Indian Journal of Agricultural Sciences **93** (8): 839–843, August 2023/Article
https://doi.org/10.56093/ijas.v93i8.138424

Production potential of short duration rice (*Oryza sativa*) in relation to age of seedlings, date of transplanting and crop geometry

PRABHJIT KAUR[1]*, K S SAINI[1], KIRANDEEP KAUR[2] and JASHANJOT KAUR[3]

Punjab Agricultural University, Ludhiana, Punjab 141 004, India

Received: 27 June 2023; Accepted: 13 July 2023

ABSTRACT

An experiment was conducted at the research farm of Punjab Agricultural University, Ludhiana, Punjab during 2018 and 2019 to determine the production potential of rice (*Oryza sativa* L.) in relation to age of seedlings, date of transplanting and crop geometry. The results revealed that growth and productivity of short duration rice crop were improved by transplanting younger seedlings of 3 and 4 weeks age (nursery sown on June 12 and June 19) as compared to the older ones 5 and 6 week old seedlings (nursery sown on May 29 and June 5). Transplanting of rice at 25th June and 10th July with 20 cm × 15 cm crop geometry recorded better growth, yield attributes and higher yield as compared to 15 cm × 15 cm crop geometry. Rice transplanted on 10th July required fewer irrigations (14 and 17) as compared to the crop transplanted on June 25 (16, 19) in 2018 and 2019, respectively. This led to a water saving of 12.5 and 10.5% during those respective years, without compromising the yield. It is worth noting that a single irrigation was applied at a depth of 7.5 cm. For higher saving in irrigation water, nursery of PR 126 can be sown up to June 20 and 25–30 days old seedlings can be transplanted up to July 10 at 20 cm ×15 cm spacing.

Keywords: Grain yield, Harvest index, Rice, Seedling age, Transplanting date

The rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system is the backbone of Indian farming, especially in the north-western region. During 2020–21, in India, rice was grown on 46.28 million ha area with a production of 129.47 MT. Punjab from 31.44 lakh ha area produced 13.7 MT of rice and contributed 12.2 MT (21.2%) rice to the central pool (Anonymous 2023). Therefore, the sustainability of rice production systems in Punjab holds paramount importance in safeguarding food security. Crop productivity is influenced by intricate interplay among genetic, environmental and cultural management factors (Dhillon *et al.* 2017). Of these factors, environmental conditions exert a significant influence and are often the least controllable. Thus, the factors which could be managed are selection of suitable genotypes and their transplantation at the optimal age, coupled with proper crop geometry act as critical determinants for enhancing rice productivity (Dhillon *et al.* 2021).

Due to the growing scarcity of farm labour and limited availability of irrigation water for puddling during the peak transplantation period, the transplantation of nursery seedlings is frequently delayed under Punjab conditions. As a consequence, the seedling age in the nursery bed increases and transplantation of older nursery seedlings leads to reduced tillering, early panicle initiation, uneven flowering and a shortened vegetative phase . Consequently, this results in a decrease in the number of grains per panicle (Jia *et al.* 2014, Pandey *et al.* 2021) . Rice is a determinate plant and reaches flowering stage at almost fixed time as this character is under strong genetic control and varying seedling age influences phenological events in rice crops. Therefore, it is essential to synchronize crop phenology with favourable environmental conditions through the selection of appropriate cultural practices in order to achieve higher yields. Extensive research has been conducted to determine the optimum seedling age with appropriate transplanting time of rice in order to maximize productivity. Keeping these facts in view we hypothesized that whether the portfolios of efficient management practices involving better crop establishment methods (crop geometry, age of seedling, date of transplanting) will helps to make such innovative approaches that have demonstrated as the potential strategies to enhance farm profitability and to reduce ecological footprint of agricultural production system for sustainable food security.

