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Effect of Microclimate Modification on Growth and Yield of Basmati Rice under Punjab Conditions

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The field experiments were conducted at the Research Farm, Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana during *kharif* 2018. Pusa Basmati variety was transplanted on 5th July (D_1) and 15th July (D_2) under three spacing (25 cm x12 cm, 20 cm x 15 cm and 30 cm x 10 cm). The micrometeorological data on photosynthetically active radiation (PAR) was recorded at different phenological stages. The periodic biometric observations on leaf area index were recorded. Growing degree days (GDD) were calculated at different phenological stages. The results indicate that PAR interception and leaf area index was higher under wider spacing (30 cm x 10 cm) followed by closer spacing (20 cm x 15 cm and 25 cm x 12 cm). The leaf area index was higher under wider spacing (30 cm x 10 cm) followed by closer spacing (20 cm x 15 cm and 25 cm x 12 cm). Correlation coefficients were worked out between periodic number of tillers of rice and temperature (maximum and minimum) and sunshine hours/day. In both dates of transplanting, maximum temperature showed a significant negative correlation with tiller number in most of the cases. The sunshine hours in both dates of transplanting showed a positive and significant correlation under different treatments. The first date

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of transplanting reported higher grain yield (30.61 q/ha) as compared to second date of transplanting (27.20 q/ha). The higher grain yield (30.57 q/ha) was recorded in basmati rice transplanted under wider spacing (30 cm x 10 cm) in comparison to closer spacing of 20 cm x 15 cm (29.25 q/ha) and 25 cm x 12 cm (26.89 q/ ha). Hence, microclimate modification through dates of transplanting and spacing is cost effective measure for increasing basmati rice yield.

Keywords: Basmati rice; dates of transplanting; spacing; yield; rice varieties; grain yield; aromatic rice.

1. INTRODUCTION

"Rice (*Oryza sativa* L.) is a short-day plant and is mostly grown in regions of high temperature, high humidity, long sunshine hours and assured rainfall. In Punjab, it covers 31.45 lakh hectares area with total paddy production of 203.71 lakh tonnes during 2021-22. Like semi-dwarf rice varieties, basmati varieties require prolonged sunshine, high humidity and assured water supply. Basmati varieties with superior cooking and eating characteristics can be produced if the crop matures in relatively cooler temperature. The high temperature during grain filling period reduces the cooking and eating quality features" [1].

Optimum date of transplanting influences rice production in three ways- by ensuring favourable temperature and sunshine hours at vegetative growth, higher minimum temperature at cold sensitive stage and milder autumn temperature at grain filling stage for better quality of grain [2]. First fortnight of July is recommended date of transplanting under Punjab conditions (Anonymous 2021). "Late planting coinciding with the flowering and maturity in cooler days has been reported to enhance the grain quality but reduction in grain yield in aromatic rice" tested by Singh et al. [3] and Asghar et al. [4] Gangwar and Sharma (1997) obtained "maximum grain yield by transplanting on 1st to 16th July as compared to 31st July and 16th July but panicle weight was not affected upto 16th July". Mahajan et al [5] reported that "significantly more grains/panicle, higher test weight and grain yield were recorded when basmati rice was transplanted on 10th July". "A subsequent delay in transplanting i.e.20th and 30th July, resulted in reduced grain yield by 8.4 and 27.1 per cent respectively as compared to 10th July transplanting. Reduction in yield was observed with delayed transplanting in second fortnight of July" [6]. "The grain yield of basmati rice cultivars decreased with delay in transplanting from 20th July" [7]. "For late transplanting, poor pollen germination may be another reason for decline in grain yield. The optimum temperature required for pollen germination is 31-33^{o}C" [8]. "For late transplanting, low temperature at the pollen development stage may cause a sharp decline in fertile or filled spikelets particularly in the photoinsensitive cultivars" [9].

"Planting geometry of a crop affects the interception of solar radiation, crop canopy coverage, dry matter accumulation and crop growth rate. Optimum planting geometry ensures proper growth of aerial as well as underground plant parts by effective utilization of solar radiation, nutrients and water" [10]. "Transplanting two seedlings per hill in lines at 20 cm x 15 cm (33 hills/ sq m) during the optimum period in a well puddled field is recommended under Punjab conditions. In the late transplanted crop, the spacing may be reduced to 15 cm x 15 cm (44 hills/sq m) to minimize the reduction in yield" (Anonymous 2021). "Closer spacing hinders intercultural operations, increases competition among the plants for nutrients, air, light, which results in weaker plants, mutual shading thus favours more straw yield than grain yield. Optimum plant spacing ensures plant to grow properly with their aerial and underground parts by utilizing more solar radiation and nutrients" [11]. Similarly, the tillering capacity and spikelet formation per panicle are also influenced by the planting geometry, which effects yield of rice.

"So, the date of transplanting and plant spacing should be optimized by keeping in mind different aspects of crop management techniques" [12]. Keeping this in view, the present study was carried out to investigate the influence of different dates of transplanting and plant spacing on growth and yield of different rice varieties.

