MAUSAM, **72**, 2 (April 2021), 425-434

633.18 : 631.53.04

Growth and yield of basmati rice under different crop establishment methods and sowing environment

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(*Received 6 July 2020, Accepted 28 September 2020*)

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सार – खरीफ ऋतु 2018 में कृषि-मौसम विज्ञान अनुभाग, शस्य प्रभाग, शेर-ए-कश्मीर यूनिवर्सिटी ऑफ एग्रीकल्चरल साइंसेज एंड टेक्नोलॉजी ऑफ जम्मू, छठ में एक फील्ड प्रयोग किया गया। तीन प्रतिकृतियों के साथ अनुप्रयोग को स्प्लिट स्प्लिट प्लॉट डिजाइन में किया गया। तीन स्थापना विधि के साथ मुख्य प्लॉट (डायरेक्ट सीड राइस, एसआरआई विधि और पारंपरिक), तीन बुवाई के सब प्लॉट (1 जून, 15 जून और 30 जून) और कल्टीवर (एसजेआर-129, बासमती-370 और पूसा-1121) को सब सब प्लॉट के रूप में लिया गया। पारंपरिक और डीएसआर की तुलना में बासमती की खेती की फेनोलॉजी एसआरआई से प्रभावित पाई गई। सभी कल्टीवर क्रमशः पारम्परिक (134 दिन) और एसआरआई (131 दिन) की तुलना में डीएसआर (119 दिन) विधि के तहत परिपक्व हुए (10-15 दिन पहले)। पौधे की ऊंचाई (177.69 cm), टिलर की संख्या (271.14 /m^2), शुष्क पदार्थ संचय (66.71 g/m^2), सीजीआर (11.94 g/m^2/ दिन), आरजीआर (85.04 g/g/m^2/ दिन), हेड रिकवरी (55.99%), अनाज की उपज (36.12 क्विंटल प्रति हेक्टेयर) एसआरआई प्रणाली में उच्च दर्ज की गई, लेकिन डीएसआर स्थापना के तहत खेती की कम लागत (22141 रुपये प्रति हेक्टेयर) और उच्च बी : सी (2.47) अनुपात दर्ज किया गया। बुवाई के माहौल के बीच दूसरी और तीसरी फसल की तुलना में पहली बोई गई फसल वृद्धि मापदंडों, पैदावार, गुणवत्ता और पोषक तत्वों के मामले में बेहतर पाई गई, जो कि अतिरिक्त संचित उच्च GDD (3191.2 °C दिन घंटे) PTU (4280.5 °C दिन घंटे) के कारण बढ़ी। हालांकि, खेती में, पूसा-1121 (38.11 क्विंटल प्रति हेक्टेयर) की उपज सांख्यिकीय रूप से एसजेआर-129 (37.96 क्विंटल प्रति हेक्टेयर) के बराबर थी, लेकिन बासमती-370 (25.57 क्विंटल प्रति हेक्टेयर) की खेती दोनों की तुलना में बेहतर थी। एक वर्ष के प्रयोग के आधार पर तैयार 1 जून को चावल की खेती, पूसा-1121 से यह निष्कर्ष निकाला गया है कि पारंपरिक और DSR के बाद जम्मू के सिंचित उपोष्णकटिबंधीय क्षेत्र के किसानों के लिए SRI फसल स्थापना विधि आर्थिक रूप से बेहतर है।

ABSTRACT. A field experiment was carried out at the Research farm of Agro-meteorological section, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha during the kharif season of 2018. The experiment was laid out in split-split plot design with three replications. The main plots with three establishment method (Direct seeded Rice, SRI method and Conventional), sub plots with three sowing environments (1st June, 15th June and 30th June) and cultivars (SJR-129, Basmati-370 and Pusa-1121) were taken as sub-sub plot. All the cultivars under investigation were grown as per the recommended package of practices except for the treatments under investigation. Phenology of basmati cultivar was found to be influenced by SRI in comparison to conventional and DSR. All the cultivar matured (10-15 days) earlier under DSR (119 days) method than conventional (134 days) and SRI (131 days), respectively. The plant height (177.69 cm), number of tillers (271.14/m^2), dry matter accumulation (66.71 g/m^2), CGR (11.94 g/m^2/day), RGR (85.04 g/g/m^2/day), head recovery (55.99 %), grain yield (36.12 q/ha) were recorded higher in SRI system however lower cost of cultivation (22141 Rs/ha) and higher B : C (2.47) ratio was recorded under DSR establishment. Among the sowing environment the first sown crop found to be superior in terms of growth parameters, yield, quality and nutrient uptake due to additionally accumulated higher GDD (3191.2 °C day hours)

