

Comparison of Yield and Water Productivity of Rice (*Oryza sativa* L.) Hybrids in Response to Transplanting Dates and Crop Maturity Durations in Irrigated Environment

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Abstract

Water scarcity, due to abruptly accruing phenomenon of climate change, is perilously disturbing agricultural crops such as rice as well as its quality in many countries of the world. It is an acute threat to livelihood of residents of those countries where water resources are already a limiting factor to agriculture. Therefore, an experiment was conducted to ascertain and compare yield and water productivity of rice (*Oryza sativa* L.) hybrids in response to transplanting dates and cultivar duration in irrigated sub-tropical regions of Punjab, Pakistan. The experiment was conducted in experimental fields of Rice Research Institute, Kala Shah Kaku. It was determined that the water productivity was increased with the shifting of transplanting date towards shorter water demand period and variety to shorter life duration. Water stress is more damaging to those varieties or hybrids that have longer life cycle as compared to early maturing hybrids and varieties. Conclusively, same method may be used to test other rice varieties and hybrids to ascertain their minimum water requirements for maximum yield returns.

Keywords: Rice; Water management; Irrigation; Water productivity; Water saving technology

Introduction

Rice is the second largest staple food crop of Pakistan and is also an exportable item. It accounts for 3.2% in the value added in agriculture of Pakistan and 0.7% of GDP. During July-March 2014-15, rice export earned foreign exchange of US\$1.53 billion. During 2014-15, rice was sown on an area of 2.89 Million hectares of Pakistan showing an increase of 3.6% over last year's area of 2.79 Million hectares. Rice recorded highest ever production at 7.01 Million tonnes, showing a growth of 3.0% over corresponding period of last year's production which was 6.79 Million tonnes [1].

Water scarcity is becoming a major problem in the agriculture sector, especially in the case of rice which is the staple food of half of the world's population. Per capita water availability has declined tremendously in many countries of Asia [2,3]. The production system of the rice crop is requiring higher water availability than other crops like cereals, fruits or vegetables. Rice is transplanted in early June on large scale during which peak evaporative demand contributes majorly to water table decline in these regions [4]. Furthermore, due to abrupt increase in urban and industrial sectors, agriculture's share of fresh water has declined by 8-10% [5,6]. Rice production in Asia is increasingly constrained by water limitation and therefore there is an increasing pressure to reduce water use in production of irrigated rice. Already declining quantity as well as quality of ground water and poor infrastructure systems is threatening the sustainability of the irrigated rice-based production system [7-10]. Exploring ways to produce more rice with less water is essential for food security and for a sustainable environment; however its confirmation still stands uncertain [11].

In Pakistan, most of the rice hybrids and cultivated varieties are late maturing. Late maturing hybrids and varieties have longer life duration and thus also show increased water requirements due to higher evapotranspiration (ET) demands crop water use efficiency (WUE)/water productivity (WP) are the most important criterion to consider where available water resources are limited or diminishing. It has been reported earlier that WP can be increased by adopting water-saving management practices e.g., improved irrigation management

technologies Bouman and Tuong [12], growing early maturing/short duration hybrids and varieties and synchronizing the crop growing cycle with the days of lower evaporative demands [13,14]. Therefore, it has now become a dire need to develop short duration rice hybrids and varieties capable of producing more grains using less water. The present study was conducted to contour methods of screening out the genotypes (hybrids/varieties) that show higher yield potential with minimum water requirements and to find out their optimum time of transplanting at maximum water productivity (WP).

Materials and Methods

A field experiment was conducted at the research fields of Rice Research Institute Kala Shah Kaku, Lahore, Pakistan during Kharif 2015. Two rice hybrids i.e., Arize Swift and INH10008 and one check variety (KSK 133) were used in the experimental study. The experiment was laid out in split plot design with three replications. Main plot treatments were consisted of three transplanting dates. 30 days old rice seedlings were transplanted on 1st, 16th July and 31st July.

