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Impact of transplanting dates on productivity and profitability of rice hybrids under lowland conditions

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Abstract

Rice is a vital staple crop for food security. In Himachal Pradesh, low productivity poses a challenge despite its significance as a primary food crop. This study was conducted to enhance productivity by identifying optimal transplanting windows and evaluating hybrid performance under specific agroecological conditions to address increasing demand. A practical investigation was executed during the *kharif* season of 2020 at the Agronomy Department Experimental Farm, located in CSK HPKV at Palampur (H.P.) to assess the effects of varying transplanting dates on the growth parameters, economic viability, and overall yield of rice cultivars. The experimental framework utilized a split-plot design, replicated thrice, encompassing a total of twelve distinct treatment combinations. The principal plot (main plot) was delineated by three transplanting dates, specifically the second, third, and fourth week of June, whereas the sub-plot incorporated four rice cultivars, comprising an inbred variety, HPR 2143, and three hybrids Arize Swift Gold, Arize 6129, and Arize AZ 6508. The results derived from this study unequivocally indicated that the transplantation occurring in the third week of June yielded significantly higher yield attributes, prominently featuring an effective number of panicles m^{-2} and grain count $panicle^{-1}$. These enhanced yield traits finally converted into higher grain yield along with straw yield. The same also became the most remunerative date as it showed a superior B: C ratio, higher net return, and gross return. When tested, every hybrid outperformed the inbred check by a wide margin. Arize AZ 6508 outperformed the other hybrids in terms of effective panicles m^{-2}, grains $panicle^{-1}$, and 1000-grain weight. Consequently, the hybrids yielded higher grain and straw yield, in addition to gross return, net return, and B : C ratio. Therefore, the third week of June is when the rice hybrids should be transplanted. Out of all the hybrids tested, Arize AZ 6508 is also the most productive.

Keywords

economics; hybrids; rice; transplanting dates; yield

Introduction

Oryza sativa L. (Rice) is the most important food crop grown globally in over 114 countries across various continents and occupies more than 11% of the world's cultivated land (1). The fact that millions of people living in poverty in Asia rely on this crop for up to 50% of their daily calorie intake indicates how important it is to the global food security situation (2). In India, this crop is the most significant food crop and was planted on 46.4 million hectares in 2021–2022, yielding 130.3 million tonnes and 28.1 q ha^{-1} of productivity (3). However, with the ever-expanding population and improving lifestyle, the country demands to produce 130 million tonnes of rice by 2025 (4). Hybrid rice is one such technology that can boost the production and yield of this plant to meet the ever-rising demand of a growing population (5). Hybrid rice varieties can produce 14-28% more than pure line varieties grown in similar conditions (6,7).

Rice stands as the second imperative *kharif* food crop, after maize, of Himachal Pradesh and is the staple food for the most of the population of the state. In 2021-22, this crop was cultivated over an area of 66.16 thousand hectares, yielding a total production of 167.5 thousand tonnes, with an average productivity of 17 q ha^{-1} (8). This lower productivity of rice can be enhanced by adopting hybrid rice technology. However, the rice hybrids are usually of long duration, and hence, it becomes important to identify a suitable transplanting window for the recommended hybrids to achieve optimum productivity under specific agro-eco-situations (9). The timing of planting determines a genotype's performance completely since rice crops planted either early or late can face a variety of stressors.

The rice crop requires an optimal temperature at different growth stages, including at the time of panicle emergence, flowering, exertion of the panicle from the flag leaf sheath and at the time of maturity. The timing of transplanting plays a crucial role in influencing these key phenological stages, as it directly affects the development and productivity of the plant. Rice transplanting at the right time results in an earlier harvest of the crop and enables the planting of the next crop at the right time. Hence, the investigation was determined to identify the most optimal transplanting time for different hybrids raised under lowland conditions.

Materials and Methods

Study area and weather conditions

The research investigation was carried out at the agricultural research farm of the Agronomy department, CSK HPKV, Palampur Himachal Pradesh, India (Fig. 1). The location of the experiment is the sub-humid zone of Himachal Pradesh, occurring at 1290 meters above mean sea level (the elevation) & latitude of 32°09' N & longitude of 76°54' E. Throughout the trial period, the average weekly maximum temperature reported, varied from 31.6 °C in the 21st standard week (May 21–27) to 24.3 °C in the 44th standard week (October 29–November 4). The mean weekly minimum temperature fluctuated between the 32nd and 44th standard weeks, ranging from 20.1°C to 8.9°C. Thus, the temperatures during the 2020 crop growing season remained well within the optimal range for successful rice