2. MATERIALS AND METHODS

The field experiments were conducted at the Research Farm, Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana during *kharif* 2018. Pusa Basmati variety was transplanted on 5th July (D_1) and 15th July (D_2) under three spacing (25 cm x12 cm, 20 cm x 15 cm and 30 cm x 10 cm). The experiment was laid out in Factorial Randomised Complete Block Design with four replications. Line Quantum Sensor was used to take diurnal cycles of photosynthetically active radiation (PAR) from 1000 hours to 1600 hours at maximum tillering stage, panicle initiation stage and grain filling stage of crop. Digital multivoltmeter was used to record output of line quantum sensor. The per cent PAR interception by the crop was calculated by using the following formula:

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

where,

PAR (I) – Photosynthetically active radiation incident above the canopy
PAR (T) – Photosynthetically active radiation transmitted to the ground
PAR (R) – Photosynthetically active radiation reflected from the canopy

Sun Scan Canopy Analyzer was used to measure green leaf area (cm^2) (at 15 days interval). The periodic number of tillers were counted for different dates of transplanting and plant spacing. Correlation coefficients were worked out between periodic number of tillers and maximum temperature, minimum temperature and sunshine hours. The yield and yield attributing characteristics were recorded at the time of harvesting. The data collected was statistically analyzed by using CPCS-1 software.

3. RESULTS AND DISCUSSION

3.1 Phenological Behaviour of Basmati Rice under Different Treatments

Crop phenology is used to estimate the most appropriate date and time of specific development process. In a particular growing environment, it is necessary to have information about exact duration of various phenological stages of crop and their impact on its yield [13]. It is the phasic development of crop with respect to the surrounding environment. The occurrence of phenological events during crop growth period can be estimated by computing accumulated growing degree days [14]. The rise in atmospheric temperature (heat stress) affects rice phenology, physiology, and yield components [15]. Increase in temperature by 4°C caused early maturity in rice by five and six days for wet and dry seasons, respectively [16]. The date of sowing also effects phenophases of a crop. Lalitha et al. [17] also reported that delay in sowing of rice crop decreases the duration of crop due to increased temperature. Priyadarshi et al. [13] reported that rice crop transplanted on 10th July experienced delayed maturity in comparison to 20th July, 30th July and 10th August in Orissa. Sharma et al. [18] also found that early transplanting caused delay in maturity. Sandhu et al. [19] found that more heat units were accumulated to attain physiological maturity in early transplanted rice (15th June) as compared to late transplanted crop (30th June) due to low temperature. Exposure to different temperature conditions had direct effect on the occurrence of different phenological stages.

The phenological stages of variety Pusa Basmati 1121 transplanted on 5th July and 15th July are presented in (Table 1). The variety Pusa Basmati 1121 when transplanted on 5th July took 16 days from transplanting to start tillering whereas it took 15 days when transplanted on 15th July due to high temperature. Lalitha et al. [17] reported that the tiller production stopped abruptly by 5th week after transplanting when mean temperature exceeded 26ºC and the duration of tillering increased to 7-8 weeks after planting. Gao et al. [20] also reported that tillering was more vigorous at high temperature than low temperature. Karuna [21] also reported that under high temperature conditions, tillering started earlier in late transplanted crop as compared to early transplanted crop. The maximum tillering occurred after 41 days after transplanting in 5th July transplanting while it occurred after 40 days after transplanting in 15th July transplanting. The panicle initiation occurred after 63 days after transplanting under 5th July transplanting while it took 62 days after transplanting under 15th July transplanting. Karuna [21] also reported similar results. The flowering occurred after 75 days after transplanting under 5th July transplanting whereas it occurred after 74 days after transplanting under 15th July transplanting. In some genotypes, the number of days from sowing to heading shortened by 4–5 days with temperature increase of 1°C Nakagawa et al. [22]. With increase in temperature, the rate of tillering increased whereas period of tillering got decreased. Thus, phenological stage was attained earlier [23]. The soft dough stage was attained in 84 days after transplanting and 83 days after transplanting under 5th July and 15th July transplanting respectively. Hard dough stage occurred 95 days after transplanting and 93 days after transplanting under 5th July and 15th July transplanting. It took 140 days to reach physiological maturity under 5th July transplanting in comparison to 139 days under 15th July transplanting. Prabhjyot-Kaur and Hundal [24] also found that the phenology of rice was advanced by as much as 1 to 15 days when the maximum temperature decreased by 0.25 to 1°C and minimum temperature increased concurrently from 1 to 3°C from normal, keeping the other climate variables constant. Also, when minimum temperature increased by 1 to 3°C and maximum temperature decreased by 0.25 to 1°C from normal, the heading stage was advanced by 1 to 4 days while physiological maturity was advanced by 2 to 8 days from normal.

