882	6934	5408
SEm (±)	107	107	84	280	531	303
CD (p=0.05)	324	324	252	846	NS	917
V × D						
V_1D_1	4009	4283	4146	8500	9068	8784
V_1D_2	3641	3722	3681	7088	8419	7753
V_1D_3	2139	4339	3239	4416	9316	6866
V_2D_1	2937	3356	3146	7737	9252	8494
V_2D_2	2473	3974	3224	6210	7393	6802
V_2D_3	1842	3955	2899	3958	6817	5387
V_3D_1	3251	2620	2936	6248	6655	6452
V_3D_2	2327	3090	2709	5561	5235	5398
V_3D_3	1008	3205	2107	3271	4671	3971
SEm (±)	186	186	144	485	919	526
CD (p=0.05)	561	561	NS	NS	NS	NS

grain yield was recorded with August sowing (2748 kg ha^{-1}). Interaction effect was found to be significant in both seasons. In first season, MR-6 sown at first fortnight of July has recorded significantly higher yield and lower yield was obtained with KMR-630 sown at first fortnight of August. In second season, MR-6 sown in August recorded higher yield and comparatively lower yield was recorded by KMR-630 at July first sowing.

MR-6, being a long duration variety performed better when compared to other varieties. Better accumulation of dry matter in long duration varieties intercepted higher amount of radiation thereby, improving grain yield. Previous findings reported variation in grain yield of finger millet genotypes in different locations (21). Among sowing dates, July first fortnight resulted in higher yield. Availability of favourable weather conditions, mainly rainfall, determined the performance of crop. Higher yield recorded under July first fortnight sowing can be attributed to the optimum rainfall that received during flowering and grain formation stages. Longer period available for vegetative growth led to increased leaf area and dry matter production, which thereafter improved the yield attributes resulting in higher yield. Higher canopy development in terms of leaf area, increased the intercepted radiation, thus improving biomass and yield. August sown genotypes had shorter vegetative phase and experienced moisture stress at flowering stage resulting in lesser growth and yield attributes. Similar findings were observed in other crops where early sowing date produced higher yields (22, 23). Slight yield variation was observed in second season, where, august sown crop recorded higher yield, which was due to occurrence of high rainfall at flowering stage of the crop. An increment in rice grain yield was reported with delay in sowing date due to favourable weather conditions that prevailed during late sown conditions (24). Similarly, higher grain yield was obtained with normal sowing date when compared to early and late date of sowing in maize (25). Pooled season data indicate higher yield for July sown genotypes, revealing the significance of longer growth duration coupled with favourable weather conditions in improving crop performance.

Straw yield

Varieties and dates of sowing had significant influence on straw yield of finger millet (Table 1). Among varieties, MR-6 recorded significantly higher straw yield in two years (6668, 8934 kg ha^{-1}). Comparatively lower straw yield was recorded with KMR-630 due to lesser biomass accumulation. Among dates of sowing, significantly higher amount of straw was produced under July first fortnight (7495 kg ha^{-1}), whereas lower straw yield was obtained with August sowing. In second season, effect of sowing dates on straw yield was found to be statistically non-significant. However, higher straw yield was recorded with July first sowing date and comparatively lesser straw yield was observed with August sowing. Interaction effect for varieties and sowing dates was observed to be statistically non-significant for straw yield in two years. Pooled data analysis revealed that, MR-6 recorded higher straw yield among genotypes. Among sowing dates, July first fortnight recorded higher straw yield and significantly lower straw yield was observed under August first fortnight.

Among varieties, high dry matter accumulation with increased duration has produced higher straw yield in MR-6. High production of biological yield coupled with better translocation efficiency might have proceeded into higher grain and straw yield in first sowing date. Similarly, less biomass accumulation in August sowing has resulted in lesser straw yield. Higher production of dry matter and reduced translocation efficiency might have resulted in higher straw yield and lesser grain yield in July first fortnight sowing in second season. This is in conformity with the findings in rice crop where heat stress had affected dry matter partitioning resulting in increased straw yield and decreased grain yield (26).