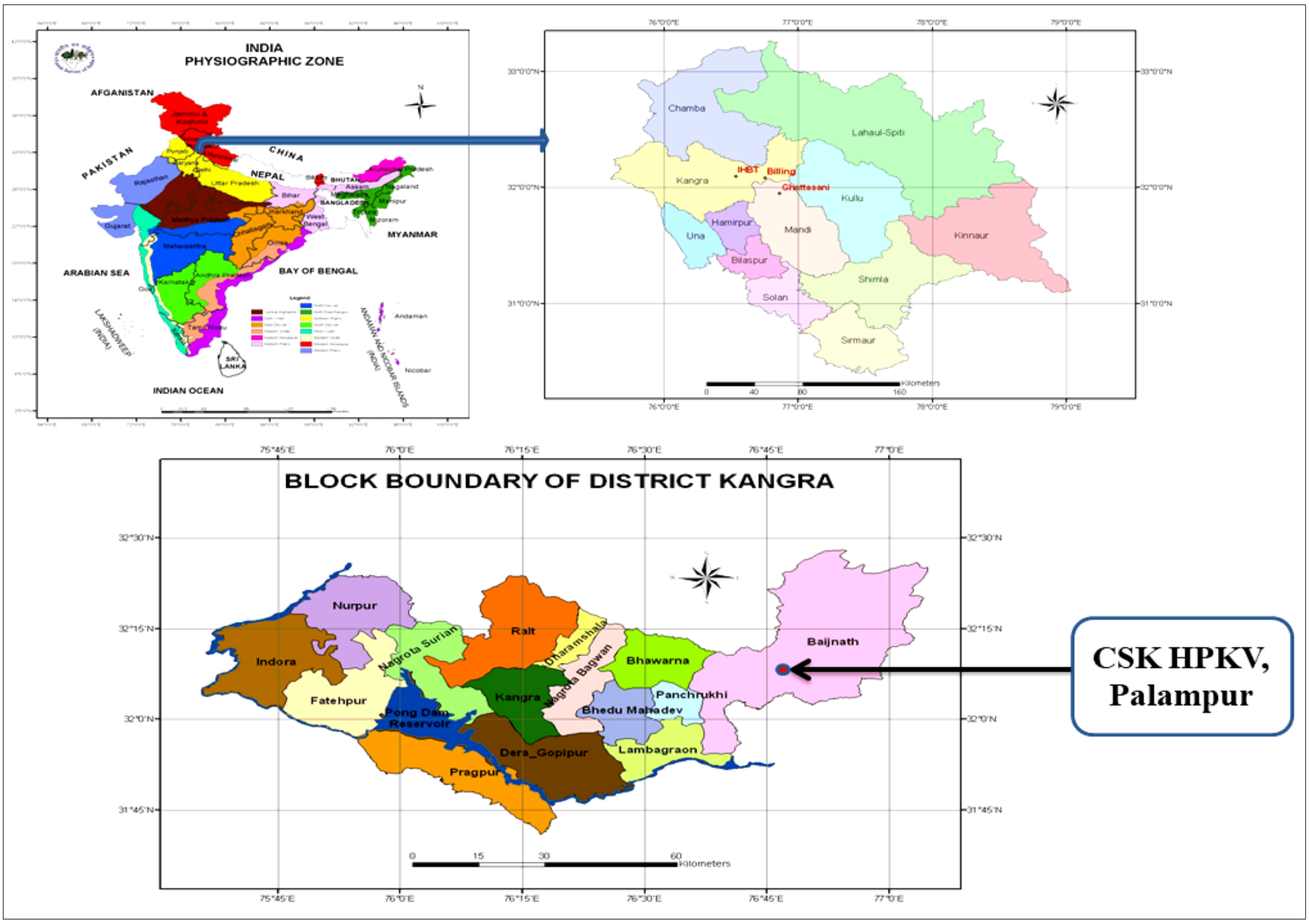

Fig. 1. Geographical location of experimental site.

cultivation, as outlined by the relevant guidelines (10). Even though October was almost completely dry, 1599.8 mm of rain fell over the whole rice-growing season in Kharif 2020. The mean relative humidity for the crop season varied from 44.95 to 92.05 percent, which was perfect for rice crops (11). It received between 2.1 and 10.9 hr of strong sunlight during the agricultural season (as indicated in Fig. 2).