Irrigations were applied when 50% plants reached to score 7 (IRRI: SES, 2002). Quantity of irrigation water was measured using water meter and water productivity computed by dividing the economic yield (kg ha⁻¹) with amount of irrigation water applied. Important dates of crop cycle such as date of sowing, date of transplanting, Date of 10% flowering, Date of finished flowering, Date of maturity, Date of harvest were noted on regular basis, and Days of flowering period, Days to maturity and Days to harvest were calculated. Furthermore, other important morphological and agronomical traits such as Number of

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Productive tillers/ square meter, Number of filled spike lets per panicle, Number of sterile spike lets per panicle, seed set (%), harvest per plot, moisture Content of grain at harvest were collected. Stress related traits such as quantity of irrigation water, adjusted yield per hectare at 14% moisture content and water productivity was computed as yield per ha/ water using the following formula given.

Water Productivity (WP) (kg/Litre)=grain yield (kg)/irrigation water (Litres)

The data for each character was statistically analysed using Analysis of Variance (ANOVA) technique and significant means were separated by using Least Significant Difference (LSD) test or comparing the means of treatments as given by Gomez and Gomez [15], Singh et al. [16].

Results and Discussion

Rice yields in different treatments as influenced by transplanting date, variety and irrigation regime are presented in Tables 1a and 1b. Results depicted in Tables 1a and 1b clearly show that both the hybrids and check variety showed highly significant different performances under stress treatment for a number of parameters that include spikelet fertility, water productivity, yield per hectare and yield per plot; while for 1000-grain weight they were significantly different. On the other hands, there was no varietal difference for other traits such as tillers per meter square, spikelet fertility and seed setting. The water stress had remarkable influence on growth and yield components of rice (Tables 1a and b). It was observed that yield, filled spikelet, 1000 grain weight, plant height and number of tillers reduced with duration of water stress cycle. These results are in consistent with the results of Chahal et al.

[14] who found a significant relation between rice yield and number of days under stress during the period of post-transplanting.

Similarly, transplanting dates had significant effects on performance of hybrids and check variety. More the duration or period of stress, less yield was recovered. Therefore, average yield was fewer in first date of transplanting as compared to second date for all the studied hybrids and variety due to the reason that genotypes had to suffer stress for a longer duration that resulted in remarkable differences in yields of hybrids transplanted at different dates.

At the probability level of 0.01, both the hybrids and check variety showed highly significantly different performances in terms of spikelet fertility, water productivity and yield as well as irrigation water required. Whereas, 1000 grain weight, spikelet fertility was seed setting were significantly different at probability level of 0.05. However, tillers per meter square were not significantly different for different genotypes and transplanting dates.

Averaged over genotypes, the paddy yields per hectare of hybrids INH10008 and Swift were 3192 and 3377 kg/ha, which were statistically at par as depicted in Table 2a. However, average yield of check variety KSK 133 was significantly different ($p < 0.01$) from both the hybrids under stress treatment in all transplanting dates. When we compare the effect of transplanting dates on average yield performance of all the three genotypes, it becomes clear that there exist a significant effect of transplanting these genotypes at different dates ($p < 0.01$) as given in Table 2b. Average yields of both the hybrids and one check variety were at par. Hybrid Swift produced highest paddy yield (3501 kg/ha) followed by INH10008 (2873 kg/ha) and KSK 133 (2539 kg/ha) under water stress treatment (Table 2c) (Figure 1).

Source of variation	Spikelet fertility	1000 grain weight (kg)	Tillers per m ²	Spikelet sterility	Seed set (%)
Replications	25.04	4.97	746.26	338.48	99.97
Dates	6814.37**	10.54*	6739.15	2318.81*	118.43*
Varieties	9786.26**	24.78*	3080.70	393.59	75.52
Dates* Varieties	2876.65*	4.81	2002.20	338.15	250.69*

*, **Significant level P=0.01

Table 1a: Mean squares of different parameters/traits.