Leaf area index

Leaf area is among the important growth components which determines the performance of crop subjected to varied

Table 2. Leaf area index, dry matter production (g plant^{-1}), light absorption ratio (%) and light transmission ratio (%) in finger millet as influenced by dates of sowing and varieties

Treatment	Leaf area index (Flowering stage)		Dry matter production (g plant^{-1}) (Harvest)		Light absorption ratio (%) (Flowering stage)		Light transmission ratio (%) (Flowering stage)	
	2023	2024	2023	2024	2023	2024	2023	2024
Varieties								
V_1 (MR-6)	2.40	2.98	24.1	31.0	80.14	85.73	19.85	14.26
V_2 (KMR-316)	2.26	2.91	21.0	27.2	77.16	83.42	22.84	16.58
V_3 (KMR-630)	1.96	2.10	19.1	22.3	73.70	81.26	26.30	18.74
SEm (±)	0.08	0.10	0.8	1.03	0.62	0.86	0.22	0.12
CD (p=0.05)	0.24	0.32	2.5	3.13	1.88	2.61	0.68	0.37
Dates of sowing								
D_1 (July I FN)	2.65	2.92	25.2	29.6	80.80	86.24	19.20	13.76
D_2 (July II FN)	2.21	2.63	22.2	26.4	77.62	83.57	22.37	16.43
D_3 (August I FN)	1.75	2.46	16.8	24.5	72.58	80.61	27.42	19.40
SEm (±)	0.08	0.10	0.8	1.0	0.62	0.86	0.22	0.12
CD (p=0.05)	0.24	0.32	2.5	3.1	1.88	2.61	0.68	0.37
V × D								
V_1D_1	2.87	3.30	28.6	32.8	83.89	88.81	16.10	11.19
V_1D_2	2.41	2.95	25.1	30.8	82.41	86.23	17.60	13.77
V_1D_3	1.92	2.71	18.5	29.4	74.13	82.16	25.86	17.84
V_2D_1	2.79	3.15	24.8	31.5	80.64	86.22	19.36	13.78
V_2D_2	2.27	2.88	21.7	26.8	77.55	83.52	22.65	16.47
V_2D_3	1.72	2.69	16.4	23.4	73.38	80.52	26.62	19.48
V_3D_1	2.29	2.32	22.1	24.5	77.87	83.68	22.13	16.32
V_3D_2	1.96	2.04	19.8	21.5	73.03	80.95	26.97	19.05
V_3D_3	1.63	1.97	15.5	20.8	70.21	79.15	29.79	20.85
SEm (±)	0.13	0.18	1.4	1.8	1.07	1.50	0.39	0.21
CD (p=0.05)	NS	NS	NS	NS	NS	NS	1.17	0.64

environmental conditions. Analysing leaf area index is crucial to understand the dynamics of crop growth. Results revealed that leaf area index was considerably affected by varieties and sowing dates (Table 2). Among varieties, significantly higher LAI was obtained with MR-6 in 2023 and 2024 with value of 2.40 and 2.98 respectively. While significantly lowest LAI was obtained with KMR-630 in both years (1.96, 2.10). Among various dates of sowing, significantly higher LAI was obtained with first date of sowing *i.e.* July first fortnight. In 2023, higher LAI was observed with July first fortnight sowing (2.65) followed by second fortnight sowing (2.21). While comparatively lower LAI was observed with August sowing (1.75). Similarly, in year 2024, higher LAI was obtained with first sowing date (2.92) and lower LAI was obtained with third sowing date (2.46). Interaction effect was found to be statistically non-significant for varieties and sowing dates.

This variation in leaf area among varieties can be attributed to the duration of plant growth. MR-6 might have utilized the longer duration available to improve plant growth before attaining reproductive stage which have contributed to higher leaf area. Whereas KMR-630 being short duration in nature receded in utilizing the opportunity to improve vegetative growth before attaining flowering. Finger millet varieties had shown a significant effect on leaf area index in a study conducted in Odisha (27). Higher LAI achieved under first date of sowing can be referred to the favourable weather conditions that occurred during vegetative stage which have contributed to increased duration of crop thereby improving leaf area when compared with delayed sowings. Similar findings were reported in other crops, where higher leaf area index was observed with early sowing dates (28, 29).