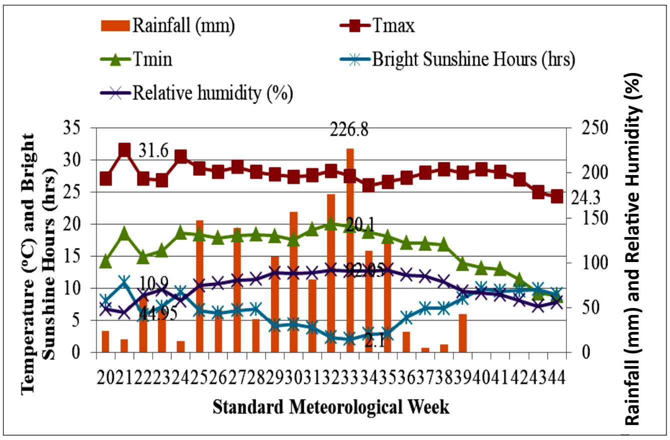

Fig. 2. Mean weekly meteorological data of *kharif* 2020 recorded at Palampur.

The experimental soil was characterized as silty clay loam, exhibiting an acidic response (Table 1). The soil had a medium level of available potassium, phosphorus, and nitrogen. The pH was measured using a glass electrode pH meter, which is a common method for determining soil acidity and alkalinity (12), and the organic carbon was determined using the rapid titration method (13). The phosphorus, nitrogen, and potassium content of the experimental sites were determined by alkaline permanganate technique (14), 0.5 $NaHCO_3$ extraction (15), and ammonium acetate extraction method (16), respectively.

Table 1. Physico-chemical properties of the soil (0-15 cm) of the experimental site

Soil property	Value	Method used
Soil	Silty clay loam	
pH (1: 2.5 soil: water suspension)	5.45	Glass electrode pH meter (12)
Organic carbon (g kg^{-1})	7.6	Rapid titration method (13)
Available Nitrogen (kg ha^{-1})	362.1	Alkaline permanganate method (14)
Available Phosphorus (kg ha^{-1})	21.1	0.5 $NaHCO_3$ extraction (15)
Available Potassium (kg ha^{-1})	246.2	Neutral normal ammonium acetate extraction method (16)

Experimental design and treatment details

The experiment was laid out in a split-plot design with three replications, with three transplanting dates in the main plot (the second, third, and fourth weeks of June) and the four rice varieties chosen for the study (Arize Swift Gold, Arize 6129 and Arize AZ 6508, HPR 2143) in the subplot treatment. Using a typical package of operations, the crop was raised, and on June 12, June 19, and June 26, transplants of 25-day-old seedlings were made.

Assessment of growth parameters

Two observational units consisting of six hills were randomly selected from each experiment's net plot, and the progressive tiller count was recorded at 30-day intervals and at harvest. Averaging the recorded data and multiplying it by 5.56 yielded the number of tillers m^{-2}. The leaf area index (LAI) is the area of leaf surface per unit area of land. Leaf area index was measured at 30 days intervals and at harvest by using the method described by (17).

$$\text{Leaf Area Index} = \frac{P \times L \times A}{1 \times 10^{7}}$$

Where, P = plant population ha^{-1} L = fully expanded green leaves $plant^{-1}$ A= single leaf area (cm^2)

Yield attributes and yield

Prior to harvest, the number of effective panicles (grain-bearing tillers) per running meter was measured in two locations within the net plot and averaged. To determine the number of effective panicles m^{-2}, the mean as recorded was multiplied by factor 5.0. Ten panicles were extracted after being chosen for panicle length measurement. After that, these panicles were manually threshed, and a seed counter was used to record the number of grains. The average number of grains per panicle was noted. 1000 grains were weighed and recorded from the composite sample taken from each net plot's production. Grain moisture content was measured, and 1000-grain weight (g) was calculated by adjusting the weight of 1000 grains at 14% moisture. At a moisture content of 14%, 1000 grain weight was adjusted using the following formula.

$$\text{1000 grain weight (at 14\% moisture)} = \frac{100 - \text{moisture (\%) in grain}}{100 - 14} \times \text{1000 grain weight}$$

Grain yield was calculated after the threshed grains were cleaned, the weight of the grains was recorded on electronic balance and converted to kg ha^{-1}. The grain yield so recorded from each net plot was subtracted from the biological yield of each net plot to get the straw yield, and then converted to kg ha^{-1}. The economics of each treatment were calculated using the current market values of the inputs and outputs to determine the economic viability treatment. All parameters were statistically examined, and treatment means were compared at a 5% level of probability (18).