MATERIALS AND METHODS

Field experiments were conducted at the research farm

[1]Punjab Agricultural University, Ludhiana, Punjab; [2]PAU-Research station, Dyal Bharang, Amritsar, Punjab; [3]PAU-Regional research station, Kapurthala, Punjab. *Corresponding author email: prabhjit.brar@yahoo.in

of Punjab Agricultural university, Ludhiana (30° 56' N 75° 52' E; 247 m amsl), Punjab located in the Indo–Gangetic Plains Region during 2018 and 2019 and meteorological data were recorded from meteorological observatory situated at PAU, Ludhiana for the study time period (Fig 1). The experimental site's climate is subtropical and semi-arid, with an annual rainfall of 759 mm. Approximately 80% of the total rainfall occurs between June and September (Kaur *et al.* 2016). The soil at the experimental site was sandy-loam in texture, characterized by low in available nitrogen (N) and high in available phosphorus (P). However, the soil exhibited medium availability of potassium (K) and soil organic carbon (SOC). Electrical conductivity and soil *p*H were within optimum range.

Treatments and experimental details: The experiment was laid out in split plot design with 4 replications. Main plot treatments were dates of transplanting (25^{th} June and 10^{th} July) and crop geometry (25 cm × 15 cm and 15 cm × 15 cm) and sub plot treatments were age of seedlings (3 weeks, 4 weeks, 5 weeks and 6 week old seedlings). The plot size was 6 m × 3.30 m=19.8 m^2. Recommended dose of fertilizers was applied @105 kg N, 30 kg P_2O_5 and 30 kg K_2O per hectare. The entire quantity of P_2O_5 and K_2O was applied before last puddling. Nitrogen application was divided in 3 equal splits, 1^{st} split was applied before last puddling, 2^{nd} at 3 weeks after transplanting and last split 3 weeks afterwards.

Micrometeorological observations

Photosynthetically active radiation interception (PARI): During clear and sunny days, measurements of incoming and outgoing radiations at the top of the canopy, as well as transmitted to the ground surface, were conducted at monthly intervals using a LI-COR-LINE Quantum sensor photometer (Dhillon *et al.* 2021). The observations were taken at random from two places in each plot between 12:30 to 13:30 h and PAR interception was calculated as:

$$\text{PAR interception (\%)} = \frac{\text{PAR (I)-PAR (T)-PAR ®}}{\text{PAR (I)}} \times 100$$

where, PAR (I), Total PAI incoming above the canopy, W/m^2; PAR (T)= PAR transmitted to ground, W/m^2; PAR ®= PAR reflected from the canopy, W/m^2.

Canopy temperature: For canopy air temperature, the data were taken from dry bulb readings which was recorded at the top and ground level of crop canopy with the help of digital temperature indicator between 9.00 AM to 10.00 AM and 3.00 PM to 4.00 PM and then mean values for the day were calculated and presented.

Crop phenology: Days taken to panicle emergence, days taken to 50 and 100% panicle emergence stage and days taken to maturity (when 50% of the plants exhibited yellowing or drying of the straw) were recorded on 5 randomly selected plants out of a total of 10 tagged plants in each plot.

Statistical analysis: To compare treatment means, statistical analysis was carried out in SAS 9.4 software using (SAS institute 2013) using Proc GLM. LSD procedure was employed, utilizing Tukey's HSD where ANOVA was significant. The comparisons were made at 5% level of significance.

RESULTS AND DISCUSSION

Micrometeorological observations

Photosynthetically active radiation interception (PARI): The PARI of rice was obtained at maximum tillering, grain filling stage and physiological maturity (Table 1). At grain filling stage, significantly higher (82.6 and 83.4) PARI was found with D1G1 followed by D2G1, D1G2 and D2G2. Whereas, PARI under D2G1 was at par with D1G1. The lowest PARI (76.8 and 79.9) was recorded in treatment