PTU (4280.5 °C day hours) HTU (18871 °C day hours) and HUE (20 g/m^2°C/day hours) as compared to second and third sown crop. However among cultivar, the yield of Pusa-1121 (38.11 q/ha) was statistically at par with SJR-129 (37.96 q/ha) but quality of Basmati-370 (25.57 q/ha) was better than both the cultivars. On the basis of one year experiment it is concluded that rice cultivars, Pusa-1121 raised on 1st June with SRI crop establishment method is better economically for farmers in irrigated sub tropical area of Jammu followed by conventional and DSR.

Key words – Agro-meteorological indices, Sowing dates, Establishment methods, Basmati cultivars, Relative economics.

1. Introduction

Rice (*Oryza sativa* L.) is monocotyledonous angiosperm belongs to grass family Graminae and is self-pollinated crop. The rice crop is grown in India in an area of about 43.79 million hectare with a production and productivity of 112.91 million tonnes and 2.5 tonnes/ha respectively (Anonymous, 2018). In Jammu and Kashmir during 2016-17 rice was grown over an area of 283.44 thousand hectare with production 5725 thousand quintals and productivity 20.20 q/ha respectively (Anonymous, 2016a). Basmati rice is one of the most important and popular quality cereal grain crop of India. India accounts for over 70% of the world's basmati rice production. It is the major *kharif* crop of Jammu and Kashmir union territory and is grown on acreage of 62.25 thousand hectares with an annual production of 129.04 thousand metric tons (Anonymous, 2016b).

The present rate of rice production growth (0.36%) is far below the population growth rate of 1.63%. Therefore, the two pronged strategy of developing new technologies through more research investments to bring efficiency in production and implementing favourable government policies will help in increasing rice production and productivity in the country to meet the future demand (Anonymous, 2020).

Rice production is affected by various meteorological variables like rainfall, temperature and solar radiation etc. (Ji *et al*., 2007). During crop growth period, the occurrence of various phenological events can be estimated by computing accumulated growing degree days (Gouri *et al*., 2005). Various developmental stages as well as harvest date of crop can be estimated from the knowledge of accumulated GDD. Heat use efficiency (HUE), efficiency of heat utilization in terms of dry matter accumulation, depends on genetic factors, crop type and sowing time and has great practical application Rao *et al.* (1999).

Crop establishment have considerable impact on growth and canopy structure establishment (Saha and Bharti, 2010). In recent years, alternate crop establishment methods of rice include direct seeded rice (DSR) and system of rice intensification (SRI) (Kumar *et al*., 2018). Direct seeding is the process of establishing a rice crop from seeds sown directly in the field rather than by transplanting of seedling from the nursery. This method of sowing ultimately saves farm labour and decreases cost of cultivation of rice. Hugar *et al*. (2009) reported that system of rice intensification (SRI) method of cultivation of rice recorded significantly higher number of effective tillers/m^2 over conventional transplanting. The SRI is an evolving set of principles and practices aimed at increasing the productivity of irrigated rice by changing the management of plant, soil, water and nutrient.

Rice is normally sown at the end of May and transplanted during the 1st week of July. Transplanting is a traditional method which gives high and stable yield but at the same time it is a laborious and expensive job. The sowing time of the rice crop is such that the vegetative growth of rice occurs during a period of high solar radiation, cold sensitive stage should occurs when the minimum night temperatures are warm and grain filling stage occurs during milder autumn temperatures, for good grain quality (Farrell *et al*., 2003). Sowing date also has a direct impact on the rate of establishment of rice seedling (Tashiro *et al*., 1999).

Basmati-370 and Pusa-1121 occupy maximum area under basmati cultivars in Jammu and Kashmir region. SJR-129 has been recently developed rice cultivar recommended for cultivation in the Jammu region.