3.2 Accumulated Growing Degree Days (AGDD) at Different Phenological Stages

Growing degree days (GDDs) is widely used temperature index to estimate crop development. The various phenophases of a crop are predicted with help of growing degree days (GDDs). The knowledge about different development stages and an estimate of harvest date can be best known through this index. The response of the plants to the thermal environment can be better expressed through the accumulated heat units in place of temperatures as ambient daily temperatures are very fluctuating. The simplest method of quantifying the thermal environment is growing degree days. This approach suggests that living organisms need a fixed amount of accumulated heat to fulfill their requirements for initiating phenological development. The concept of heat unit presumes a linear or logarithmic relationship between growth and temperature prophesied by Van’t Hoff’s Law. The Heat unit measure is departure of mean daily temperature from base temperature below which the internal biochemical activity ceases.

The results indicate that first date of transplanting (5th July) accumulated higher number of growing degree days (2178.9 ºC day) than 15th July transplanting i.e. (2066.1ºC day). Sandhu et al. [19] reported that cumulated heat units to attain physiological maturity were more in early transplanted rice (15th June) as compared to late transplanted crop (30th June) due to low temperature. Exposure to different temperature conditions had direct effect on the occurrence of different phenological stages. Karuna [21] also reported that higher number of heat units are required by the crop under early transplanting. Kaur et al. [25] also found that early transplanting (15th June) accumulated the highest number of degree days than late transplanting (30th June) at almost all the phenophases of rice.

3.3 Photosynthetically Active Radiation Interception

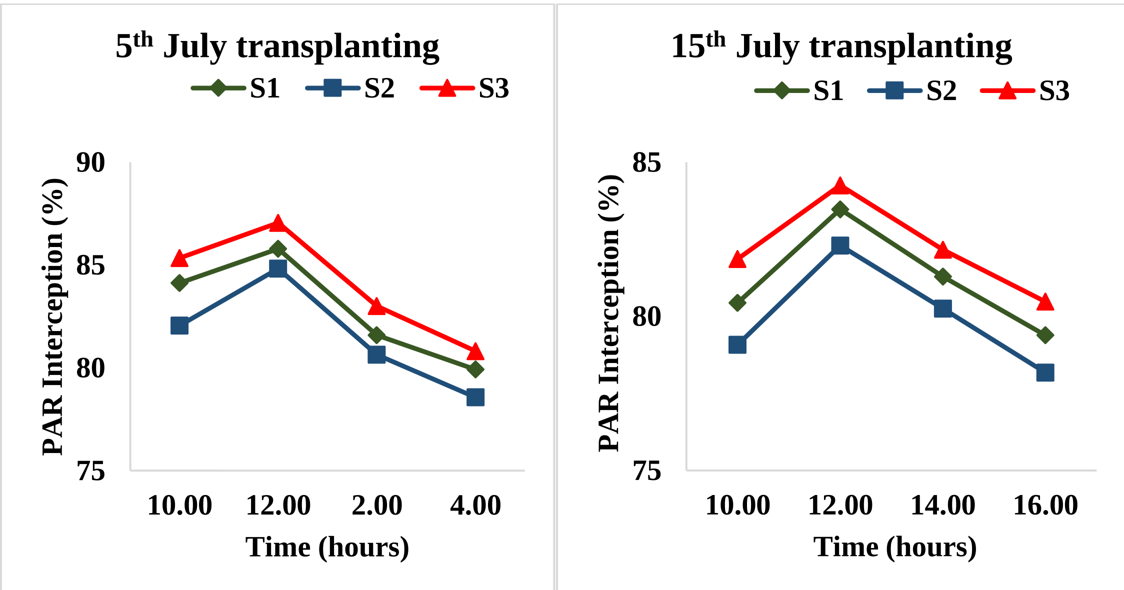
Photosynthetically Active Radiation (PAR) is the amount of light in the wavelength range of 0.4-0.7µ useful for photosynthesis. Biomass production largely depends on intercepted PAR. The quantum of biomass production and harvest index regulates rice yield [26]. The growth and yield of the plant largely depends on the radiation interception and efficiency of plant to use all resources and it is strongly influenced by microclimate of crop stand [27]. The PAR interception is influenced by canopy geometry and morphology such as leaf area, leaf angle and orientation [28].

Table 1. Phenological behaviour and accumulated growing degree days (˚C day) of variety Pusa Basmati 1121 transplanted on 5th July and 15th July

Phenological stages	5th July		15th July	
	Number of days taken	AGDD	Number of days taken	AGDD
Date of Transplanting	-	18.6	-	21.6
Tillering start	16	312	15	300.95
Maximum Tillering	41	843.5	40	812.25
Panicle Initiation	63	1294.7	62	1258.45
Flowering	75	1529.3	74	1454.95
Soft dough stage	84	1670.1	83	1606.55
Hard dough stage	95	1837.6	93	1754.05
Physiological maturity	110	2178.9	109	2066.1