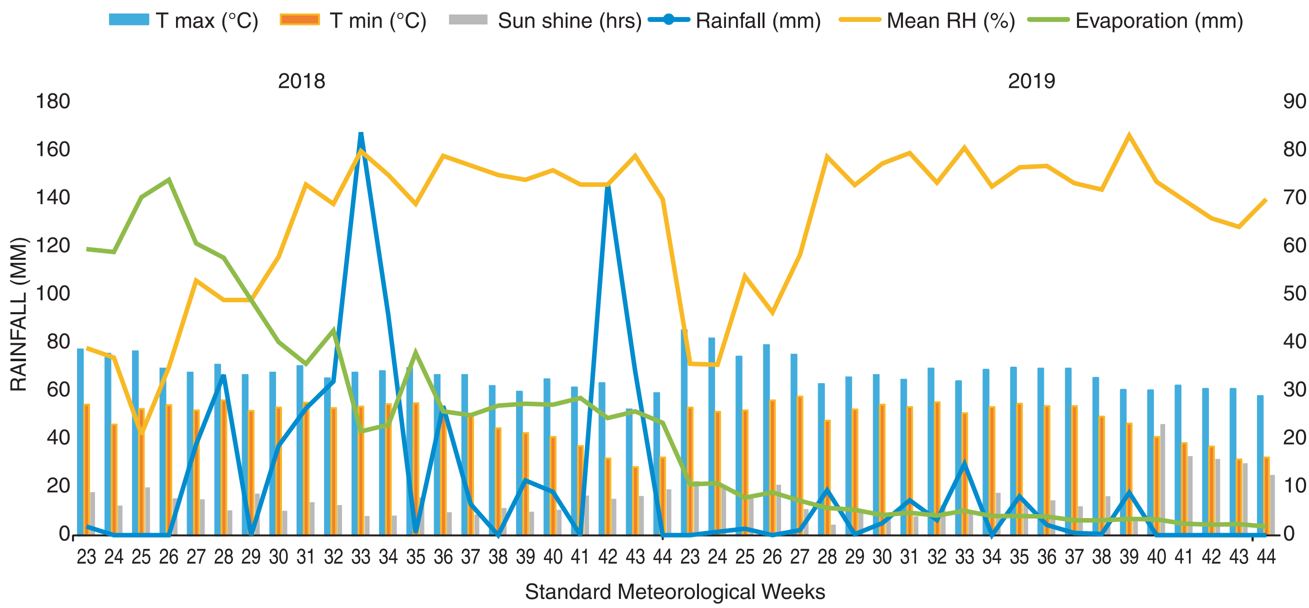

Fig 1 Daily agro-meteorological parameters variability at Ludhiana during rice seasons of 2018 and 2019.

with D2G2 during 2018 and 2019, respectively. Similar trend of PARI was found at physiological maturity during both years. Whereas, maximum (82.8 and 84.5) PARI was observed with 3-week which in turn at par with 4-week-old seedlings (82.0 and 83.3). However, the lowest PARI (76.7 and 77.6) was recorded with 6 week old seedlings at grain filling stage during 2018 and 2019, respectively. The results also indicated that the value of PARI was relatively higher at grain filling stage than physiological maturity in both years (Kaur and Mahal 2018).

Canopy temperature (°C): Canopy temperature during the maximum tillering stage was not significantly affected by the transplanting dates, crop geometries and age of seedlings. D2G1 had significantly lower (32.7°C and 33.6°C) canopy temperature compared to D1G2 and D2G2 (Table 1). Whereas, the highest canopy temperature (35.2°C and 36.0°C) was observed in D2G2 during 2018 and 2019, respectively. A similar trend of canopy temperature was observed at physiological maturity stage. Among different seedlings age, the lowest canopy temperature (32.7°C and 33.6°C) was observed with 3-week-old seedlings, while the highest canopy temperature (34.5°C and 35.3°C) was recorded with 6-week-old seedlings during grain filling stage in both years. Similar trend of canopy temperature was found at physiological maturity during both the years of study. The results also indicated that the value of canopy temperature was relatively higher at grain filling stage than physiological maturity during both the years of study (Vishwakarma *et al.* 2016).