Dry matter production

Total dry matter accumulation in crop is direct measure of productivity. The amount of dry matter produced helps in analysing crop growth, radiation interception and yield. Favourable environmental conditions help in better accumulation and translocation of photosynthates from source to sink. Results revealed a decrease in dry matter accumulation with delay in sowing date and with varieties having shorter duration (Table 2). Among varieties, significantly higher dry matter accumulation at harvest was observed with MR-6 (24.1, 31.0 g plant^{-1}) in both the years. While comparatively lower dry matter was accumulated with short duration variety KMR-630 (19.1, 22.3 g plant^{-1}). Among various dates of sowing, sowing of crop at first fortnight of July produced higher dry matter when compared with delayed sowings. In year 2023, higher dry matter was observed with July first fortnight sowing (25.2 g plant^{-1}) followed by second fortnight sowing (22.2 g plant^{-1}). While significantly lower dry matter was recorded with August sowing (16.8 g plant^{-1}). Similar results were obtained with 2024 season. However, the decrease in dry matter accumulation in first fortnight of August is not much pronounced in second season. A 17 % decrease in dry matter was observed with August sowing date when compared with July first fortnight in 2024. Whereas, in 2023, a 33 % decrease was observed in August first fortnight when compared with July first fortnight. Interaction effect for varieties and sowing dates had no statistical significance for dry matter production.

Genotypic variation plays a significant role in crop growth with longer duration varieties being provided with favourable environmental conditions can accumulate higher number of leaves and dry matter thereby improving crop yield. Similar findings were observed in finger millet varieties in an experiment conducted in West Bengal (30). Among sowing dates, higher dry matter accumulated during July first fortnight can be attributed to better crop growth in terms of leaf area, which was subjected to longer crop duration and higher amount of intercepted radiation. Reduced leaf area index along with less PAR interception in August sown condition resulted in less dry matter production. A decrease in dry matter accumulation was observed with delay in sowing date in rapeseed (31). Thus, results revealed that availability of longer duration varieties along with suitable environmental conditions recorded higher growth attributes in finger millet.

Light absorption ratio and light transmission ratio

Varieties and dates of sowing in finger millet significantly affected light absorption and light transmission ratio (Table 2). Among varieties, MR-6 recorded higher LAR in first season (80.1 %) and second season (85.7 %). Whereas significantly lower LAR was recorded with KMR-630. Among dates of sowing, higher light absorption was observed with July first fortnight sowing in first (80.8 %) and second season (86.2 %) when compared with July second fortnight and August first fortnight sowing. Whereas light transmission was comparatively higher for KMR-630 variety and August first fortnight sowing in both the seasons. KMR-630 recorded higher light transmission ratio in first season (26.3 %) and second season (18.7 %) when compared to other varieties. Significantly lower light transmission was observed with MR-6. Similarly, sowing of finger millet at August first fortnight recorded higher light transmission ratio in 2023 (27.4 %) and 2024 (19.4 %) when compared with July month sowings with significantly lower light transmission being observed under July first fortnight.

Interaction effect was significant for light transmission ratio in both seasons where sowing of KMR-630 at August first fortnight recorded higher light transmission ratio values. Higher light absorption and lesser light transmission ratio being observed with MR-6 and first sowing date can be attributed to the higher amount of intercepted photosynthetically active radiation with MR-6 variety and early sowing date. Optimum crop growth resulted in higher interception of radiation leading to higher amount of light being absorbed and lesser amount of light being transmitted in MR-6. Better crop growth led to decreased light transmission ratio in intercropping system of pigeon pea and green gram (32).

PAR interception

Radiation interception is crucial to analyse the crop growth and development. Interception of photosynthetically active radiation by crop directly impact the crop growth dynamics and influence productivity of crop. Crop canopy and biomass accumulation highly impact absorption of PAR. Optimum crop growth leads to better absorption of light and reduces transmission and reflection from ground. Intercepted PAR data were analyzed for finger millet varieties under three dates of sowing at different phenophases. Among all phenophases, higher IPAR was observed at 50 % flowering stage in all varieties (Fig. 3). Results revealed that MR-6 variety intercepted higher amount of PAR in both seasons. An increase in IPAR was observed with progress in crop phenology with maximum amount of radiation being intercepted at flowering stage.