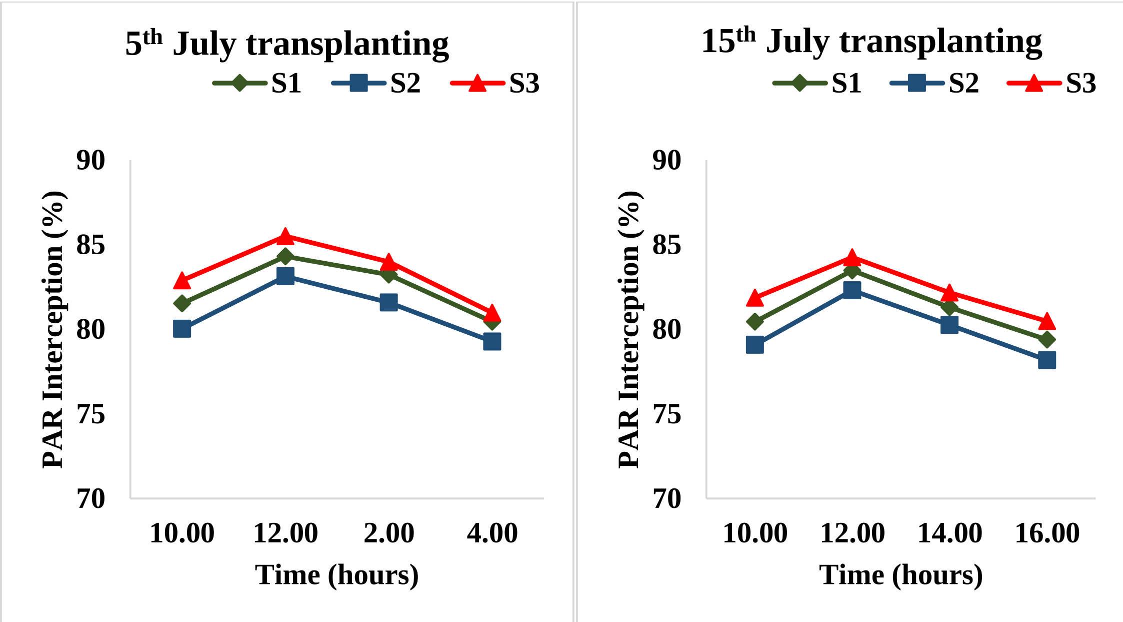
The PAR interception was recorded in Pusa Basmati 1121 at different phenological stages under different plant spacing transplanted on 5th July and 15th July (Fig. 1 to Fig. 3). PAR interception varied at different phenological stages i.e. tillering, panicle initiation and grain filling stage under different plant spacing in Pusa Basmati 1121. At maximum tillering stage, the PAR interception was higher in early transplanted crop (5th July) in comparison to late transplanted crop (15th July) (Fig. 1). The PAR interception was higher in 5th July transplanting (84.05 per cent) as compared to 15th July transplanting (82.92 per cent) under 30 cm x 10 cm spacing. The PAR interception remained higher for 20 cm x 15 cm (82.85 per cent) and 25 cm x 12 cm (81.52 per cent) in case of early transplanting. Under 30 cm x 10 cm spacing, PAR interception was higher in 5th July transplanting (88.13 per cent) as compared to 15th July transplanting (86.42%) at panicle initiation stage. Karuna [21] also reported that PAR interception was higher in wider spacing (30 cm x 10 cm) than closer spacing 20 cm x 15 cm and 25 cm x 12 cm spacing. At grain filling stage, PAR interception in 5th July transplanting was higher in early transplanted crop (79.85 per cent) as compared to late transplanted crop (78.72 per cent) under 30 cm x 10 cm spacing (Fig. 3). It was 78.77 per cent and 77.32 per cent for 20 cm x 15 cm and 25 cm x 12 cm spacing, respectively. The PAR interception (%) was higher during panicle initiation stage as compared to other stages because leaf area index at this stage was higher. The PAR interception was more in 20th June transplanted crop as compared to 30th June transplanted crop.

Kaur [25] also found that PAR interception was higher in early transplanted crop than late transplanted crop as early transplanted crop has a long vegetative growth period. Thus, plant is able to harvest more of solar energy. The geometry of crop stand is responsible for allowing radiations inside the crop for its absorption and its transmission to lower leaves. Due to dense stand and effective canopy, sunshine reaches the ground in patches only. Closer spacing increases competition among the plants for light which results in weaker plants. Optimum plant spacing ensures plant to grow properly with their aerial and underground parts by utilizing more solar radiation and nutrients. Mutual shading thus favours more straw yield than grain yield. Thus, more light penetration in wider spacing occurs as compared to closer spacing [29]. Due to wider spacing and proper light penetration, the PAR interception was higher in 30 cm x 10 cm spacing in all phenological stages Sharma et al. [18]. Dhaliwal et al. [30] also reported the similar results.



