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Shivani Thakur
Subject Matter Specialist Agrometeorology, KVK, Mandi, Sundernagar, Himachal Pradesh, India

Ranbir Singh Rana
Department of Agronomy, CSKHPKV, Palampur, Palampur, Himachal Pradesh, India

Sandeep Manuja
Department of Agronomy, CSKHPKV, Palampur, Palampur, Himachal Pradesh, India

Karan Verma
Assistant Professor, Faculty of Agriculture, Guru Kashi University, Talwandi Sabo, Bathinda, Punjab, India

Corresponding Author:
Shivani Thakur
Subject Matter Specialist Agrometeorology, KVK, Mandi, Sundernagar, Himachal Pradesh, India

Growth, development and profitability of rice (*Oryza sativa* L.) as affected by varying growing environments in north Western Himalayas

Shivani Thakur, Ranbir Singh Rana, Sandeep Manuja and Karan Verma

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Abstract
A field experiment was carried out during kharif seasons of 2017 and 2018 to study the growth, development and profitability of rice varieties at different phenological stages under varying growing environments. The treatment had three cultivars *viz*., HPR 1068, HPR 2880 and HPR 2143 with five dates of transplanting *viz*., 15th June, 25th June, 5th July, 15th July and 25th July in Factorial RBD. The temperature variation among the selected transplanting window was about 1- 3 °C. The results of present study showed that the 15th June transplanted crop produced significantly taller plants and have higher tiller count throughout the crop cycle, though it was at par with 25th June transplanted crop, whereas, 25th July transplanted crop resulted in significantly shorter plants at all the stages of observation during both growing seasons. Similarly, a significantly higher value of leaf area index and dry matter was recorded in the 15th June transplanted crop which fall successively and significantly with delay in transplanting from the 15th June to 25th July transplanting at tillering to maturity, during both the growing seasons. The economics of crop shows that significantly maximum gross returns (103998 Rs ha^{-1} & 119877 Rs ha^{-1}), net returns (73672 Rs ha^{-1} & 86001 Rs ha^{-1}) and BC ratio (2.6 and 2.5) was recorded in crop transplanted on 15th June during both seasons whereas minimum gross returns (59317 Rs ha^{-1} and 68447 Rs ha^{-1}), net returns (29081 Rs ha^{-1} and 34571 Rs ha^{-1}) and BC ratio (1.2 and 1.1) was recorded in 25th July transplanted crop. The per cent decrease in net returns of 25th July transplanting over the 15th June transplanting was about 59-60%. Variety HPR 2143 recorded significantly taller plants, a higher number of tillers, Leaf area index, dry matter and returns followed by HPR 1068 and HPR 2880. The early transplanted crop took a relatively more number of days to attain phenological stages *viz*. tillering, panicle initiation, 50% flowering and maturity in all the three varieties *viz*. HPR 1068, HPR 2880 and HPR 2143 as compared to the late transplanted crop in both the years. Thus, the effect of transplanting dates in rice cultivation is considered to be of at most important for its higher productivity, sustainability and profitability.

Keywords: Rice, tillering, physiological maturity, economics

Introduction
For more than half of the world's population, rice (*Oryza sativa* L.) forms staple food. The rice crop covers the most of area in India, followed by China and Indonesia, with China has the highest production. Globally it is grown in approximately 164 million hectares area, with annual productivity and production of 3105 kg ha^{-1} and 509 million tonnes, respectively. India covers approximately 45 million ha area, with an annual production and productivity of 118 million tonnes and 2641.5 kg ha^{-1}, respectively (Anonymous, 2022) [1]. In Himachal Pradesh also, on the area basis rice is one of the important cereal crops next to wheat and maize. Among the different constraints in the rice production, apart from different inputs for yield variability more attention was gained by the time of transplanting. The different sowing windows have direct effect on length of growing season which may reduce yield by 20 to 50% by 2050 in rainfed area (Kang *et al*., 2009) [8]. Optimum time of transplanting not only affects the growth, development and yield of crops, but also it ultimately decides the yield and profitability of a crop. There is the drastic reduction in yield when it is transplanted too early or too late. The appropriate transplanting dates ensure satisfactory vegetative growth, development, grain quality and quantity (Farrell *et al*., 2003) [4]. Increase in temperatures is associated with spikelet sterility at flowering stage.