Phenological observations

Days taken to panicle initiation: Among different dates of transplanting and crop geometries, during 2018 and 2019, it was observed that D1G2 had taken more days to panicle initiation and 50% panicle emergence as compared to other treatments i.e. D1G1, D2G2 and D2G1 (Table 2). Whereas, D2G1 recorded significantly fewer number of days taken to panicle emergence than other treatments during both the years of study.

The age of seedlings had a significant impact on the panicle emergence of rice in both the years of study. Days taken to panicle initiation were significantly higher with 3-week old seedlings than other treatments. Whereas, days taken to panicle initiation of rice were significantly lower in 6-week old seedlings than other treatments during both years of study, respectively. Kaur and Mahal (2018) also observed that the panicle initiation stage commenced later in the early-sown crop (25th June), while 50% flowering occurred earlier in the late-sown crop (10th July).

Days taken to 50% panicle emergence: Maximum number of days taken to attain 50% panicle emergence was observed with treatment D1G2 followed by D1G1, D2G2 and least number of days taken was observed with D2G1 during 2018 and 2019, respectively. The effect of different age of seedlings was significant on 50% panicle emergence of rice. The maximum duration for 50% panicle emergence in paddy was observed in the 3-week nursery, taking 68.3 days from transplanting. Comparatively, the durations for the 4-week, 5-week and 6-week-old nurseries were 66.5, 63.1 and 59.7 days, respectively. Similarly, according to Dhillon *et al.* (2021) as the transplanting date is delayed, the duration from transplanting to 50% panicle emergence decreases.

Days taken to physiological maturity: Among different age of seedlings, significantly maximum days taken to physiological maturity were recorded with 3-week-old seedlings followed by 4, 5 and 6-week-old seedlings. Whereas, lesser number of days attained to physiological maturity were found to be significantly lower in 6-week-old seedlings during 2018 and 2019. The physiological maturity of 3 weeks-old-seedlings was attained in 94.2 to

Table 1 Effect of age of seedling, date of transplanting and crop geometry on photosynthetically active radiations interception (%) and canopy temperature (^{0}C) of rice

Treatment	PARI (%)						Canopy temperature (^{0}C)					
	Maximum tillering		Grain filling stage		Physiological maturity		Maximum tillering		Grain filling stage		Physiological maturity	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Date of transplanting and crop geometry												
D1G1	57.7a	59.2a	82.6a	83.4a	62.7a	63.1a	30.9a	31.4a	32.8c	33.7c	32.3c	32.6c
D1G2	55.2a	55.8a	80.7c	81.2b	59.8b	60.7b	32.0a	32.3a	33.9b	34.8b	33.4b	33.7b
D2G1	56.8a	57.5a	81.9b	82.7a	61.4a	62.8a	31.8a	32.0a	32.7c	33.6c	32.2c	32.5c
D2G2	52.3a	54.5a	76.8d	79.9c	56.3c	59.2c	32.5a	32.9a	35.2a	36.0a	34.7a	35.1a
Age of seedlings												
A1 (3 week)	58.4a	59.4a	82.8a	84.5a	63.6a	64.1a	30.8a	31.2a	32.7d	33.6d	32.2d	32.5c
A2 (4 week)	56.8a	58.1a	82.0a	83.3a	61.9a	63.4a	31.5a	31.9a	33.4c	34.3c	32.9c	33.2b
A3 (5 week)	54.7a	55.0a	80.6b	81.9b	58.4b	60.7b	32.1a	32.5a	34.0b	34.9b	33.4b	33.7b
A4 (6 week)	52.2a	53.4a	76.7c	77.6c	56.1c	57.8c	32.8a	33.0a	34.5a	35.3a	34.1a	34.5a

Similar alphabetical letters denote no differences at the $P<0.05$ level based on Tukey's multi comparison test.

D1, 25th June; D2, 10th July; G1, 20 cm × 15 cm; G2, 15 cm × 15 cm.