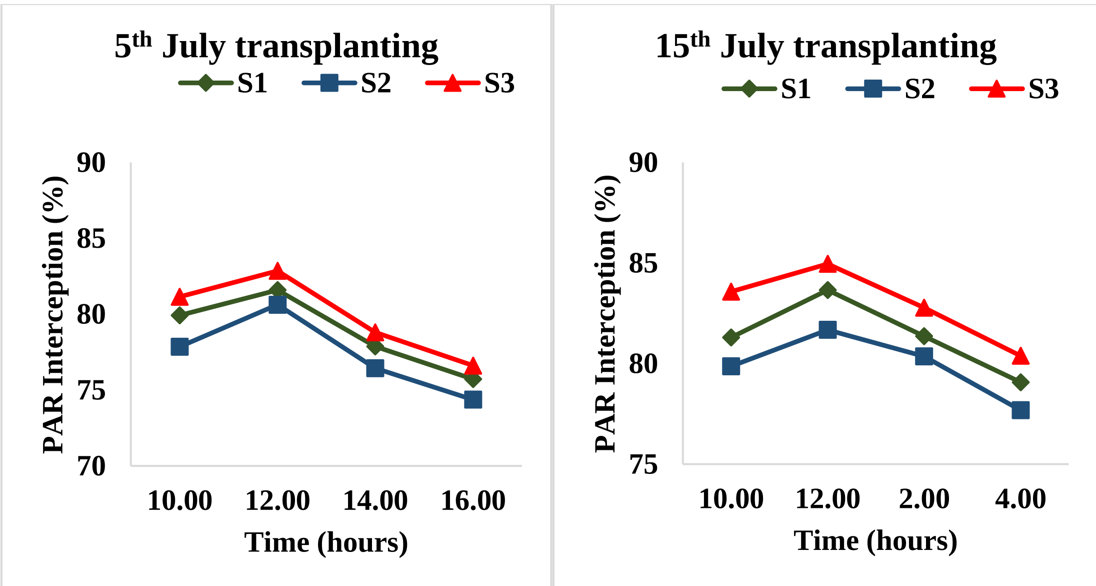
S_1 = 20 cm x 15 cm, S_2 = 25 cm x 12 cm, S_3 = 30 cm x 10 cm

Fig. 1. PAR interception at maximum tillering under different spacing in variety Pusa Basmati 1121 transplanted on 5th July and 15th July



S_1 = 20 cm × 15 cm, S_2 = 25 cm × 12 cm, S_3 = 30 cm × 10 cm

Fig. 2. PAR interception at panicle initiation under different spacing in variety Pusa Basmati 1121 transplanted on 5th July and 15th July



S_1 = 20 cm × 15 cm, S_2 = 25 cm × 12 cm, S_3 = 30 cm × 10 cm

Fig. 3. PAR interception at grain filling stage under different spacing in variety Pusa Basmati 1121 transplanted on 5th July and 15th July

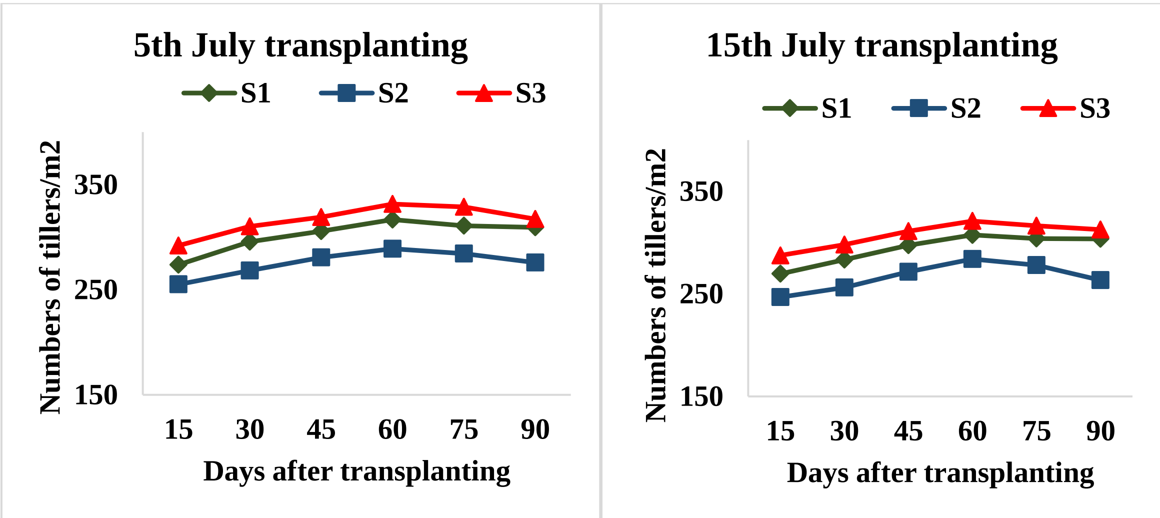
3.4 Leaf Area Index

The predominant factor that affects radiation interception and process of photosynthesis is leaf area index (LAI). It is a solid index to boost the source-sink relationship. More the leaf area index, more is PAR interception and more is the rate of photosynthesis. Optimum leaf area development ensures maximum dry matter production. The persistence of high LAI over greater part of vegetative phase gives higher productivity of crop. With an increase in crop age, LAI increases and later it decreases at maturity due to withering of leaves. In variety

Pusa Basmati 1121, the highest LAI (4.56) was recorded under 5th July transplanting in comparison to 15th July transplanting (4.42) at 60 days after transplanting (Table 2). Significant difference between LAI under both the transplanting dates was found except at 45 days after transplanting. Among the spacing, higher LAI was obtained under 30 cm x 10 cm (4.70) spacing followed by 20 cm x 15 cm spacing (4.61) and 25 cm x 12 cm spacing (4.17) after 60 days after transplanting.