If there is increase in ambient temperature within the grain filling period of the crop, it improves the rate of metabolic actions and as a result, expedites the grain filling rate (Gornall *et al*., 2010) [6]. In most of the areas transplanting of rice is normally done between May to July and the effect of this varies from region to region, which in return effects the vegetative and reproductive growth of plant. When crop is transplanted early it produces more tillers, biomass, taller plants, bolder grains with higher 1000-grain weight and grain yield (Khalifa, 2009) [10]. The late transplanting effect the crop by limiting the growth period which in turn reduces the leaf area, panicle length and the mean number of kernels per panicle (Bashir *et al*., 2010)[2]. In delayed transplanted crop there is decrease in the number of productive tillers, spikelets, panicle and the weight of the grains were also reduced. (Hayat *et al*., 2003) [7]. So to attain maximum yield and for the efficient conversion of biological yield into economic yield the optimization of transplanting time is an important parameter and management option. The present field investigation was therefore, conducted to find out the effect of different transplanting dates on growth, development and economics on different varieties of rice.

Materials and Methods

The study was conducted at Experimental Farm of CSKHPKV, Rice and Wheat Research Centre, Malan during the Kharif seasons of 2017 and 2018. Agro climatically, the experimental site falls under the sub-temperate humid zone of Himachal Pradesh which is characterized by mild summers and cool winters. The experiment was laid out in factorial RBD design with five dates of transplanting (15th June, 25th June, 5th July, 15th July and 25th July) and three varieties of rice (*viz*., HPR 1068, HPR 2880 and HPR 2143) with three replications. Meteorological data *viz*., rainfall (mm), maximum and minimum relative humidity (%), maximum and minimum temperature (°C), duration of bright sunshine (hours), wind speed (kmh) etc. were recorded from meteorological observatory of Rice and Wheat Research Centre Malan. Data on the mentioned parameters in the Table 1 have been taken at the tillering and maturity. The height of 10 plants was measured in centimeters from the ground level of the plant up to top most leaf tip. The average height was worked out and expressed in centimeters. The leaf area was measured with leaf area meter and then leaf area index was worked out using the formula given by Redford (1967) [17]. The progressive tiller count was recorded at different phenological stages from two observational units of one meter row length, earmarked randomly in each net plot of experiment. The data so recorded were averaged and multiplied by factor 5 to get number of tillers m^{-2}. For dry matter, all the shoots from 30 cm row length leaving a border of 25 cm on both sides were cut from the ground level, processed and dried in oven at 70 °C for 5 days. After that, the dry matter accumulation per square metre was calculated by multiplying with factor 16.6 at different phenological stages. Net return per rupee invested was calculated by dividing net return with cost of cultivation. The data so obtained from field as well as laboratory studies were subjected to statistical analysis as per procedure given by Gomez and Gomez (1984) [5]. Critical difference (CD) was calculated for parameters where the effects exhibited significance at 5 per cent probability level.