Table 2 Effect of age of seedling, date of transplanting and crop geometry on phenological observations of rice

Treatment	Phenology (Days taken to)					
	Panicle initiation		50% panicle emergence		Physiological maturity	
	2018	2019	2018	2019	2018	2019
Date of transplanting and crop geometry						
D1G1	53.0b	53.6b	62.5b	64.6b	91.2b	92.5b
D1G2	53.5a	54.3a	63.0a	65.1a	92.3a	93.7a
D2G1	51.9d	52.9d	61.2d	63.7d	86.2d	88.6d
D2G2	52.8c	53.5c	62.0c	64.2c	88.3c	90.0c
Age of seedlings						
A1 (3 week)	54.6a	55.1a	66.5a	68.3a	94.2a	95.6a
A2 (4 week)	53.6b	54.4b	64.7b	66.5b	92.1b	93.5b
A3 (5 week)	52.6c	53.5c	61.3c	63.1c	87.9c	90.3c
A4 (6 week)	50.4d	51.3d	56.2d	59.7d	83.8d	85.5d

D1, 25th June; D2, 10th July; G1, 20 cm × 15 cm; G2, 15 cm × 15 cm.

95.6 days as compared to 83.8 to 85.5 days taken by 6-weeks old seedlings. In the study conducted by Vishwakarma *et al.* (2016), it was observed that the delay in transplanting significantly influenced the timing of 100% flowering and physiological maturity in rice plants. This was attributed to the fact that older seedlings, which had spent a longer period of their life in the nursery, required fewer days to reach maturity after being transplanted (Sattar *et al.* 2017).

Yield and yield attributes

Effective tillers/m^2: Among different dates of transplanting and crop geometries at PAU, during 2018 and 2019, effective tillers/m^2 square were found to be significantly reduced in D2G2 (9.21, 7.49, 8.94% and 7.80, 5.79, 7.57%) as compared to other treatments i.e. D1G1, D1G2 and D2G1 (Table 3). Among different age of seedlings, effective tillers/m^2 at PAU were recorded significantly higher with 3-week-old seedlings than 5 and 6-week old seedlings and it which was at par with 4-week old seedlings. Whereas, the effective tillers per meter square of rice were found to be significantly lower in 6-week-old seedlings than all other treatments during 2018 and 2019, respectively. Thus, age of seedlings during transplanting plays a crucial role in achieving a uniform stand establishment in rice cultivation. It is worth noting that exceeding the optimal age of seedlings can negatively impact tiller production, as it shortens the vegetative period and ultimately leads to reduced yields (Bashir *et al* 2010) Similarly, number of effective tillers/m^2 were significantly higher with 3-week-old seedlings than 5 and 6-week and which was at par with 4-week old (Dhillon *et al.* 2021).

Panicle length: Among different dates of transplanting and crop geometries, during 2018 and 2019, panicle length was recorded significantly lower in D2G2 as compared to other treatments i.e. D1G1, D1G2 and D2G1. Whereas, D1G1 recorded significantly higher panicle length (26.4 cm during 2018 and 26.8 cm during 2019) which was at par with D2G1 (26.0 cm during 2018 and 26.5 cm during 2019) followed by D1G2 (25.2 cm during 2018 and 25.4 cm during 2019). Whereas, among different age of seedlings, highest (27.4 cm and 27.7 cm) panicle length was observed with 3-week-old which was at par with 4-week old seedlings (26.6 cm and 26.9 cm), in turn these two were significantly superior to 5 and 6-week old seedlings as they recorded the less panicle length during 2018 and 2019, respectively. In the second year of experiment, significantly higher panicle length was observed with 3-week old seedlings. The decrease in panicle length observed with older seedlings can be attributed to the limited time available for their vegetative growth (Kalita *et al.* 2023). This limited vegetative phase results in a faster transition to the reproductive phase, leading to the production of shorter panicles.