3.5 Periodic Number of Tillers

Tillering is an important agronomic trait that determines shoot architecture and grain production in rice crop. The number of tillers have direct correlation with grain yield of rice. The tiller production and yield of rice are greatly influenced by plant spacing. Thus, the final yield is the function of number of tillers per unit area. The number of tillers per meter square showed significant response to different transplanting dates [31]. This was mainly due to low temperature at pollen development stage which may reduce the number of tillers (Gill et al 2006). In Pusa Basmati 1121, maximum number of tillers were found in 5th July transplanting 30 cm x 10 cm spacing (332) followed by 20 cm x 15 cm (320) and 25 cm x 12 cm spacing (266). In 15th July transplanting, more number of tillers were recorded under 30 cm x 10 cm spacing (321) as compared to 20 cm x 15 cm (308) and 25 cm x 12 cm spacing (254). Bhowmik et al. [32] reported that under optimum plant density, proper growth of plants occur. Proper plant spacing within row influence the tiller production and solar radiation interception. Due to favourable soil & air temperatures and more radiation interception, the periodic



S_1 = 20 cm × 15 cm, S_2 = 25 cm × 12 cm, S_3 = 30 cm × 10 cm

Fig. 4. Periodic number of tillers under different transplanting dates and spacing in variety Pusa Basmati 1121 transplanted on 5th July and 15th July

Table 2. Leaf area index of Pusa Basmati 1121 under different transplanting dates and spacing

Treatments	Days after transplanting					
	15	30	45	60	75	90
Date of transplanting						
5th July	2.22	3.08	3.65	4.56	4.14	3.55
15th July	2.10	2.90	3.56	4.42	3.90	3.41
CD(p=0.05)	0.06	0.15	NS	0.12	0.08	0.10
Spacing						
25 cm x 12 cm	1.97	2.71	3.32	4.17	3.73	3.17
20 cm x 15 cm	2.20	3.05	3.69	4.61	4.12	3.59
30 cm x 10cm	2.31	3.18	3.81	4.70	4.21	3.68
CD(p=0.05)	0.07	0.18	0.15	0.15	0.10	0.12

number of tillers was more in wider spacing [33]. Sultana et al. [29] found that the row to row spacing significantly influences the yield contributing characters of rice. Number of sterile spikelet per hill and number of effective tillers per hill were significantly influenced by row to row spacing, grain yield was highest with 25 cm row spacing because of the improved number of effective tillers per hill (13.11). However, straw yield (5.56 t per ha) and biological yield (9.89 t per ha) were obtained significantly higher in 20 cm row spacing. Mondal et al. [34] studied under subtropical to evaluate the effect of spacing on assimilate availability, yield attributes and yield of modern rice varieties. Four modern rice cultivars BINA dhan5, BINA dhan 6, Iratom and BRRI dhan 29 were sown with three spacing (20 × 20), (20 ×15) and (20 × 10) cm^2. The results showed that wider spacing (20 × 20) cm^2 had stupendous performance in all morpho-physiological and yield attributing characters, which resulted in highest grain yield (8.53 t ha^{-1}). In another experiment carried out by Sultana et al. [29] at Bangladesh Agricultural University, Mymensingh study the effect of row and hill spacing on the yield of rice cultivar BRRI dhan 45 under aerobic system of cultivation in boro rice revealed that the crop sowing at spacing 25 × 15 cm^2 obtained the maximum grain yield (5.69 t per ha) over the grain yield (2.11 t per ha) obtained with spacing 20 × 25 cm^2. Vishwakarma et al 2016 conducted an experiment with three dates of transplanting (27 June, 7 July and 17 July) and revealed that higher growth parameters such as plant height (104.2 cm), tillers hill-1 (20.4), leaf area index (5.16) and dry matter accumulation hill-1 (31.2 g) and yield attributes such as effective tillers m-2 (248.2), panicle length (30.5 cm), grains panicle-1 (176), weight panicle-1 (5.08 g) and test weight (23.11 g), grain and straw yield (6.67 and 8.71 tonnes ha-1, respectively) and harvest index (43.17) were observed under 27 June transplanting as compared to rest of the two dates of planting.

3.6 Relationship of Periodic Number of Tillers with Temperature and Sunshine Hours

Temperature affects rate of tiller production and growth of rice crop. Under high temperature conditions, more tiller buds are produced. Although, tillering rate is boosted but tillering period is decreased which leads to production of less number of tillers (Sreenivasan 1985). Thus, reduction in yield was observed under higher maximum and minimum temperatures conditions during tillering period [23]. Under high temperature conditions, the maximum tillering stage was early as compared to normal temperature conditions due to production of more number of tillers per square meter during early development period. Panicle differentiation happens by and large at temperatures somewhere in the range of minimum temperature (18°C) and maximum temperature (30°C) [35]. The periodic number of tillers were correlated with maximum temperature and minimum temperatures during *kharif* 2018 (Table 3). In both dates of transplanting, maximum temperature showed a significant negative correlation with tiller number in most of the cases. Yao et al. [36] also found that photosynthetic production capability of rice is affected by higher temperature due to decrease in leaf photosynthetic velocity which ultimately affects grain yield. The fluctuation in maximum temperature and minimum temperature during the rice growing season leads to such results. Biswas [33] also reported that temperature influenced the number of tillers which ultimately determines the yield by influencing the number of panicles per unit area.