Results and Discussion

Growth Parameters

Plant height (cm)

The data presented in Table 1 revealed that plant height was significantly influenced by different dates of transplanting during both the years of study. Significantly taller plants were obtained with the 1st date of transplanting (15th June) at all the stages of observation, though this treatment was at par with the 2nd and 3rd dates of transplanting (25th June and 5th July) during both the years expect at physiological maturity in 2018 where the 3rd date of transplanting produced significantly shorter plants as compared to 1st date of transplanting. Significantly shorter plants were recorded from the 5th date of transplanting (25th July) though the treatment was also at par with the height recorded at 4th date of transplanting of 15th July. Generally, the plant height increased at a faster rate up to 90 days after transplanting and rate of increase was marginal thereafter. Increase in plant height in early transplanting might be due to longer growing period and response of respective date to weather element favoured better growth and development. Late transplanting resulted in the lesser growth period which forced the crop to flower earlier and also mature earlier. The present findings are in conformity with Khakwani *et al*. (2006) [9]; Kumar and Subramanian (1991) [11]; Venkateswarlu (1989) [21], Ramana *et al*. (2007) [16], Singh *et al*. (2012) [20] and Safdar *et al*. (2013) [18]. The influence of temperature may be the reason for the reduction in plant height with delay in plantings. Amongst the varieties tested significantly taller plants were observed in HPR 2143 at all the stages of observation during both the years though it was at par with HPR 1068 at all the stages during both the years. Significantly shorter plants were recorded in HPR 2880.

Tiller count

Number of tillers was also affected by varying growing environment. Tiller count continued to increase up to panicle initiation stage in each date of transplanting and decreased thereafter (Table 1). The maximum number of tillers were recorded with 1st date of transplanting on 15th June which remained at par to 2nd date of transplanting 25th June at all phenological stages during both growing season and significantly lower tiller count was observed in 25th July transplanted crop. These results are in conformity with those of Dileep *et al*. (2018) [3] who also found that maximum tillers were formed in crop transplanted in June. Among the variety HPR 2143 recorded significantly higher number of tillers during both growing seasons at all phenological stages from tillering to physiological maturity followed by HPR 1068 and HPR 2880. However, during 2017, varieties HPR 1068 and HPR 2880 were at par with each other at all the growth stages.

Leaf area index

Leaf area index (LAI) is an important factor effecting the interception of solar radiation, photosynthesis and ultimately the total biomass production. It is an indicator of source size and dictates the efficiency of photosynthetic surface. At maturity leaf area index decreased due to leaf aging and senescence, shading and competition between plants for light and other resources. Among the transplanting windows from 15th June to 25th July, significant lower LAI was observed in 25th July transplanted crop and the highest value was observed when transplanted on the 15th June crop during all phenological stages. The maximum LAI recorded was 1.96 & 1.81 (tillering), and 3.90 & 3.69 (physiological maturity) on 15th June during 2017 and 2018, while minimum LAI was recorded in 25th July as 1.46 & 1.28 (tillering), and 3.41 & 3.21 (physiological maturity) in both the years, respectively. Decrease in LAI with delayed transplanting was due to less favourable weather conditions, shorter growing period which resulted in reduced crop growth, particularly plant height as compared to optimum transplanting dates. These results are observed by Nayak *et al*. (2003) [14], Rai and Kushwaha, (2008) [15] and Mohammad *et al*. (2008) [13]. However, among varieties the highest LAI of 4.55 & 4.30 was attained by variety HPR 2143 as compared to variety HPR 1068 (4.41 & 4.18) and HPR 2880 (4.29 & 4.09) during both the years.

Table 1: Effect of dates of transplanting and varieties on growth parameters of paddy during 2017 and 2018