In first season, higher amount of intercepted PAR was observed with MR-6 variety at first date of sowing (81.9 %) at flowering stage (Fig. 3A). Comparatively lower amount of intercepted PAR was observed with KMR-630 at third date of sowing (64.7 %) (Fig. 3B-C). Mean intercepted PAR in first season was higher for MR-6 averaged across all dates of sowing (67.8 %) followed by KMR-316 (64.3 %) and KMR-630 (60.2 %). Among dates of sowing, mean intercepted PAR was higher for July first fortnight sowing averaged across varieties (68.2 %). Whereas comparatively lower mean intercepted PAR was observed under August first fortnight sowing (59.8 %). Similarly, in second season, at flowering stage higher amount of intercepted PAR was recorded with MR-6 at first date of sowing (86.3 %) (Fig. 3D). While lower amount of intercepted PAR was recorded with KMR-630 at third sowing date (73.1 %) (Fig. 3F). Mean intercepted PAR was higher for MR-6 (71.9 %) followed by KMR-316 (68.5 %) and KMR-630 (65.3 %). Among dates of sowing, mean intercepted PAR averaged across phenophases and varieties was higher for first sowing date (72.2 %) followed by second (68.5 %) and third sowing date (64.9 %). Similar results were reported in other crops, where higher amount of PAR was intercepted under early sowing window (33, 34). Positive relationship was observed between intercepted PAR and leaf area index and dry matter production in both years (Fig. 4,5). The coefficient of determination (R^2) is 0.91 and 0.71 for leaf area index in 2023 and 2024 respectively. Significant relationship was observed with dry matter production with R^2 value of 0.93 and 0.90 in first and second season respectively. Previous studies revealed a significant relationship between PAR interception, leaf area index and dry matter production (35, 36).

Improved crop growth with higher leaf area and biomass accumulation in MR-6 might have resulted in higher PAR absorption. Similarly, favourable environment that prevailed during July first fortnight might have increased crop duration thereby improving crop growth and radiation interception. These findings are in conformity with those reported in pigeon pea cultivars (37).

Conclusion

Climate change has profound influence on performance of rainfed crops. In agronomic point of view, optimizing ideal date of sowing and selection of suitable variety is essential to obtain higher yield. Present study revealed that sowing of crop at July first fortnight improved crop growth and yield when compared with delayed sowings. Availability of favourable weather at early sowing, led to extended crop duration with better development of leaf area, which in turn increased intercepted radiation and biomass accumulation, contributing to higher yield. Varieties with comparatively longer duration like MR-6 improved crop growth and yield. Thus, early sowing of crop with long duration varieties can enhance the sustainability of finger millet yield contributing to climate resilient crop production.

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Authors' contributions

Conceptualization by HPK, M and TMN. Planning and supervision by HPK, M, MMH, TMN, VBG and TK. HPK, M, MMH, TMN, Avand PRS conduct field experiment. Data analysis is carried out by HPK, LH, SDV, AV and PRSKHP prepared manuscript draft. Manuscript review by M, MMH, TMN, VBG and