Weather is playing a considerable role not only on growth and yield of rice but also affecting its quality. Jarrod *et al*. (2010) reported that increase in temperature (1-4 °C) and decreased solar radiation has detrimental impact on growth parameters ultimately resulting in yield reduction. The day and night temperature differences during crop season especially during reproductive phase under sub-tropical condition affect quality and quantity of basmati rice. The temperature is a key factor determining growth since development of plants and all physical and physiological processes are temperature dependent. The heat unit system assumes a direct relationship between growth of plant and temperature (Parthasarathi *et al*., 2013). The effect of weather parameters (Maximum & Minimum temperature, rainfall & its distribution etc.) highly influence yield of basmati rice under subtropical conditions.

Keeping the above facts the present investigation was conducted to know the effect of crop establishment methods and sowing environment on growth and yield of basmati cultivars.

2. Materials and method

The field experiment was conducted during *Kharif*-2018 at the Research Farm, Agromet Section, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Main campus Chatha, Jammu (32°39′33″ N, 74°48′45″ E, 293 meters above mean sea level). The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction (7.13), low in organic carbon (0.38%), available nitrogen (212.13 kg/ha) and medium in phosphorus (14.12 kg/ha) and potassium (134.54 kg/ha). The experiment was laid out in Split-Split Plot design with three replications. The main plot consists of three establishment methods (Direct seeded rice (DSR), SRI method and Conventional Transplanting), sub-plot consisted of three sowing dates (1st June, 15th June and 30th June) and sub-sub plot consisted of three cultivars (SJR-129, Basmati-370 and Pusa-1121).

Sowing was performed at a 3 cm depth by opening furrows in lines manually with the help of liner at a specified row to row distance of 20 cm under DSR and seeds sown by *Kera* method. Transplanting of 13 and 25 days old seedlings in the experimental field was done manually in SRI and conventional method at 25 × 25 cm and 20 × 10 cm spacing, respectively. The other agronomic practices were followed as per the recommended package of practices for this region. The data on number of days taken to attain phenophases (*viz*; emergence/establishment, tillering, panicle initiation, flowering, milking and physiological maturity) as influenced by different treatments adopted was recorded. Similarly, to understand the influence of different weather parameters on the variation in days in attainment of phenophases different agro-meteorological indices (*viz*. GDD, PTU, HTU and HUE). Growth parameters (plant height (cm), dry matter accumulation (g/m^2), LAI) and Yield parameters (such as grain yield (q/ha), straw yield (q/ha) and harvest index) were recorded and all these observations were statistically analyzed adopting a standard analysis of variance and their CD were worked out at 5 per cent probability level.

3. Results and discussion

3.1. I*nfluence of crop establishment methods, sowing dates and cultivars on different phenophases of Rice*

3.1.1. *Days to emergence*

The data given in Table 1 revealed that all three rice establishment methods took numerically different number of days for emergence/establishment of plant and recorded 4.7 days for establish with conventional method followed by SRI (4.5 days) and direct seeded sowing (4.5 days), respectively. Among different sowing dates, *i.e.*, (1st June, 15th June and 30th June), the 30th June took significantly more days (4.7 days) to emergence/establish than 1st June (4.4) which was statistically at par with 15th June (4.6). Regarding different cultivars 5.18 days to emergence were recorded with Bamati-370. Which was statistically significant than Pusa-1121 (4.3) and SJR-129 (4.2), respectively.

3.1.2. *Days to tillering*

The data given in Table 1 revealed that all three rice establishment methods took statistically different number of days to tillering and recorded 47.9 days for tillering with conventional method of establishment followed by SRI (43.9 days) and direct seeded sowing (41.1 days), respectively. Among different rice sowing environment, maximum number of days to tillering (44.3 days) were recorded with 1st June of sowing which was statistically at par with 15th June and 30th June sowing environment, respectively. Among rice cultivars, maximum number of days (47.3 days) to tillering was taken for Basmati-370 which was statistically significant from SJR-129 (40.4 days) and at par with Pusa-1121 (45.2 days).

3.1.3. *Days to panicle initiation*

All three rice establishment methods took statistically different number of days to panicle initiation and recorded 60.0 days for panicle initiation with conventional method of establishment followed by SRI and direct seeded sowing which were in tune of 55.8 and 54.7 days, respectively. All three rice sowing dates took statistically different number of days to panicle initiation and recorded 57.5 days for panicle initiation with 1st June of sowing followed by 15th June and 30th June which were in tune of 56.9 and 56.2 days, respectively. Among different cultivars, Basamti-370 was taken higher number of days (60.2 days) to panicle initiation which was statistically significant from Pusa-1121 and SJR-129, respectively.