Treatment	Plant height (cm)				Tillers m^{-2} (No.)				Leaf area index				Dry matter accumulation (g m^{-2})			
Date of Transplanting	Tillering		Physiological Maturity		Tillering		Physiological Maturity		Tillering		Physiological Maturity		Tillering		Physiological Maturity	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
15th June	59.0	57.1	110.0	105.3	274.8	263.5	296.4	278.6	1.96	1.81	3.90	3.69	328.4	317.7	1370.5	1325.9
25th June	58.0	56.4	109.2	103.3	266.6	256.6	288.9	264.2	1.76	1.66	3.70	3.57	318.3	304.5	1310.0	1252.4
5th July	57.5	56.0	108.4	102.8	257.3	249.6	274.7	249.9	1.67	1.52	3.62	3.44	304.0	291.9	1228.4	1151.1
15th July	54.3	53.0	106.1	100.8	250.0	241.6	264.8	240.2	1.58	1.40	3.47	3.28	296.4	262.7	1039.9	985.6
25th July	51.8	50.8	103.7	99.8	241.6	238.1	2525	230.2	1.46	1.28	3.41	3.21	260.4	236.3	853.8	860.4
SE m±	0.71	0.62	0.70	0.47	3.8	2.9	3.9	4.2	0.027	0.018	0.028	0.025	4.3	4.0	18.3	20.3
CD (P=0.05)	2.51	2.18	2.42	1.68	13.3	10.3	13.8	14.9	0.095	0.062	0.096	0.088	15.2	14.1	64.3	71.3
Variety																
HPR 1068	56.0	54.6	107.7	103.0	257.6	249.7	274.0	251.7	1.68	1.55	3.62	3.44	301.5	285.5	1169.3	1109.7
HPR 2880	54.7	53.2	105.1	100.8	250.0	239.4	269.0	241.0	1.59	1.41	2.52	3.33	295.2	266.1	1129.0	1087.4
HPR 2143	57.6	56.1	108.8	103.7	266.5	259.2	283.4	264.5	1.78	1.65	3.72	3.54	307.8	296.2	1183.3	1148.3
SE m±	0.55	0.48	0.52	0.37	2.9	2.2	3.1	3.3	0.021	0.013	0.021	1.019	3.4	3.1	14.2	15.7
CD (P=0.05)	1.60	1.39	1.55	1.07	8.5	6.6	8.8	9.5	0.060	0.040	0.062	0.056	9.7	8.9	41.2	45.6

Dry matter accumulation (g m^{-2})

Dry matter accumulation (DMA) is one of the most important factor showing the final outcome of the interaction of various crop growth factors and reflects the growth and metabolic efficiency of plants. The data on dry matter accumulation (Table 1) revealed that DMA fall successively and significantly with delay in transplanting from 15th June to 25th July transplanting at tillering, and physiological maturity, during both the years. Dry matter accumulation increased with the ontogeny of the crop. The maximum DMA recorded was 328.4 & 317.7 g m^{-2} (tillering) and 1370.5 & 1325.9 g m^{-2} (physiological maturity) in 15th June during 2017 and 2018, while the minimum DMA was recorded in 25th July transplanting crop as 260.4 & 236.3 g m^{-2} (tillering) and 853.8 & 860.4 g m^{-2} (physiological maturity) during 2017 and 2018, respectively. DMA decreased with delay in transplanting time because of less favourable weather conditions and shorter crop growing period, reduced plant height and LAI (Table1). These results are in conformity with the results reported by Kumar and Sharma (2004) [12] under similar agro-climatic conditions. The results are supported by the findings of Vishwakarma *et al*. (2016) [22] as they observed significantly higher biomass in early transplanted crop (27th June) as compared to delayed planting (17th July and 27th July).