Results

Growth parameters

There were notable variations in the data regarding the impact of transplanting dates on many growth metrics (Table 2). Although the crop was transplanted in the third week of June, the number of tillers per square meter was consistently higher at all observation points (30, 60, and 90 days after transplanting). This trend was like what was observed for crops transplanted in the second week of June. However, the crop transplanted in the fourth week of June showed fewer tillers than expected. Among the

Table 2. Impact of transplanting dates on growth parameters of rice hybrids

Treatment	Number of tillers (No. m^{-2})			Leaf Area Index		
	30 DAT*	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
Dates of transplanting						
D_1: 2nd week of June (12 June 2020)	125.9	244.1	233.1	1.31	3.49	4.35
D_2: 3rd week of June (19 June 2020)	132.1	247.2	236.2	1.38	3.58	4.50
D_3: 4th week of June (26 June 2020)	121.6	227.3	217.6	1.27	3.40	4.21
SEm±	1.9	3.5	3.5	0.03	0.04	0.06
CD (P=0.05)	7.4	13.6	13.6	NS	0.16	0.24
Varieties						
V_1: Arize AZ 6508	131.5	255.0	244.0	1.37	3.65	4.75
V_2: Arize Swift Gold	127.6	245.7	234.7	1.33	3.54	4.50
V_3: Arize 6129	125.0	230.6	219.7	1.31	3.48	4.42
V_4: HPR 2143	122.0	226.9	217.5	1.27	3.29	3.76
SEm±	2.2	4.0	4.0	0.06	0.08	0.10
CD (P=0.05)	6.4	12.0	12.0	NS	0.24	0.30

*DAT: Days after transplanting.

different cultivars studied, a significantly lower number of tillers m^{-2} were recorded from the inbred check HPR 2143, even though this variety was also at par with Arize 6129 at all observation stages. Arize AZ 6508 demonstrated a significantly greater number of tillers m^{-2} across all observation stages, despite being on par with Arize Swift Gold.

Varieties and transplanting dates did not significantly affect the leaf area index (LAI) at 30 days after transplant. A considerably higher leaf area index (LAI) was recorded from the third week of June transplanting. Although this treatment was comparable to the transplanting in the second week of June, and it was also at par with the fourth week of June of transplanting at both 60 and 90 days. While the variety HPR 2143 reported much lower LAI, this variety was at par with Arize 6129, and all three hybrids were at par with each other at 60 DAT. Arize AZ 6508 recorded a significantly greater LAI at 90 DAT, which was at par with Arize Swift Gold, which in turn was comparable to Arize 6129. HPR 2143 recorded substantially lower LAI.

Table 3. Impact of transplanting dates on yield attributes of rice hybrids

Treatment	Number of effective panicles m^{-2}	Number of grains panicle^{-1}	1000 Grain weight (g)
Date of transplanting			
D_1: 2nd week of June (12 June 2020)	213.8	124.9	24.6
D_2: 3rd week of June (19 June 2020)	216.9	130.3	25.3
D_3: 4th week of June (26 June 2020)	200.1	115.7	24.7
SEm±	3.0	2.1	0.2
CD (P=0.05)	12.1	8.4	NS
Varieties			
V_1: Arize AZ 6508	225.6	128.1	25.9
V_2: Arize Swift Gold	218.7	126.6	25.3
V_3: Arize 6129	204.6	130.5	24.0
V_4: HPR 2143	192.2	109.2	24.3
SEm±	3.7	2.1	0.3
CD (P=0.05)	10.9	6.4	0.9

Yield attributes and yield

An examination of the data on yield attributes indicated that the crop transplanted in the third week of June had a significantly higher number of effective panicles per square meter which was statistically comparable to the crop transplanted in the second week of June, in contrast, the crop transplanted in the fourth week of June exhibited a significantly lower number of effective panicles per square meter (Table 3). Among the varieties, Arize AZ 6508 yielded a notably higher number of effective panicles m^{-2}, though it was on par with Arize Swift Gold. In contrast, HPR 2143 produced a significantly lower number of effective panicles. Comparable outcomes were noted for the number of grains per panicle, with crops transplanted in the third week of June showing a similar grain count to those transplanted in the second week. These transplanting times resulted in significantly higher grain numbers per panicle, while the crop transplanted in the fourth week of June produced significantly fewer grains per panicle. All the hybrids tested showed a significantly higher number of grains per panicle compared to the check variety. Variations in the transplanting dates did not appreciably affect the 1000-grain weight. Even though Arize Swift Gold was comparable, Arize AZ 6508 yielded grains with a noticeably greater 1000-grain weight. Significantly lower 1000-grain weight was noted in Arize 6129 while this was comparable to the check variety HPR 2143. The economics of several rice types, as well as the impact of varying transplanting dates on grain and straw yield, was given in Table 4. The crop transplanted in the third week of June produced significantly higher yields of both grain and straw, even though its performance was statistically like the crop transplanted in the second week of June. While the yields of the second and fourth-week transplanting were comparable, the third-week transplanting consistently outperformed in terms of productivity.