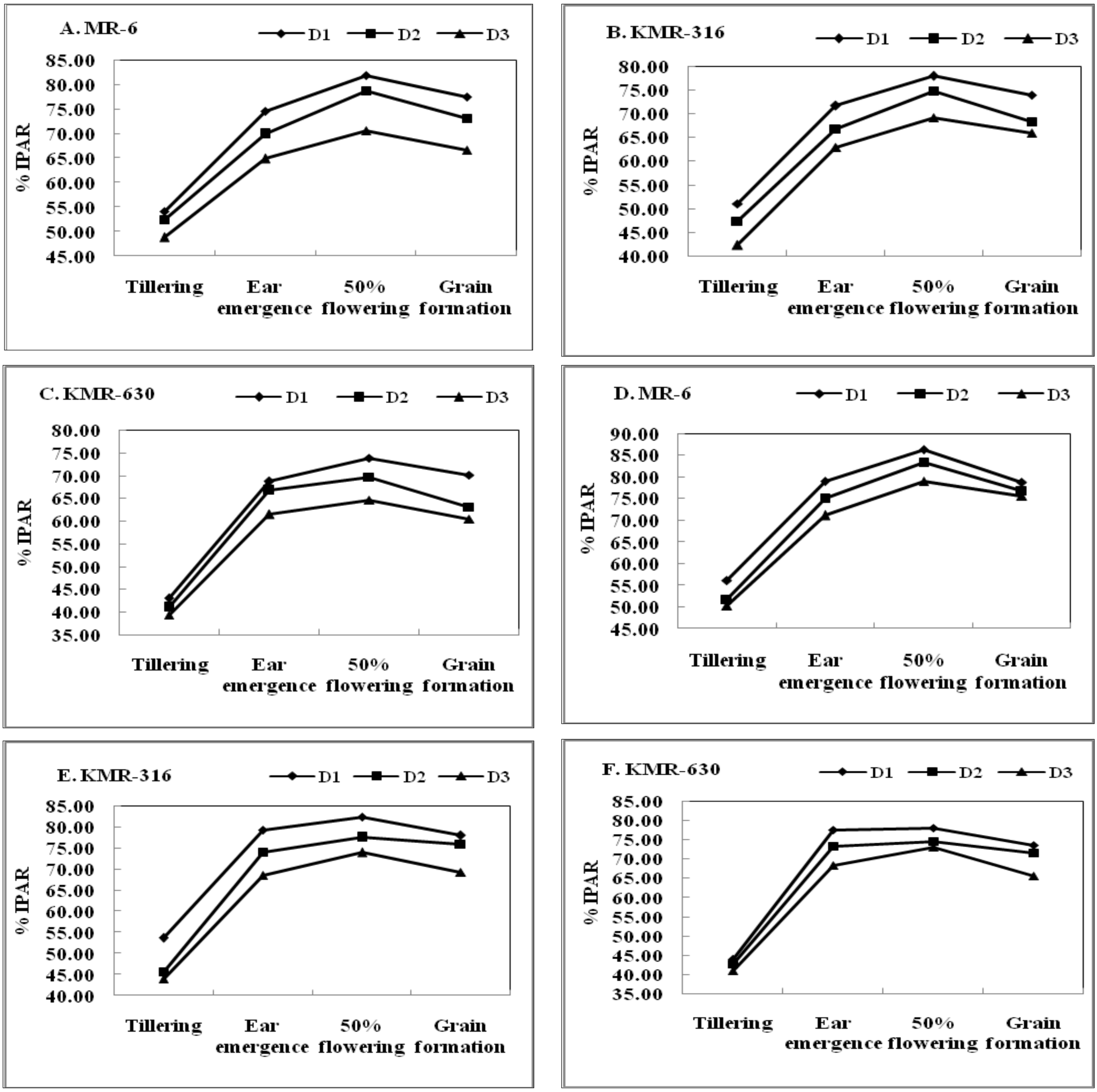

Fig. 3. Percentage PAR interception of three finger millet varieties under three dates of sowing during year 2023 (A, B, C) and 2024 (D, E, F).

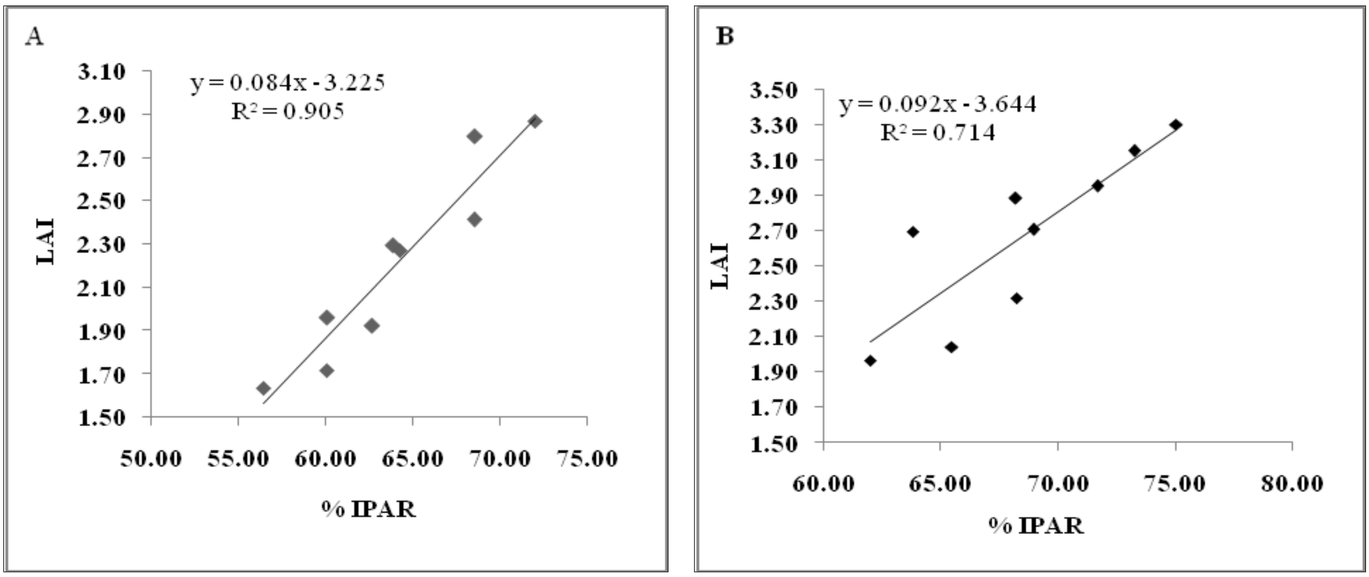

Fig. 4. Relationship between intercepted PAR and LAI in finger millet during year 2023 (A) and 2024 (B).

