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Research Paper

Spikelet sterility, harvest index and yield of rice (*Oryza sativa*) cultivars as influenced by low temperature and transplanting dates in temperate Kashmir

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ABSTRACT

A field experiment was carried out during *kharif* seasons of 2006 and 2007 at Research Station Wadura of Sher-E-Kashmir university of Agricultural Sciences and Technology-Kashmir to study influence of low temperature and transplanting dates on rice spikelet sterility, harvest index and yield of rice (*Oryza sativa* L.) cultivars. Low temperature during the reproductive phase of rice caused marked reduction in grain yield of rice. Negative effect (% increase from normal early sowing) of late sowing on spikelet sterility was greatest in CV 'Shalimar rice 1' (15.8-50.9% increase over early and normal sowing) followed by 'Jhelum' (19.2-46%). Under late sown conditions, there was reduction in harvest index of cultivars in the order of 'Shalimar Rice 1'> 'Jhelum'> 'Chenab'> 'China 1039'. Heat susceptibility index (S) among different *rice* cultivars ranged from 0.82% in 'Chenab' to 1.17% in 'Shalimar rice 1' while, stability ratio raised from 46.28% in 'Shalimar rice 1' to 62.13% in 'Chenab'. Low temperature induced sterility losses can be reduced by planting early.

Key words : Rice cultivars, Temperature, Spikelet sterility, Susceptibility index, Sterility ratio

Rice, a staple food in Kashmir valley, is sown on an area of almost 0.14m ha. Low temperatures during critical growth periods, lack of timely inputs, proper selection of variety and socio-economic conditions are main constraints resulting in low yield. Under temperate conditions as in Kashmir valley, temperature plays a major role in crop production and therefore planting date assumes significance (Summerfield *et al.,* 1992). Total biomass production of rice is determined mainly by crop photosynthesis and respiration losses, both of which are sensitive to temperature (Horie *et al.,* 1994). Though, growth period of rice crop in Kashmir valley is limited by low temperature in spring, temperature fluctuations at flowering during cooler years result in high spikelet sterility (Singh *et al.,* 2005). In rice the reproductive processes occurs within 1 hour after dehisence of anthers, shedding of pollens, germination of pollen grains on stigma and elongation of pollen tubes and is sensitive to night temperatures below 20°C, which results in spikelet sterility with a subsequent reduction in seed set and grain yield (Ziska *et al.,* 1996). Temperature cannot be manipulated easily under field conditions but seeding/ transplanting date can be adjusted to meet specific requirements for physiological stages of crop growth cycle. The adverse effect of late transplanting can also be minimized by selecting a suitable cultivar as magnitude of yield reduction varies with the rice cultivars. No information is available on the differences between the existing rice varieties in relation to low temperature. The objective of the present study was to quantify the effect of low temperature on spikelet steritility and harvest index of rice and to select suitable cultivars for low temperature conditions as obtained in Kashmir valley.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* seasons of 2006 and 2007 at the Agronomy farm of Regional Research Station Wadura of Sher-e- Kashmir University of Agricultural Sciences and Technology-Kashmir (35°-52 N, 74°-89 E, 1587 m above mean sea level). The soil was a silty clay loam (Hapludalf) with 0.9% organic carbon and 280, 19.1 and 268 kg/ha of available N, P and K, respectively. Twelve treatment combinations of 3 transplanting dates (25 May, 10 June and 25 June) and 4 rice varieties ('Jhelum', 'Chenab', 'China 1039' and 'Shalimar Rice 1') were tested in randomized split plot design with three replications. The nursery was raised in low polythene tunnels during a period of low temperature (< 10°C). Three thirty two days old seedlings were transplanted at a spacing of 15 cm × 15 cm. A uniform dose of