Source of variation	Water productivity (kg-ha/Lit.)	Yield (kg/ha) (14% M.C.)	Yield (kg/plot) (14% M.C.)	Irrigation per hectare (Lit.)	Irrigation per plot (Lit.)
Replications	5.642E-08	2643	0.132	3.549E+10	60018
Dates	2.556 E-07**	2147370**	2.073**	1.229 E+12**	2077263**
Varieties	5.687 E-07**	2740890**	5.291**	1.274 E+11	215701
Dates* Varieties	1.352 E-07**	1605876**	2.200**	4.930 E+10	83370

*, **Significant level P=0.01

Table 1b: Mean squares of different parameters/traits.

	Source of variation	Water productivity		Yield per hectare		Yield per plot	
		Between hybrids	Between dates	Between hybrids	Between dates	Between hybrids	Between dates
1	KSK 133	9.07 E-04 B	9.90 E-04 B	2343.0 B	2539.3 C	3.1533 B	3.7680 AB
2	INH 10008	1.25 E-03 A	1.27 E-03 A	3192.9 A	2873.0 B	4.1853 A	4.5483 A
3	Swift	1.39 E-03 A	1.28 E-03 A	3377.8 A	3501.3 A	4.6517 A	3.6740 B

Table 2a: Pair-wise comparisons (at 0.01 probability) of means of varieties transplanted at different dates.

	Source of variation	Spikelet fertility		1000 grain weight (kg)		Irrigation per hectare	
		Between hybrids	Between dates	Between hybrids	Between dates	Between hybrids	Between dates
1	KSK 133	84.11 B	151.11 A	23.589 AB	22.200 A	2.80 E+06 A	2.97 E+06 A
2	INH 10008	127.22 A	110.44 B	24.933 A	24.322 A	2.59 E+06 A	2.77 E+06 A
3	Swift	148.89 A	98.67 B	21.633 B	23.633 A	2.60 E+06 A	2.25 E+06 B

Table 2b: Pair-wise comparisons (at 0.01 probability) of means of varieties transplanted at different dates.

	Source of Variation	Irrigation per plot		Spikelet sterility		Tillers per m ²	
		Between hybrids	Between dates	Between hybrids	Between dates	Between hybrids	Between dates
1	KSK 133	3643.8 A	3862.8 A	43.000 A	67.000 A	254.00 A	264.11 AB
2	INH 10008	3369.9 A	3601.3 A	49.333 A	35.444 B	235.89 A	223.33 B
3	Swift	3381.8 A	2931.3 B	56.222 A	46.111 AB	272.89 A	275.33 A

Table 2c: Pair-wise comparisons (at 0.01 probability) of means of varieties transplanted at different dates.

	Name of variety	Filled spikelets	1000-Grain weight (g)	Tiller/m ²	Yield at 14% M.C. (kg/ha)	Quantity of irrigation water/ha (Lit.)	Water productivity (kg-ha/Lit.)
D1	KSK 133	80	22.00	280	982	3062882	0.00046
	INH10008	193	23.00	240	3458	2795508	0.00127
	Swift	180	21.67	272	3178	3055539	0.00124
D2	KSK 133	88	25.10	225	3428	2947974	0.00117
	INH10008	95	26.83	224	3274	2796000	0.00118
	Swift	148	21.03	221	3803	2566256	0.00148
D3	KSK 133	84	24.11	257	2619	2397384	0.00109
	INH10008	94	24.56	244	2847	2185231	0.00130
	Swift	118	22.24	325	3153	2182154	0.00147

Table 3: Average yield performances of three genotypes at all the three transplanting dates along with their some yield important yield components.

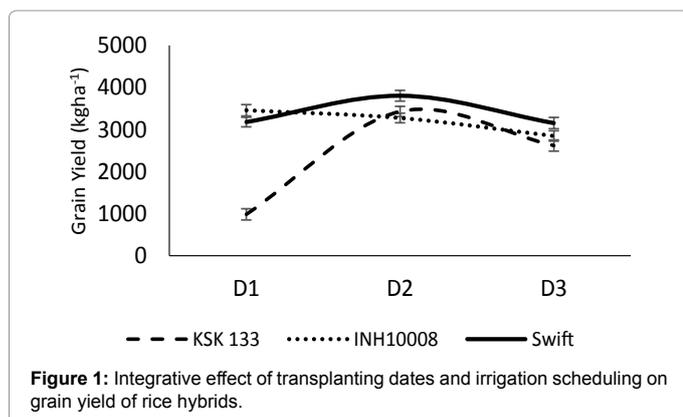


Figure 1: Integrative effect of transplanting dates and irrigation scheduling on grain yield of rice hybrids.