3.1.4. *Days to flowering*

All three rice establishment methods took different number of days to flowering with 104.5 days for conventional method of establishment followed by SRI (101.8 days) and DSR (91.0 days) respectively. However, the number of days required to flowering with conventional and SRI method was found statistically at par. Among sowing dates, the maximum number of days to flowering (101.4 days) was recorded with 1st June sown

TABLE 1

Effect of crop establishment methods and sowing environment on different phenophases (days) of rice cultivars

Treatments	Phenophases					
	Day to emergence/Establishment	Tillering	Panicle initiation	Flowering	Milking	Physiological maturity
Crop establishment methods						
S_1 : Direct Seeded Sowing	4.46	41.10	54.74	90.57	101.82	119.02
S_2 : SRI	4.52	43.87	55.81	101.76	115.26	130.37
S_3 : Conventional	4.68	47.91	59.99	104.51	122.34	133.74
SEm (±)	0.06	1.47	1.81	1.90	1.91	1.12
CD (5%)	0.25	5.76	4.63	7.46	7.51	4.39
Sowing environment						
E_1 : 1st June	4.41	44.25	57.47	101.35	114.74	129.15
E_2 : 15th June	4.58	44.29	56.87	100.24	112.91	127.74
E_3 : 30th June	4.67	44.34	56.21	95.25	111.77	126.24
SEm (±)	0.05	0.59	0.79	2.15	0.86	1.42
CD (5%)	0.16	1.82	2.44	6.63	2.64	4.39
Cultivars						
V_1 : SJR-129	4.17	40.36	53.26	89.44	100.48	114.63
V_2 : Basmati-370	5.18	47.28	60.20	107.53	122.19	138.47
V_3 : Pusa-1121	4.31	45.24	57.09	99.87	116.76	130.03
SEm (±)	0.08	0.83	0.73	2.20	1.12	1.21
CD (5%)	0.22	2.37	2.10	6.32	3.20	3.48

Interactions : Non-Significant

crop which was at par with 15th June (100.2 days) and significantly differed with 30th June (95.3 days). Among rice cultivars, Basmati-370 required 107.5 days to maturity as compared to Pusa-1121 (99.9 days) and SJR-129 (89.4 days), respectively, which was significantly differed from Basmati-370 (Table 1).

3.1.5. *Days to milking*

Among the different establishment methods, the maximum numbers of days (122.3) to milking were recorded with conventional method of establishment with DSR (101.8 days) and at par with SRI (115.3 days). Among the sowing date, maximum days (114.8 days) to milking was recorded with 1st June of sowing followed by 15th June and 30th June which were in tune of 112.9 and 111.8 days, respectively. However, among rice cultivars, Basmati-370 required a higher number of days (122.2 days) to milking which was significantly higher from Pusa-1121 (116.8 days) and SJR-129 (100.5 days), respectively (Table 1).

3.1.6. *Days to physiological maturity*

Among rice establishment methods took a statistically different number of days to physiological maturity and recorded 133.74 days for physiological maturity with conventional method of establishment followed by SRI and direct seed sowing which were in tune of 130.37 and 119.02 days, respectively. Among rice sowing dates, maximum number of days to physiological maturity (129.15 days) were noticed with 1st June of sowing which was found statistically non-significant form the sowing environment of 15th June (127.74 days) and 30th (June 126.24 days), respectively. Similarly, maximum number of days (138.47 days) required to attend physiological maturity of Basmati-370, which was significant higher from Pusa-1129 (116.76 days) while minimum days of 114.63 to attain physiological maturity were observed in SJR-129 (Table 1).

Results revealed that among crop establishment methods DSR attain all the growth stages earlier as

TABLE 2

Effect of crop establishment methods and sowing environment on morphological characters of rice cultivars