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120 kg N, 60 kg P_2O_5 and 45 kg K_2O and 15 kg Zn SO_4 / ha was applied in all plots. Entire quantity of P, K and Zn and 50% N was applied before transplanting and the remaining nitrogen was applied in two equal splits at mid tillering (20 DAT) and panicle initiation (40 DAT) stages. Anthesis was determined when 50 % of panicles were visible in the center of the plot. The crop reached physiological maturity when 95 % of spikelets had turned yellow. Leaf area index was determined in situ by canopy analyzer Accupar LP-80 (Decagon devices USA). At panicle emergence, 12 randomly selected panicles (one from each separate plant) were tagged in each cultivar. These tagged panicles were harvested at physiological maturity and data on numbers of filled and unfilled grains per panicle were recorded. Each spikelet was pressed between forefinger and thumb to determine if the grain was filled or not. Number of filled grains included both completely and partially filled grains. Grain yield was calculated on 14% moisture basis. Correlation and regression analyses were performed to determine the relationship between yield mean maximum and mean minimum temperature (25 days mean maximum and mean minimum temperatures during the period from10 days before flowering to 15 days after anthesis) and grain yield. Mean maximum and mean minimum temperatures during the period from10 days before flowering to 15 days after anthesis (25 days window) during 2006 and 2007 are given for each cultivar. The harvest index was calculated using the formulae of Donald and Hambline (1976). Heat susceptibility index (S) was calculated for seed yield as per Fisher and Maurer (1978). S = (1-Y/Yp)/1-X/Xp, where, Y is mean grain yield of genotype in a stress environment (D3), Yp is mean grain yield of a genotype in a stress free environment (D1), X is mean Y of all the cultivars and Xp is mean Yp of all cultivars. S is the relative heat stress tolerance (S< 0.5 stress tolerant, S> 0.5-1.0 moderlatly stress tolerant and S > 1.0 susceptible). Yield stability ratio (YS) was calculated by taking the ratio of seed yield under D3 (late) and D1 (Normal) conditions as per Lewis, (1954); 'YS = (Grain yield under D3/Grain yield under D1) X 100'.

RESULTS AND DISCUSSION

Weather

In general, weather conditions were normal (as obtained at Wadura) during rice growing season (Fig 1). Crop duration was longer under early transplanting as compared to late transplanting irrespective of cultivars, primarily due to the warmer weather conditions at critical anthesis stage in early sown crop. The low temperature along with short periods of sunshine in late August particularly under late transplanting were responsible for the lower percentage of grain filling (Singh and Singh, 2006).

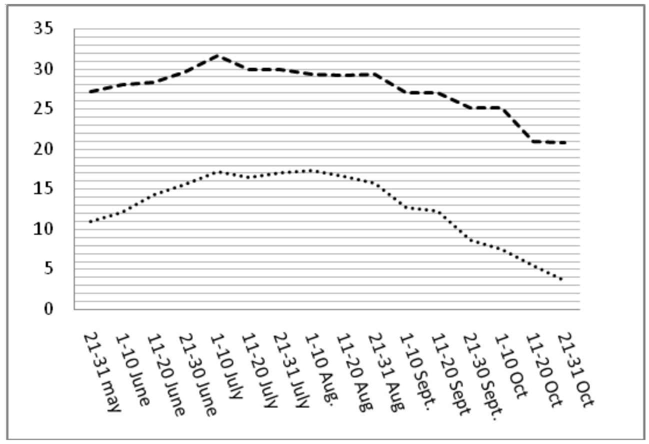

Fig. 1. Varaition in maximum and minimum temperature during the rice growing season during 10-day periods (Mean over last ten years)

The rice season in the temperate during this period valley is May through October, and the maximum temperature varies from 20.8 to 31.59 °C and minimum temperature fluctuates from 3.6 to 17.2 °C. There is strong relationship between mean temperatures (Max and Min) and rice production in Kashmir valley.

Yield attributes

Significant variation in leaf area index at anthesis, spikelets per panicle, filled grains and spike sterility percentage were recorded under late sowing (D2) compared to normal sown plants (Table 1). On an average across cultivars, late transplanting decreased yield attributes significantly. The maximum reduction in tillers/m^2, spikelets/ panicle, grains/ panicle and sterility occurred in 'Shalimar rice 1' followed by 'Jhelum' under late transplanting. However spikelet sterility was of the order of 50%, 46% and 36.3% in Shalimar rice 1, Jhelum and Chenab, respectively in late (25 June) transplanting. Among the yield components, spikelet fertility is the major contributor to the response of grain yield to rice cultivars (Yang *et al*., 2006). Among rice cultivars effective tillers/m^2, spikelets/ panicle grains per panicle and spikelet sterility ranged between 339.4-380.7, 110-133.8, 94.4-108.4 and 14.2-19.2% respectively under early transplanting (D_1). The significant variation in these characters was obviously due to their genetic potential and environmental response. Farrel *et al*, 2006 also reported quantitative photoperiodic response of rice cultivars. Cultivars 'Shalimar rice 1' and 'Jhelum' did not show much reduction in number of effective tillers and number of spikelets. However, reduction in grains per panicle was high and was due to floral sterility caused due to low temperature at critical anthesis stage when planted late. Negative effects (% increase from normal early sowing) of late sowing on spikelet sterility was greatest in Shalimar rice 1 (15.8-50.9%) followed by Jhelum (19.2-46%) and thus these cultivars are classified as highly susceptible to late transplanting. Cultivars Chenab (14.2-36.2%) and China 1039 (14.7-32.4%) were intermediate with respect to spikelet sterility caused by late transplanting. Under temperate valley condition low temperatures at and soon after anthesis can result in poor anther dehiscence, poor pollen germination and retarded pollen tube growth (Ziska *et al.*, 1996). All of these can cause enhanced spikelet fertility. Previous research has shown that minimum temperature at flowering was important in determining the level of cold damage caused by low temperature (Gunawardhan and Fukai, 2005)