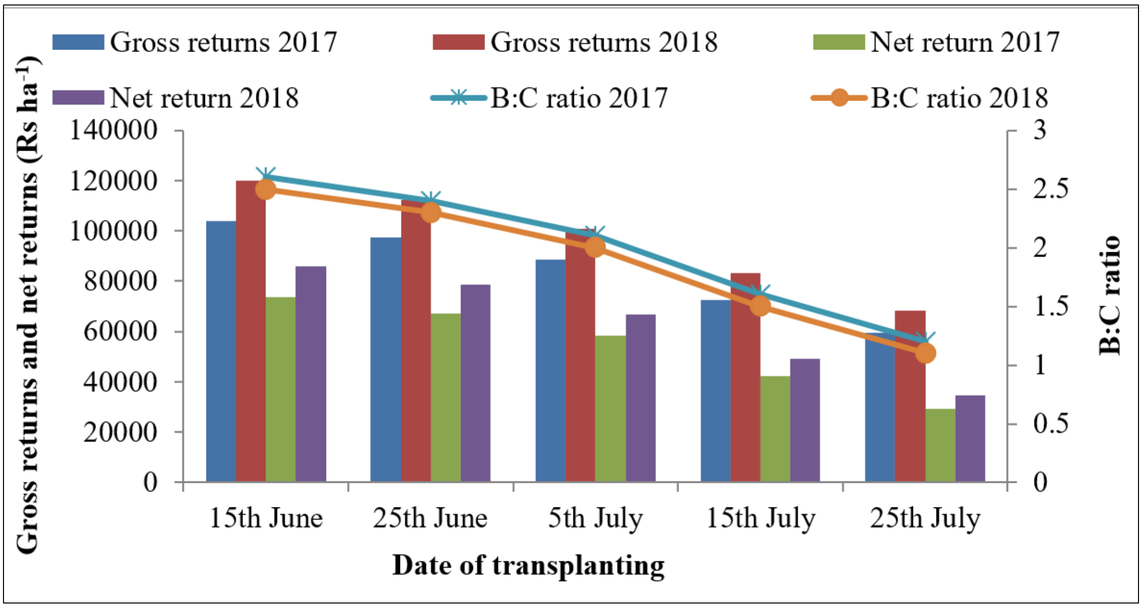
Development studies

As the transplanting date was delayed, the number of days for each phonological stage from transplanting to maturity continued to decrease (Table 2). The early transplanted crop took relatively more number of days to attain phenological stages *viz*. tillering, panical initiation, 50% flowering and maturity in all the three varieties *viz*. HPR 1068, HPR 2880 and HPR 2143 as compared to late transplanted crop in both the years. With the increase in the mean maximum temperature the number of days required to reach the panical initiation stage reduces by 3-9 days from 25th June to 25th July compared to 15th June transplanted crop. There was a difference of 10 and 11 days to attain maturity between 15th June and 25th July during 2017 and 2018, respectively, which showed a reduction of 7-8% in number of days taken to attain maturity. This trend has also been reported by Rai and Kushwaha (2008) [15] and Sharma *et al*. (2011) [19]. Among varieties, HPR 2143 took significantly more number of days (116 & 115) to attain physiological maturity followed by varieties HPR 2880 and HPR 1068, which took equal number of days (115 & 114) to attain physiological maturity during both the years.

Table 2: Effect of dates of transplanting and varieties on days taken to different phenological stage during 2017 and 2018

Treatment	Days							
Date of Transplanting	Tillering		Panicle Initiation		50% Flowering		Physiological Maturity	
	2017	2018	2017	2018	2017	2018	2017	2018
15th June	46	47	69	68	94	93	121	120
25th June	45	45	66	66	92	91	118	117
5th July	44	44	65	65	89	88	115	114
15th July	43	44	63	63	87	85	112	111
25th July	42	43	60	61	84	83	110	109
SE m±	0.3	0.3	0.6	0.4	0.4	0.3	0.4	0.4
CD (P=0.05)	1.2	1.1	2.1	1.5	1.4	1.3	1.5	1.4
Variety								
HPR 1068	44	44	63	64	89	87	115	114
HPR 2880	43	45	64	65	89	89	115	114
HPR 2143	45	45	66	65	90	89	116	115
S.Em±	0.3	0.3	0.5	0.3	0.3	0.2	0.3	0.7
CD (P=0.05)	0.8	0.7	1.4	0.7	0.9	0.8	0.9	0.9