Solar radiation intercepted in rice canopy plays a major role in determining biomass and grain yield. Solar radiation requirements of a rice crop are different at different phenophases. It influences crop growth and productivity [3] Reduction in light intensity and duration causes reduction in photosynthesis. The shading of plants cause delay in tillering and reduced tillering rate and total dry matter production Jagdish and Muthurajan [37]. The sunshine hours play a major role during the vegetative phase of rice crop. The periodic number of tillers were correlated with sunshine hours. The results indicate that sunshine hours in both dates of transplanting showed a positive and significant correlation under different treatments (Table 3). Physical capacity of rice is decided by tiller number per unit area. Since temperature and sunshine hours are correlated, they have profound effect on tiller rate [18]. During vegetative stage low sunshine hours has little influence on grain yield as compared to reproductive stage. The vegetative lag phase is affected by less light stress and thus, tiller mortality occurs and panicles m^{-2} formed are less [38] Kaur [25] also found that PAR interception was higher in first date of transplanting as compared to second date of transplanting due to longer vegetative growth period. Thus, plant is able to utilise more of solar energy.

Table 3. Correlation coefficients (r) between periodic number of tillers of rice and temperature and sunshine hours

Treatments	Dates of transplanting					
Spacing	5th July			15th July		
	Tmax	Tmin	Ssh	Tmax	Tmin	Ssh
25 cm x 12 cm (S_1)	-0.41	-0.25	0.83**	-0.44	-0.48*	0.80**
20 cm x 15 cm (S_2)	-0.14	0.12	0.58*	0.05	0.15	0.23
30 cm x 10 cm (S_3)	-0.26	-0.12	0.76**	-0.35	-0.38	0.71**

*Significant at the 0.05 level, **Significant at the 0.01 level*

3.7 Effect of Plant Spacing on Yield and Yield Contributing Characteristics

Optimum row spacing is one of the most important factors determining the yield of rice crop. The growth, development and yield of rice crop are significantly influenced by row and plant spacing under field conditions. Closer spacing hinders intercultural operations, increases competition among the plants for nutrients, air, light, which results in weaker plants, mutual shading thus favours more straw yield than grain yield. Optimum plant spacing ensures plant to grow properly with their aerial and underground parts by utilizing more solar radiation and nutrients [29].

Different plant spacing showed significant differences among number of effective tillers, 1000-grain weight, plant height, panicle length and number of grains per panicle. All these yield contributing characteristics were higher in 30 cm x 10 cm spacing as compared to that of 20 cm x 15 cm spacing and 25 cm x 12 cm spacing. During *kharif* 2018, wider spacing (30 cm x 10 cm) recorded higher number of effective tillers per plant (15.24) as compared to closer spacing of 20 cm x 15 cm (13.82) and 25 cm x 12 cm (12.63) as presented in Table 4. Under wider spacing (30 cm x10 cm), panicle length was found to be higher (22.68 cm) than that of other two spacing viz. 20 cm x 15 cm (22.06 cm) and 25 cm x 12 cm (21.41 cm). The test weight among the three spacing, 30 cm x 10 cm spacing (30.34 g) and 20 cm x 15 cm spacing (29.18 g) and 25 cm x 12 cm spacing (228.84 g) were statistically differed from each other. The wider spacing (30 cm x 10 cm) recorded higher grain yield (30.57 q/ha) in comparison to closer spacing of 20 cm x 10 cm spacing (29.25 q/ha) and 25 cm x 12 cm spacing (26.89 q/ha). The wider spacing (30 cm x 10 cm) recorded higher biological yield (92.05 q/ha) followed by 20 cm x 15 cm spacing (88.39 q/ha) and 25 cm x 12 cm spacing (83.66 q/ha) and were statistically different from each other. This was mainly because higher PAR interception was observed under wider spacing as compared to closer spacing which led to better photosynthetic activity and higher yield contributing characterstics which led to higher biological, straw and grain yield under wider spacing as compared to closer spacing [18]. Closer spacing hinders intercultural operations, increases competition among the plants for nutrients, air, light, which results in weaker plants, mutual shading thus favours more straw yield than grain yield. Optimum plant spacing ensures plant to grow properly with their aerial and underground parts by utilizing more solar radiation and nutrients [29]. These results are supported by Oteng et al. [39]. Hasan et al. [40] also reported that wider spacing produced better yield due to proper availability of nutrients. But on other hand in closer spacing the nutrient competition is there in between plants. Among the spacing, the highest seed yield was recorded by 40 x 40 cm2 while it was at par between 20 x 20 cm2 and 30 x 30 cm2. The increase in seed yield under 40 x 40 cm2 might be due to better root development and more sunlight interception which might have led to more nutrient uptake to the source and ultimately to greater grain yield [41]. Most of the traits were found superior in 25x25 cm and 20x20 cm spacing which suppose Bara variety performed better in wider than narrower spacing. Comparing the results of the two planting distances (25x25 cm and 20x20 cm), it can be seen that spacing of 25x25 cm performed the best for most of the agro-morphological characters evaluated [42] Durga et al (2015) concluded that 16 days old seedlings planted at 20x20 cm, 12 days / 20x20 cm (56.2 q ha^{-1}) and 14 days / 20x20 cm (53.4 q ha^{-1}), 12 days / 25x25 cm (52.2 qha^{-1}) and 12 days / 30x30 cm (51.2 q ha^{-1}) were found superior for grain yield and were significantly different from the rest of the treatments. Further, 12 days old seedlings planted at 25x25 cm recorded 100% germination with longer seedlings and high seedling vigour index. Whereas Singh et al. 2013 reported that wider row