Table 3 Effect of age of seedling, date of transplanting and crop geometry on yield attributing characters, grain yield (q/ha), straw yield (q/ha) and harvest index of rice

Treatment	Effective tillers (/m^2)		Panicle length (cm)		Grains per panicle (no.)		Grain yield (q/ha)		Straw yield (q/ha)		Harvest index (%)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Date of transplanting and crop geometry												
D1G1	323.6a	327.2a	26.4a	26.8a	126.4a	127.0a	79.4a	80.0a	116.6a	119.2a	40.5a	40.1a
D1G2	318.5b	321.1b	25.2b	25.4b	122.8b	123.2b	75.8b	76.1b	112.1b	114.4b	40.4a	39.9a
D2G1	322.8a	326.5a	26.0a	26.5a	125.2a	126.0a	78.0a	78.3ab	115.3a	117.4a	40.4a	40.0a
D2G2	296.3c	303.5c	24.3c	24.6c	120.3c	120.9c	72.2c	73.1c	107.7c	110.4c	40.1a	39.8a
Age of seedlings												
A1 (3 week)	329.6a	333.6a	27.4a	27.7a	128.2a	128.5a	79.9a	80.1a	117.0a	119.7a	40.6a	40.1a
A2 (4 week)	325.9a	329.9a	26.6a	26.9a	126.3a	127.0a	78.0a	78.7ab	115.3a	117.9a	40.4a	40.0a
A3 (5 week)	311.7b	314.6b	24.6b	24.8b	122.3b	123.3b	75.9b	76.5b	111.8b	114.4b	40.4a	40.1a
A4 (6 week)	293.9c	300.1c	23.3c	23.9c	117.8c	118.4c	71.7c	72.1c	107.6c	109.6c	40.0a	39.7a

D1, 25th June; D2, 10th July; G1, 20 cm × 15 cm; G2, 15 cm × 15 cm.

Grains/panicle: Grains/panicle were greatly influenced by different dates of transplanting, crop geometries and age of seedlings. Among different dates of transplanting and crop geometries, during 2018 and 2019, grains per panicle were statistically lower in D2G2 as compared to other treatments, i.e. D1G1, D1G2 and D2G1. Whereas, D1G1 recorded significantly higher grains per panicle (2.93 and 3.08%) as compared to D1G2 and (5.07 and 5.04%) D2G2 which was at par with D2G1 during 2018 and 2019, respectively. Whereas, highest (128.2 and 128.5) number of Grains/panicle were obtained with 3-week-old seedlings and it was on par with 4-week-old seedlings (126.3 and 127.0), these two were statistically superior to 5 and 6-week-old seedlings as they recorded the less grains/panicle during 2018 and 2019, respectively.

1000-grain weight (g): 1000-grain weight was non-significant with different dates of transplanting, crop geometries and age of seedlings during both 2018 and 2019. From different dates of transplanting and crop geometries, D1G1 was numerically better than other treatments such as D1G2, D2G1 and D2G2. However, among different age of seedlings 3-week-old seedlings (24.9 and 25.8 g) had a numeric edge on other seedlings age in 2018 and 2019, respectively.

Grain yield (q/ha): Grain yield varied significantly with different dates of transplanting, crop geometries and age of seedlings (Table 3). Among different dates of transplanting and crop geometries, during 2018 and 2019, D2G2 recorded lowest yield than all other treatments i.e. D1G1, D1G2 and D2G1. Whereas, D1G1 recorded statistically maximum grain yield than D1G2 (4.74 and 2.17%) and D2G2 (9.97 and 9.43%) which were at par with D2G1 during 2018 and 2019, respectively.

Transplanting using seedling of different ages resulted in a significant increase in grain yield with 3-week (5.27, 11.43%) and 4-week-old seedlings (4.79. 11.09%) as compared to 5 and 6-week old seedlings during 2018 and 2019, respectively. Whereas, statistically lower yield was recorded with 6-week old seedlings (71.7 and 72.1 q/ha) than other younger age of seedlings during 2018 and 2019, respectively. The increased grain yield in rice crop planted with 3-week-old seedlings can be attributed to higher plant population, increased leaf area index, enhanced light interception and a greater effective tillers per square meter. These combined factors contribute to the overall improvement in yield for the 3-week-old seedlings (Pramanik and Bera 2013, Dhillon *et al.* 2021).