Economics: The economics (Fig. 1) of the crop shows that significantly maximum gross returns (103998 ha^{-1} & 119877 ha^{-1}), net returns (73672 ha^{-1} & 86001 ha^{-1}) and BC ratio (2.6 and 2.5) was observed in crop transplanted on 15th June during both seasons whereas minimum gross returns (59317 and 68447 Rs ha^{-1}), net returns (29081 and 34571 Rs ha^{-1}) and BC ratio (1.2 and 1.1) was observed in 25th July transplanted crop. The per cent decrease in net returns of 25th July transplanting over 15th June transplanting was about 59-60%. In case of varieties significantly highest gross returns were obtained in variety HPR 2143 to the tune of 91723 Rs ha^{-1} during 2017 and 106141Rs ha^{-1} during 2018 followed by HPR 1068 (86149 Rs ha^{-1} in 2017 and 99878 Rs ha^{-1} during 2018) and HPR 2880 (75061 Rs ha^{-1} during 2017 and 84807 Rs ha^{-1} in 2018). Similarly significantly highest net returns (61487 Rs ha^{-1} and 72265 Rs ha^{-1}) and benefit cost ratio (2.2 and 2.1) were accrued in variety HPR 2143 as compared to HPR 1068 and HPR 2880 during both the years.



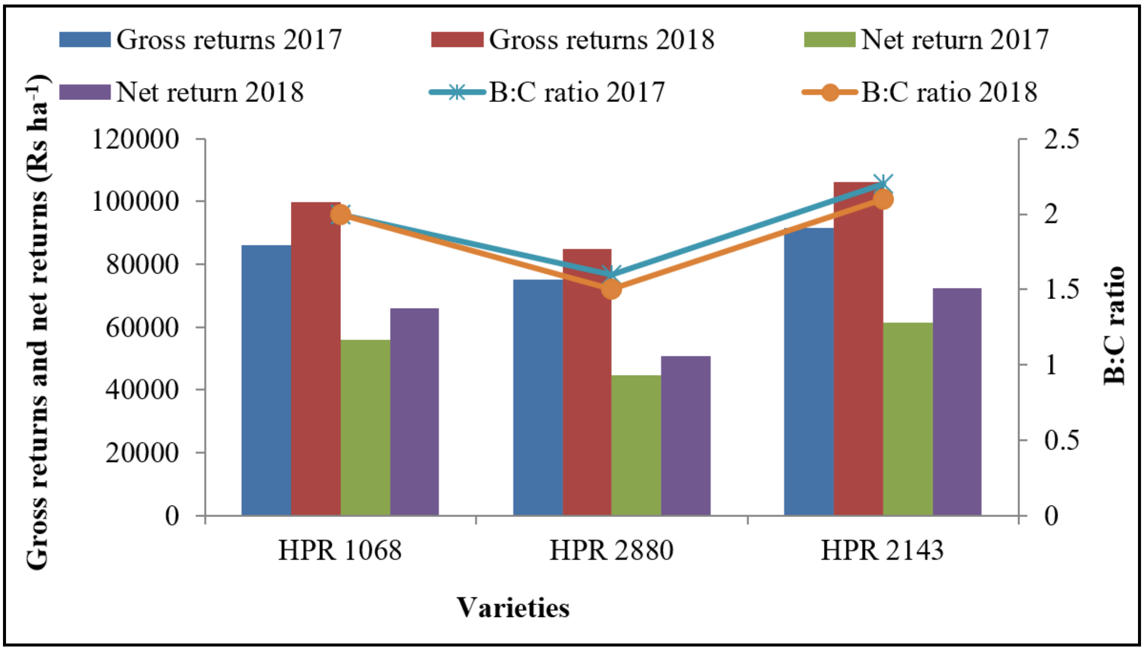


Fig 1: Effect of different treatments on economics of rice

Conclusion

Transplanting dates significantly affected growth, development and profitability of crop. Over two years of study, it can be concluded that transplanting of paddy on 15th June recorded highest rice productivity and profitability. Further delay in sowing could cause a significant loss of yield as well as economics of the farmers. The synchronization of the critical phenophases with the favourable weather conditions ensures promising crop yield and quality which is only possible by adjusting the sowing window. Thus, it is important to confirm the optimum sowing window for higher productivity, profitability of rice and food security.

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