Table 4. Yield and yield contributing characteristics of basmati rice under different transplanting dates and spacing during *kharif* 2018

Treatments	Plant height (cm)	No. of effective tillers / plant	Panicle length (cm)	No. of grains per panicle	1000-grain weight (gm)	Biological yield (q/ha)	Straw yield (q/ha)	Grain yield (q/ha)
Dates of transplanting								
5th July	87.71	14.34	22.33	51.60	29.59	120.47	89.86	30.61
15th July	85.15	13.46	21.77	49.28	29.32	113.42	86.21	27.20
CD (P=0.05)	2.13	NS	0.43	2.31	NS	2.29	1.83	1.49
Spacing								
25 cm x 12 cm	83.36	12.63	21.41	47.62	28.84	110.56	83.66	26.89
20 cm x 15 cm	86.82	13.82	22.06	50.34	29.18	117.64	88.39	29.25
30 cm x 10 cm	89.13	15.24	22.68	53.38	30.34	122.63	92.05	30.57
CD (P=0.05)	2.61	1.35	0.53	2.83	0.87	2.81	2.24	1.82

spacing of 30 cm × 30 cm significantly favoured higher values of yield attributes, grain yield, economics, nutrient uptake, and soil health due to profuse root growth of rice.

3.8 Effect of Dates of Transplanting on Yield and Yield Contributing Characteristics

The first date of transplanting (5th July) had higher number of effective tillers than second date of transplanting (15th July). The crop transplanted on 5th July had higher (14.34) number of effective tillers per plant followed by 15th July transplanted crop (13.46). The number of effective tillers reduced in case of 2nd date of transplanting. Panicle length was better in 5th July transplanting (22.23 cm) followed by 15th July transplanting i.e. 21.77 cm. Number of grains per panicle and 1000-grain weight were also higher under 5th July transplanted crop (51.60) as compared to 15th July transplanted crop (49.28), respectively. The 1000-grain weight in 5th July transplanted crop was 29.59 g followed by 29.32 g in 15th July transplanted crop, respectively. In 5th July transplanting, all the yield contributing characters were higher resulting in higher grain yield (30.61q/ha) as compared to 15th July transplanting (27.20 q/ha) (Table 4). The biological yield was also recorded higher in 5th July transplanting (120.47 q//ha) which was statistically different from 15th July transplanting (113.42 q/ha). Mahajan et al. [43] reported that significantly more grains/panicle, higher test weight and grain yield were recorded when basmati rice was transplanted on 10th July. [44,45]. A subsequent delay in transplanting i.e.20th and 30th July, resulted in reduced grain yield by 8.4 and 27.1 per cent respectively as compared to 10th July transplanting. Akram et al. [7] reported that the grain yield of basmati rice cultivars decreased with delay in transplanting from 20th July. For late transplanting, poor pollen germination may be another reason for decline in grain yield. The optimum temperature required for pollen germination is 31-33°C [8]. For late transplanting, low temperature at the pollen development stage may cause a sharp decline in fertile or filled spikelets particularly in the photoinsensitive cultivars [9].

4. CONCLUSIONS

The first date of transplanting reported higher basmati rice grain yield as compared to second date of transplanting. The crop transplanted under wider spacing (30 cm x 10 cm) recorded higher yield and yield contributing characters as compared to closer spacing (25 cm x 12 cm and 20 cm x 10 cm) due to higher PAR interception and less competition for nutrients, light etc in wider spacing. Optimum plant spacing ensures plant to grow properly with their aerial and underground parts by utilizing more solar radiation and nutrients. Hence, microclimate modification through dates of transplanting and spacing is cost effective measure for increasing basmati rice yield. Additionally, beyond the immediate implications for yield enhancement, optimizing transplanting dates and spacing configurations can contribute to overall crop health and resilience, as well as resource use efficiency. These findings thus provide valuable insights for agricultural practitioners and policymakers seeking sustainable strategies to increase basmati rice production in a changing climate and resource-constrained environment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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