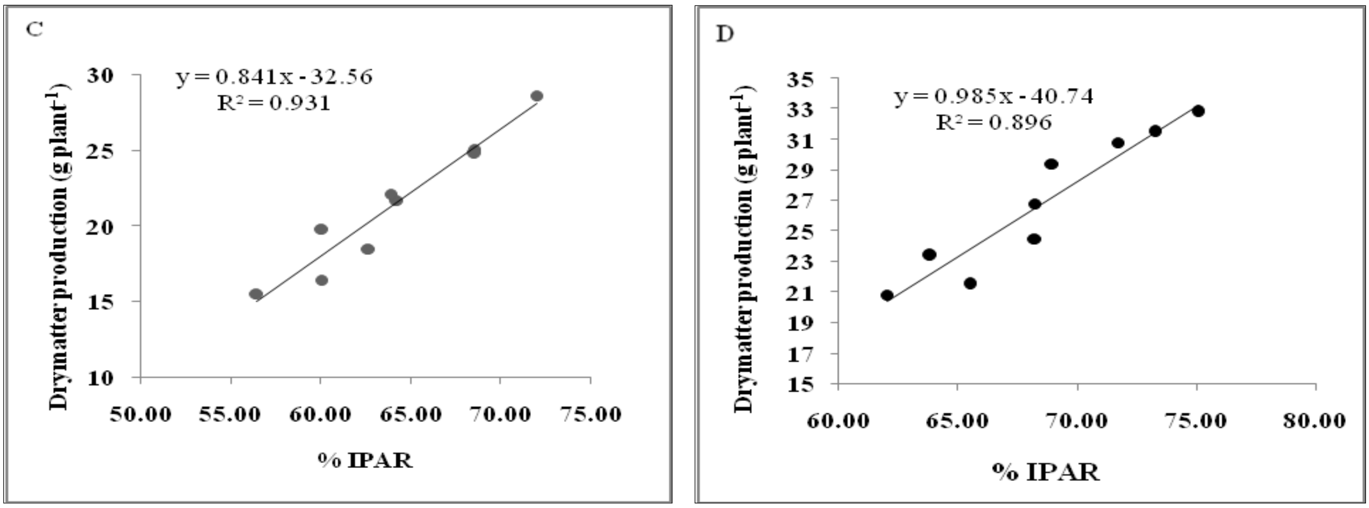

Fig. 5. Relationship between intercepted PAR and dry matter production in finger millet during the year 2023 (C) and 2024 (D).

TK. HPK, LH, SDV, AV and PRS done manuscript editing. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