Treatment	Morphological characters		
	Plant height (cm)	Dry matter accumulation (g/m^2)	Leaf Area Index (LAI)
Crop establishment Methods			
S_1 : Direct Seeded Sowing	155.51	563.14	1.09
S_2 : SRI	177.69	667.19	1.24
S_3 : Conventional	170.72	616.75	1.17
SEm (±)	2.66	7.13	0.01
CD (5%)	6.61	24.42	0.06
Sowing environment			
E_1 : 1st June	172.40	618.83	1.22
E_2 :15th June	166.82	616.63	1.17
E_3 : 30th June	157.70	611.61	1.11
SEm (±)	0.42	0.52	0.01
CD (5%)	1.30	1.62	0.03
Cultivars			
V_1 : SJR-129	149.87	605.05	1.14
V_2 : Basmati-370	189.41	624.97	1.20
V_3: Pusa-1121	164.63	617.06	1.16
SEm (±)	3.87	1.18	0.01
CD (5%)	10.49	3.39	0.02

compared to other methods resulting in reduced crop duration followed by SRI and conventional respectively. This might be due to early establishment in the main field without any nursery. Similar findings were found by Kumar *et al*. (2016) and Ali *et al*. (2013). Among different sowing dates 1st June sown crop attained physiological maturity in less number of days followed by 15th and 30th day sown crop. Similar, findings were reported with Wani *et al*. (2013) and Kumar *et al*. (2017). Among different cultivars, Basmati-370 took more number of days at all stages of growth followed by Pusa-1121 and SJR-129. This might be a genetic trait of cultivars and might be a probable reason for best grain quality. This data is in conformity with Khalifa (2012) and Sharif *et al*. (2017).

3.2. *Influence of crop establishment methods, sowing dates and cultivars on morphological characters of rice*

The morphological characters of rice presented in (Table 2) were significantly influenced by crop establishment method and in terms of plant height, dry matter accumulation and LAI maximum values were recorded with system of rice intensification. It might be due to facilitation of good transplanting, better nutrient availability, ensures better seedling establishment kills weeds and helps plants to grow vigorously. However, conventional methods recorded the maximum plant height might be due to increased competition for light apart from having better conditions for establishment. These results are in conformity with Chen *et al*. (2013) and Kumar and Kumar (2018).

Regarding sowing environment results showed that 1st June sown crop performed better and recorded higher vegetative growth over other dates of sowing indicating the role of time of planting in paddy crop due to variation in the duration, photo-sensitiveness, thermo-sensitiveness and vegetative lag period of the cultivar. Similar findings were found by Patra *et al*. (2015) and Naik *et al*. (2015).

Results on morphological characters showed that the Basmati-370 resulted in significantly higher plant height (cm), dry matter accumulation, leaf area index at all the growth intervals till physiological maturity of crop. Such significant variation among the different cultivars might be owing to differences in their parental origin which caused variation in their genetically inheritance for such traits. These findings corroborate with Vange *et al*. (2017) and Grace *et al*. (2018).

TABLE 3

Accumulated thermal time (ΣGDD) during various phenophases of basmati cultivars as influence by establishment methods and sowing environment

Treatments	Growing degree days (°C days)					
	Days to emergence/ Establishment	Tillering	Panicle initiation	Flowering	Milking	Physiological maturity
Crop establishment Methods						
S_1 : Direct Seeded Sowing	97.5	1355.5	1745.2	2482.4	2676.3	2980.4
S_2 : SRI	97.5	1443.3	1785.2	2696.1	2914.9	3150.2
S_3 : Conventional	119.4	1620.2	1863.7	2731.7	3030.7	3191.2
Sowing environment						
E_1 : 1st June	109	1533.6	2186.6	2676.3	2902.9	3136.0
E_2 :15th June	103.4	1457.3	1804.4	2536.1	2728.2	2925.1
E_3 : 30th June	94.5	1251.5	1697.3	2193.3	2409.9	2582.2
Cultivars						
V_1 : SJR-129	97.5	1312.2	1726.4	2439.8	2657.5	2902.9
V_2 : Basmati-370	119.4	1598.2	1863.7	2782.1	3030.7	3253.8
V_3 : Pusa-1121	97.5	1533.6	1785.2	2657.5	2945.3	3150.2

3.3. *Influence of crop establishment methods, sowing dates and cultivars on agro-meteorological indices of rice*

The crop growth response is mainly influenced by the microclimate of crop canopy. The role of temperature, bright sunshine hours and day length on different basmati cultivars under different methods of establishment at different sowing dates to complete different phenophases during the crop growth period was observed using various agro-meteorological indices

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3.3.1. *Growing degree days (GDD)*

Among crop establishment methods, conventional method took maximum growing degree days at various phenophases for basmati followed by SRI and DSR, respectively. The accumulated GDD to reach physiological maturity during different establishment method ranges between 2980.4 and 3191.2 °C. Rice crop sown on 1st June consumed higher accumulated thermal time, *viz*., 3136 °C for attaining physiological maturity as compared to corresponding value in delayed sowing (15th and 30th June). Among cultivars, Basmati-370 expended more accumulated growing degree days during all the growth stages followed by Pusa-1121 and SJR-129. This indicates that GDD decreases with delay in date of sowing irrespective of method of establishment and basmati cultivars. These findings are in conformity with Abhilash, 2017.