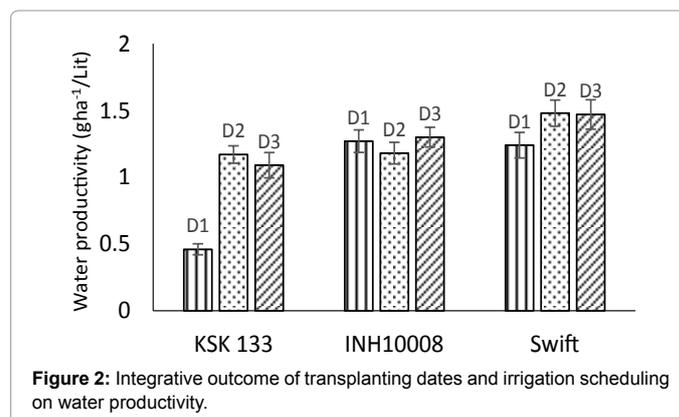


Figure 2: Integrative outcome of transplanting dates and irrigation scheduling on water productivity.

Apparent crop water productivity under different date of transplanting and genotypes are given in Table 3. The values ranged from 0.00046 to 0.00148 kg-ha/ Lit, which are close to the measured data in an independent experiment conducted by Singh et al. [16]. Keeping in view the results elaborated in Table 3, it becomes obvious that first transplanting date (D1) gave least yield due to the fact that both the hybrids and the check variety had to suffer water stress for a longer duration as compared to late of transplanting. For early transplanting, hybrid INH10008 gave highest yield (3458 kg/ha), followed by Swift (3178 kg/ha) and KSK 133 (982 kg/ha) as given in Table 3. Similarly, in second and third transplanting dates, Swift hybrid was the best yielder with average yield of 3803 and 3153 kg/ha respectively. Likewise, Swift showed maximum/significantly highest water productivity values in second and third dates of transplanting, while KSK 133 showed the lowest. However, at D1, INH10008 showed highest that was at par with Swift. Considering these results, it can be emphasized that Swift hybrid may be considered as best among studied hybrids under water stress conditions.

Comparing the average yields of all the three genotypes at three transplanting dates, D1 was the lowest yielding as compared to other two dates. Likewise, D2 gave highest yield while the yield was again reduced when further delayed to D3. However, the date of transplanting showed a significant interaction with the genotypes. Average paddy yield in the D3 treatment declined significantly compared to D2. It might be due to

the shorter period of growth till flowering than required for optimum vegetative growth that in turn contributes to final yield (Figure 2).

The amount of total irrigation water applied (Table 3) in D3 was 2.25 million litres, that is 0.516 and 0.201 million litres less than D1 and D2 treatments, respectively. Comparatively in short duration variety irrigation water applied was much less than that in long duration varieties. Therefore, shorter duration varieties and hybrids should be evolved for saving more water required.

Considering the obtained results, it can be concluded that the water productivity were increased with the shifting of transplanting date towards lower evaporative demand period and variety to short duration. Swift hybrids showed maximum value for water productivity (0.00148 and 0.00147 kg-ha/L at D2 and D3 respectively) as compared to other hybrid and KSK 133 (check). At D1, both hybrids were at par for their water productivity.

Conclusion

Considering the obtained results, it may be concluded that the water productivity were increased with the shifting of transplanting date towards shorter water demand period and variety to short duration. Keeping in view the results, hybrid Swift may be considered best in terms of its yield performance under water stress condition as well as its high value of water productivity. Water stress is more damaging to those varieties or hybrids that have longer life cycle as compared to

shorter duration hybrids and varieties. KSK 133 was least performing under water stress due to its longer life cycle as compared to shorter life durations of other hybrid varieties. Swift showed highest water productivity and paddy yield due to its shorter life cycle as compared to INH10008 hybrid.

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