1. Dida MM, Devos KM. Finger millet. In: Kole C, editor. Genome mapping and molecular breeding in plants. Berlin: Springer; 2006:333-43. https://doi.org/10.1007/978-3-540-34389-9_10
2. Chandrashekar A. Finger millet: *Eleusine coracana*. In: Steve LT, editor. Advances in food and nutrition research. Cambridge: Academic Press; 2010:215-62. https://doi.org/10.1016/S1043-4526(10)59006-5
3. Maharajan T, Antony Ceasar S, Ajeesh Krishna TP, Ignacimuthu S. Finger millet (*Eleusine coracana* (L.) Gaertn): an orphan crop with a potential to alleviate the calcium deficiency in the semi-arid tropics of Asia and Africa. Front Sustain Food Syst. 2021:5. https://doi.org/10.3389/fsufs.2021.684447
4. Gebreyohannes A, Shimelis H, Mashilo J, Odeny DA, Tadesse T, Ojiewo CO. Finger millet (*Eleusine coracana*) improvement: challenges and prospects—a review. Plant Breed. 2024;143(3):350-74. https://doi.org/10.1111/pbr.13169
5. Indiastat. Selected state-wise area, production and productivity of ragi in India (2023-2024). 2025. https://www.indiastat.com/table/ragi-finger-millets/selected-state-wise-area-production-productivity-r/1456832
6. Kumar B, Singh M, Kumar A, Kumar D, Kumar Singh A, Kumar R, et al. Finger millet scientific cultivation and its uses in India. In: Yadav L, Upasana, editors. Millets - rediscover ancient grains. Uttar Pradesh: IntechOpen; 2024. http://doi.org/10.5772/intechopen.111391
7. Molotoks A, Smith P, Dawson TP. Impacts of land use, population and climate change on global food security. Food Energy Secur. 2021;10(1):261. https://doi.org/10.1002/fes3.261
8. Farooq MS, Uzair M, Raza A, Habib M, Xu Y, Yousuf M, et al. Uncovering the research gaps to alleviate the negative impacts of climate change on food security: a review. Front Plant Sci. 2022;13. https://doi.org/10.3389/fpls.2022.927535
9. Wang X, Folberth C, Skalsky R, Wang S, Chen B, Liu Y, et al. Crop calendar optimization for climate change adaptation in rice-based multiple cropping systems of India and Bangladesh. Agric For Meteorol. 2022;315. https://doi.org/10.1016/j.agrformet.2022.108830
10. Sandhu SS, Kaur P, Gill KK, Vashisth BB. The effect of recent climate shifts on optimal sowing windows for wheat in Punjab, India. J Water Clim Change. 2020;11(4):1177-90. https://doi.org/10.2166/wcc.2019.241
11. Saikia RJ, Neog P, Deka RL, Medhi K. Importance of PAR interception and radiation use efficiency on growth and yield of potatoes under different microclimates in the upper Brahmaputra valley zone of Assam. Mausam. 2024;75(1):205-14. https://doi.org/10.54302/mausam.v75i1.3892
12. Singh J, Singh SP, Biswas B, Kaur V. Optimizing maize production through sowing date, nitrogen levels and cultivar selection in northwest region of India. J Plant Nutr. 2024;47(20):3823-43. https://doi.org/10.1080/01904167.2024.2385591
13. Ali W, Ali M, Ahmad Z, Iqbal J, Anwar S, Kamal MK. Influence of sowing dates on varying maize (*Zea mays* L.) varieties grown under agro-climatic condition of Peshawar, Pakistan. Eur J Exp Biol. 2018;8(6):36. https://doi.org/10.21767/2248-9215.100077
14. Sagar J. Impact of weather parameters on phenology, growth and productivity of basmati rice (*Oryza sativa* L.) varieties under varying transplanting environments and weed management practices. Jammu: Sher-e-Kashmir University of Agricultural Sciences and Technology; 2024.
15. Singh J, Biswas B, Dhaliwal LK. Growing environments and cultivar selection limits wheat growth and yield potential in Punjab. Plant Sci Today. Forthcoming 2025. https://doi.org/10.14719/pst.5785
16. Mrubata K, Nciizah AD, Muchaonyerwa P. Planting date and tillage effects on yield and nutrient uptake of two sorghum cultivars grown in sub-humid and semi-arid regions in South Africa. Front Agron. 2024:6. https://doi.org/10.3389/fagro.2024.1388823
17. Watson DJ. The physiological basis of variation in yield. Adv Agron. 1952;4:52-69. https://doi.org/10.1016/S0065-2113(08)60307-7
18. Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd ed. New York: John Wiley and Sons; 1984.
19. Dhaliwal LK, Hundal SS, Kular JS, Chahal SK, Aneja A. Radiation interception, growth dynamics and agroclimatic indices in raya (*Brassica juncea*). J Agrometeorol. 2007;9(2):242-6. https://doi.org/10.54386/jam.v9i2.1137
20. Yoshida S, Forno DA, Cock JH, Gomez KA. Laboratory manual for physiological studies of rice. Philippines: International Rice Research Institute; 1972.
21. Simion T, Markos S, Samuel T. Evaluation of finger millet (*Eleusine coracana* (L.) Gaertn.) varieties for grain yield in lowland areas of

southern Ethiopia. Cogent Food Agric. 2020;6(1). https://doi.org/10.1080/23311932.2020.1788895