3.3.2. *Helio Thermal Unit (HTU)*

The HTU accumulated by different basmati cultivars under different methods of establishment sown on different sowing dates are shown in Table 4. The accumulated helio-thermal unit was higher under conventional transplanting for basmati rice at all growth stages rather than SRI and DSR methods. Early sown rice crop took maximum helio-thermal unit as compared to delayed (15th and 30th) sown crop. Among the cultivars, Basmati-370 accumulated maximum helio-thermal units 19395 °C day hrs, followed by 18552 °C day hrs for Pusa-1121 and 16669 °C day hrs for SJR-129 respectively to attain the physiological maturity. From the above findings, it can be enumerated that with the delay in sowing the crop gets less exposed to brighter sunshine hour irrespective of establishment method and cultivar.

3.3.3. *Photo Thermal Unit (PTU)*

Accumulated PTU is presented in Table 5. Results showed that among the crop establishment methods, conventional method of transplanting accumulate maximum accumulated PTU followed by SRI and DSR, respectively. Among the sowing environment, 1st June sown rice had maximum accumulated PTU during all the growth stages. The minimum accumulated PTU were accumulated with 30th sown crop at all the growth stages. Among the cultivars, Basmati-370 recorded maximum accumulated PTU during all the growth stages over Puas-1121 and SJR-129.

TABLE 4

Accumulated helio-thermal unit during various phenophases of basmati cultivars as influenced by establishment methods and sowing environment

Treatments	Growing degree days (°C days)					
	Days to emergence/ Establishment	Tillering	Panicle initiation	Flowering	Milking	Physiological maturity
Crop establishment Methods						
S_1 : Direct Seeded Sowing	468.6	7382.4	9482.3	13932.4	15042.2	17186.6
S_2 : SRI	468.6	7774.8	9641.4	15182.7	16669.1	18552.1
S_3 : Conventional	584.3	8866.1	10143.6	15386.9	17561.8	18871.6
Sowing environment						
E_1 : 1st June	584.3	8481.6	9770.1	15042.2	16669.1	18439.5
E_2 :15th June	476.6	7507.6	8939.0	14328.7	15757.4	17407.3
E_3 : 30th June	470.7	6890.3	8386.7	13300.8	15084.3	16467.8
Cultivars						
V_1 : SJR-129	468.6	7360.3	9407.1	13680.3	15034.7	16669.1
V_2 : Basmati-370	594	8661.5	10143.6	15731.0	17561.8	19395.3
V_3 : Pusa-1121	468.6	8481.2	9641.4	15034.7	15731.0	18552.1

TABLE 5

Accumulated photo-thermal unit at various phenophases of basmati cultivars as influenced by establishment methods and sowing environment

Treatments	Accumulated photo-thermal units (°C day hrs)					
	Days to emergence/ Establishment	Tillering	Panicle initiation	Flowering	Milking	Physiological maturity
Crop establishment Methods						
S_1 : Direct Seeded Sowing	1327.4	19118.9	23717.3	34298.6	36724.2	40383.5
S_2 : SRI	1327.4	20349.5	25085.6	36968.1	37618.6	42342.9
S_3 : Conventional	1677.2	22809.3	26156.6	37404.8	40970.9	42805.3
Sowing environment						
E_1 : 1st June	2168.0	21605.7	25348.4	36724.2	37404.8	42181.1
E_2 :15th June	1741.7	20446.6	23688.2	34303.8	34616.6	38760.3
E_3 : 30th June	1327.4	17329.0	20478.3	29057.4	30052.0	33362.4
Cultivars						
V_1 : SJR-129	1327.4	18513.2	24277.2	33757.8	36492.6	39469.9
V_2 : Basmati-370	1677.2	22503.9	26156.6	38019.4	40970.9	43503.9
V_3 : Pusa-1121	1327.4	21605.7	25085.6	36492.6	39971.1	42342.9