Table 4. Impact of transplanting dates on yield and economics of rice hybrids

Treatment	Grain Yield (q ha^{-1})	Straw yield (q ha^{-1})	Net return (INR ha^{-1})	B : C ratio
Dates of transplanting				
D_1: 2nd week of June (12 June 2020)	50.5	60.7	62848	1.26
D_2: 3rd week of June (19 June 2020)	55.1	62.8	72116	1.44
D_3: 4th week of June (26 June 2020)	46.0	57.1	53326	1.07
SEm±	1.3	1.1	2524	0.05
CD (P=0.05)	5.0	4.2	9911	0.21
Varieties				
V_1: Arize AZ 6508	56.5	67.4	74828	1.47
V_2: Arize Swift Gold	53.4	55.1	65282	1.28
V_3: Arize 6129	51.1	59.5	62244	1.22
V_4: HPR 2143	41.1	58.9	48700	1.06
SEm±	1.5	1.5	3093	0.06
CD (P=0.05)	4.5	4.5	9189	0.18

While Arize Swift Gold and Arize 6129 were statistically comparable, Arize AZ 6508 produced a noticeably greater grain yield among the types. When it came to straw yield, Arize AZ 6508 produced a noticeably larger yield than the other three kinds combined.

The third week of June transplanting had the greatest net return as well as B: C ratio, followed by the second and fourth weeks of June transplanting. Arize AZ 6508 had the greatest net return as well as B: C ratio values among the several kinds, but HPR 2143 showed the lowest value of economic indicators.

Discussion

Growth parameters

The third week of June produced the highest tiller count throughout all observation stages, indicating that transplanting dates had a substantial impact on growth parameters. This is explained by the ideal amount of sunlight and the ideal weather during active tillering (19, 20,21,22). Genetic advantages in tillering capability allowed hybrids, especially Arize AZ 6508, to routinely outperform the inbred check (HPR 2143) (23). Higher leaf area index (LAI), which improves photosynthetic efficiency, was another outcome of hybrids' capacity to keep leaves greener for longer (24).

Yield and yield attributes

The favorable environmental circumstances during the panicle emergence and blooming stages resulted in increased effective panicle numbers and grains per panicle when rice was transplanted during the third week of June. Because low temperatures degenerate spikelets, late transplanting in the fourth week produced fewer grains per panicle (25). Previous research has shown that Arize AZ 6508 has superior yield features across varieties because of its superior genetic potential for grain-setting (26). In line with favorable environmental conditions that enhance panicle growth and grain filling, the largest grain and straw yields were observed during the third week of transplanting. By better-utilizing resources through enhanced root-shoot development and nutrient uptake, Arize AZ 6508 produced the highest yields and economic returns. These results are consistent with earlier studies that showed the higher productivity of hybrids when operating at optimal settings (27). Some researchers also observed that stress factors such as less sunlight and less-than-ideal temperatures caused yields to be significantly impacted by early or late transplantation (28).

Conclusion

The study concludes that in Himachal Pradesh's mid-hill, lowland conditions, the third week of June is the best period to transplant rice hybrids. At key development stages, such as tillering and flowering, this scheduling ensures optimal growth, higher yield qualities, and better economic returns because of favourable environmental conditions. Arize AZ 6508 was the most prolific hybrid among the evaluated varieties, exceeding the others in terms of 1000-grain weight, grain count, and effective panicle number. In addition, it produced the highest grain and straw yield and the best economic metrics, including benefit-to-cost ratio, net returns, and gross returns. agro-ecological optimize productivity and profitability; these results highlight how crucial it is to match transplanting schedules with agroecological conditions. To ensure improved resource use, increased food security, and economic sustainability in comparable agro-ecological zones, the study offers practical recommendations for farmers and policymakers for improving rice cultivation practices.

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Authors' contributions

SK, SM, AS and AS performed the experiment. SM, RP, GD and AK designed the research. SK, AS, CS and AS wrote the manuscript. SM, AS, VS and CS revised and corrected the manuscript. All authors have contributed for different sections of writing, reviewing, correction and statistical analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare no conflict of interest.

Ethical issues: None

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