22. Moustafa ES, El-Sobky ES, Farag HI, Yasin MA, Attia A, Rady MO, et al. Sowing date and genotype influence on yield and quality of dual-purpose barley in a salt-affected arid region. Agronomy. 2021;11(4):717. https://doi.org/10.3390/agronomy11040717
23. Khan A, Najeeb U, Wang L, Tan DK, Yang G, Munsif F, et al. Planting density and sowing date strongly influence growth and lint yield of cotton crops. Field Crops Res. 2017;209:129-35. https://doi.org/10.1016/j.fcr.2017.04.019
24. Liu K, Song C, Ye P, Liu H, Xia Z, Waseem H, et al. Optimizing rice sowing dates for high yield and climate adaptation in Central China. Agronomy. 2023;13(5). https://doi.org/10.3390/agronomy13051339
25. Maresma A, Ballesta A, Santiveri F, Lloveras J. Sowing date affects maize development and yield in irrigated mediterranean environments. Agriculture. 2019;9(3):67. https://doi.org/10.3390/agriculture9030067
26. Lü GH, Wu YF, Bai WB, Bao MA, Wang CY, Song JQ. Influence of high temperature stress on net photosynthesis, dry matter partitioning and rice grain yield at flowering and grain filling stages. J Integr Agric. 2013;12(4):603-9. https://doi.org/10.1016/S2095-3119(13)60278-6
27. Mukesh G, Sairam M, Maitra S, Gaikwad DJ, Anuradha N, Sahoo U, et al. Performance evaluation of different finger millet (*Eleusine coracana* L. Gaertn.) cultivars for growth, productivity and nutrient quality of grains under hot and subhumid region of Odisha. Int J Exp Res Rev. 2024;39:1-14. https://doi.org/10.52756/ijerr.2024.v39spl.001
28. Pal R, Mahajan G, Sardana V, Chauhan BS. Impact of sowing date on yield, dry matter and nitrogen accumulation and nitrogen translocation in dry-seeded rice in North-West India. Field Crops Res. 2017;206:138-48. https://doi.org/10.1016/j.fcr.2017.01.025
29. Muhammad A, Basıt A. Effect of climatic zones and sowing dates on maize emergence and leaf parameters. Acta Ecol Sin. 2019;39(6):461-6. https://doi.org/10.1016/j.chnaes.2018.11.005
30. Das N. Effect of sowing date, variety and nutrient management on finger millet in new alluvial zone of West Bengal [dissertation]. Mohanpur, Nadia: Bidhan Chandra Krishi Viswavidyalaya; 2024. Available from: https://krishikosh.egranth.ac.in/server/api/core/bitstreams/af4c79f0-a37f-447a-be42-ec9e46ed8726/content
31. Sieling K, Böttcher U, Kage H. Sowing date and N application effects on tap root and above-ground dry matter of winter oilseed rape in autumn. Eur J Agron. 2017;83:40-6. https://doi.org/10.1016/j.eja.2016.11.006
32. Dhandayuthapani UN, Latha KR. Analysis of light transmission ratio and yield advantages of pigeonpea in relation to intercrop and different plant population. Afr J Agric Res. 2015;10(8):731-6. https://doi.org/10.5897/AJAR2014.9122
33. Gregory PJ, Eastham J. Growth of shoots and roots and interception of radiation by wheat and lupin crops on a shallow, duplex soil in response to time of sowing. Aust J Agric Res. 1996;47(3):427-47. https://doi.org/10.1071/AR9960427
34. Honnaiah PA, Sridhara S, Gopakkali P, Ramesh N, Mahmoud EA, Abdelmohsen SA, et al. Influence of sowing windows and genotypes on growth, radiation interception, conversion efficiency and yield of guar. Saudi J Biol Sci. 2021;28(6):3453-60. https://doi.org/10.1016/j.sjbs.2021.03.010
35. Tesfaye K, Walker S, Tsubo M. Radiation interception and radiation use efficiency of three grain legumes under water deficit conditions in a semi-arid environment. Eur J Agron. 2006;25(1):60-70. https://doi.org/10.1016/j.eja.2006.04.014
36. Mehta P, Dhaliwal LK. Radiation interception, growth dynamics and agroclimatic indices of wheat under different sowing dates. J Agrometeorol. 2022;24(3):312-5. https://doi.org/10.54386/jam.v24i3.1650
37. Patel NR, Mehta AN, Shekh AM. Radiation absorption, growth and yield of pigeonpea cultivars as influenced by sowing dates. Exp Agric. 2000;36(3):291-301. https://doi.org/10.1017/S001447970000301X

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