3.4. *Rice yield attributes under different crop establishment methods and sowing dates*

The rice yield attributes under different treatments are presented in the Table 6. Results showed maximum grain yield was recorded in system of rice intensification followed by conventional transplanting. This might be attributed due to transplanting of young, single and widely spaced seedling which might have resulted in better availability of nutrients, light and space during growth

TABLE 6

Effect of crop establishment methods and sowing environment on grain attributes of rice cultivars

Treatments	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvest index (%)
Crop establishment methods				
S_1 : Direct Seeded Sowing	30.74	74.70	105.43	29.18
S_2 : SRI	36.12	69.36	105.47	34.24
S_3 : Conventional	34.73	65.24	99.97	34.74
SEm (±)	0.76	0.65	1.14	0.47
CD (5%)	2.99	2.56	4.49	1.83
Sowing environment				
E_1 : 1st June	36.04	74.06	110.10	32.73
E_2 :15th June	33.99	72.61	106.60	31.89
E_3 : 30th June	31.55	62.63	94.17	33.50
SEm (±)	0.54	0.61	0.93	0.36
CD (5%)	1.68	1.88	2.85	1.12
Cultivars				
V_1 : SJR-129	37.96	62.12	100.09	37.92
V_2 : Basmati-370	25.51	78.05	103.56	24.63
V_3 : Pusa-1121	38.11	69.12	107.23	35.54
SEm (±)	0.62	0.99	0.85	0.62
CD (5%)	1.78	2.83	2.43	1.77

stages resulting in establishment of ideal source to sink relationship. DSR recorded maximum straw yield contributing towards higher biological yield and least harvest index. This might be due to increased plant population per unit area surpassed the intensive tillers development from individual plant. Similar result was reported by Kumar *et al*. (2007) and Naresh *et al*. (2013).

The productivity parameters were found exactly in accordance with the physiological parameters under different sowing dates. Results showed that yield is significantly influenced by sowing environments. Grain yield, straw yield, biological yield was highest when the crop was sown on 1st June as compared to delayed sowing. The yield reductions might be due to reduction in vegetative growth period on account of delayed sowing. Similar findings were observed by Mukesh *et al*. (2013) and Acquaah *et al*. (2018).

Among different cultivars Pusa-1121 produced higher grain yield and lower straw yield while, reverse trend was observed in case of Basmati-370 in which higher straw yield and lower grain yield. Cultivar SJR-129 had less grain yield from Pusa-1121 and straw yield form Basmati-370 (Table 6) All these variations might be attributed to genetic makeup of cultivar and its adaptability to the surrounding environment in which it is grown (Khalifa, 2012; Gagandeep and Gandhi, 2015).

3.5. *Influence of crop establishment methods, sowing dates and cultivars on relative economics of Basmati rice*

Among the different methods of establishment, the gross returns from conventional method were maximum but due to lower cost of cultivation DSR observed to be more profitable with higher net returns and B : C ratio over other methods of cultivation.

Among the different sowing environments, even though cost of cultivation incurred during all the dates of sowing was same but gross returns, net returns and ultimately B : C ratio was higher with 1st June sown crop followed by 15th and 30th June sown crop.

Among the different varieties, variation of quality of grain attributed towards higher sale price of Basmati-370

which resulted in making this variety more profitable with higher net returns and B : C ratio over other varieties, respectively.

4. Conclusions

In rice tillering and physiological maturity stages were found weather sensitive with different weather parameters. The panicle initiation is positively significant correlated with minimum temperature, rainfall, morning and evening relative humidity, whereas the flowering stage is positive significant correlated with minimum temperature rainfall as well as evening relative humidity. Among the different crop establishment methods, DSR proved to be more suitable method for basmati rice than SRI and conventional in economical terms. However, SRI proved to be more suitable method for enhancing the grain yield and quality of grain was considered. The 1st June sown crop proved to be best sowing date for grain yield and monetary benefit than delay in sowing by fortnight interval due to higher heat use efficiency. The Basmati-370 found to be more suitable and profitable cultivar as compared to Pusa-1121 and SJR-129 with respect to different sowing methods and environments in terms of net return and benefit-cost ratio of basmati rice.

Acknowledgement

The authors would like to thank Division of Agronomy, SKUAST-J for their continuous encouragement and providing all the facilities to carry out this research work.

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The contents and views expressed in this research paper/article are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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