Straw yield and harvest index: Straw yield was significantly lower in D2G2 than other transplanting dates and crop geometries i.e. D1G1, D1G2 and D2G1. Whereas, D1G1 recorded significantly higher straw yield (116.6 q/ha during 2018 and 119.2 q/ha during 2019) except D2G1 (Table 3). Straw yield was significantly higher with 3 and 4-week old seedlings than 5 and 6-week old seedlings. Maximum harvest index was recorded with 3-week old seedlings as compared to 4 and 5-week old seedlings.

Analysis of data highlights that transplanting younger seedlings (3 and 4-weeks old) for short-duration rice crops improves growth and productivity compared to older seedlings (6-weeks old). Transplanting rice on 25th June and 10th July with a crop geometry of 20 cm × 15 cm results in better growth, yield attributes and overall yield compared to a crop geometry of 15 cm × 15 cm. Rice transplanted on 10th July requires fewer irrigations and saves a significant amount of irrigation water (12.5% in 2018 and 10.5% in 2019) without compromising yield. To maximize water savings, it is recommended to sow PR 126 nursery by 20th June and transplant 25–30 day-old seedlings by 10th July at a spacing of 20 cm × 15 cm.

REFERENCES

Anonymous. 2023. Package and practices for crops of Punjab (*kharif*). Punjab Agricultural University, Ludhiana, Punjab.

Bashir M U, Akber N, Iqbal A and Zaman H. 2010. Effect of different sowing dates on yield and yield components of direct seeded coarse rice (*Oryza sativa* L.). *Pakistan Journal of Agricultural Sciences* **47**(4): 361–65.

Dhillon B S, Kaur G, Mangat G S and Kaur P. 2021. Influence of seedling age on growth, productivity and heat use efficiency of rice genotypes in north-west India. *Journal of Agrometeorology* **23**(1): 30–37.

Dhillon, B S, Sharma P K and Kingra P K. 2017. Agronomic measures to improve thermal energy utilization by spring sunflower. *Journal of Agrometeorology* **19**(1): 34–38.

Jia X, Zhu Q, Yang Z, Sun Y, Guo X, Shi Y and Ma J. 2014. Effect of seedling age on yield and population quality of mechanized transplanted hybrid rice. *Transactions of Chinese Society of Agricultural Engineering* **30**(1): 18–25.

Kalita R, Thakuria R K, Medhi B K and Saikia M. 2023. Production maximization of rainy season rice through effective use of water and solar radiation under modified system of rice intensification in Assam. *Indian Journal of Agronomy* **68**(1): 1–8.

Kaur J and Mahal S S. 2018. Growth and micro-environment of barley as influenced by sowing methods, crop residues and irrigation schedules. *Agricultural Research Journal* **55**(2): 258–64.

Kaur P, Sandhu S S, Singh H, Kaur N, Singh S and Kaur A. 2016. Climatic features and their variability in Punjab. Technical Bulletin. AICRP on Agrometeorology, pp. 78. Punjab Agricultural University, Ludhiana.

Pandey S R, Singh A K, Tiwari H and Tiwari A. 2021. Effect of age of seedlings and planting geometry on growth of rice (*Oryza sativa*). *Journal of Pharmacognosy and Phytochemistry* **10**(1): 185–88.

Pramanik K and Bera A K. 2013. Effect of seedling age and nitrogen fertilizer on growth, chlorophyll content, yield and economics of hybrid rice (*Oryza sativa* L.) *International Journal of Agronomy and Plant Production* **4**(2): 3489–99.

Sattar A, Kumar M and Vijayakumar P. 2017. Crop weather relation in *kharif* rice for north-west Alluvial Plain Zone of Bihar. *Journal of Agricultural, Food and Environmental Sciences* **2**(2): 8–18.

Vishwakarma A, Singh J K, Singh R K and Jat A L. 2016. Productivity and profitability of rice hybrids as influenced by date of transplanting and age of seedling under system of rice intensification. *Indian Journal of Agronomy* **61**(3): 315–20.