Yield

Due to late transplanting, grain yield, straw yield, biological yield and harvest index significantly declined in all cultivars of rice under temperate valley conditions (Table 2). The negative effects of late transplanting on grain yield was greater than on biomass yield leading to drastic reduction in harvest index. Among the cultivars highest percentage reduction in grain yield (54.2%) due to late transplanting was recorded in 'Shalimar rice 1' followed by 'Jhelum' (52.2%). Due to late transplanting, harvest index was significantly decreased across all cultivars. Singh *et al.*, (2006) also reported that in temperate Kashmir late transplanted crop had a low grain yield associated with truncated grain growth because low temperatures coincide with anthesis; decrease in harvest index ranged from 1.7% to 39.6%. In general, harvest index is highly correlated with grain yield, which in turn is mainly correlated with spikelet sterility; a function of percent of unfilled grains (Yang *et al.*, 2006). Heat susceptibility index (S) which ranged from 0.82 %(Chenab) to 1.17% (Shalimar rice 1) and yield stability ratio (YS) range from 46.28% (Shalimar rice 1) to 62.06% (Chenab), among different rice cultivars (Table 3). Cultivars 'Chenab' and 'China 1039' showed temperature dipping tolerance at later stages (anthesis) and thus recorded low heat susceptibility index and higher yield stability ratio. Similarly cultivars 'Shalimar rice 1' and 'Jhelum' registered comparatively higher heat susceptibility index and lower yield stability ratio, showing their sensitivity to late transplanted conditions. These cultivars are susceptible if the temperature dips at later stages. Therefore an optimum transplanting time of 25 may for these cultivars was identified, which reduced the likeli-

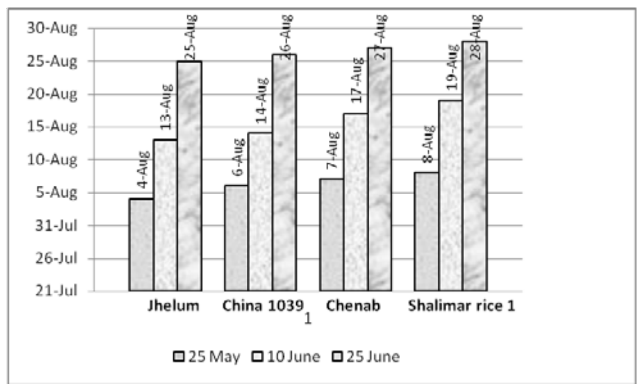

Fig. 2. Date of anthesis as influnced by different genotypes transplanted at different dates (mean over 2 years).

Table 1. LAI and Yield attributes of rice as influenced by genotypes and transplanting dates (Data pooled over 2 years of study)

	LAI at anthesis			Effective tillers/m^2			Spikelets/panicle			Grains / panicle			Sterility percentage		
	25 May	10 June	25 June	25 May	10 June	25 June	25 May	10 June	25 June	25 May	10 June	25 June	25 May	10 June	25 June
'Jhelum'	4.4	5.4	4.9	339.4	330.4	319.4	133.8	130.2	122.7	108.1	100.4	66.2	19.2	22.9	46.0
'China-1039'	4.2	5.2	4.6	380.7	376.8	372.3	112.3	108.0	103.0	95.8	89.1	69.6	14.7	17.5	32.4
'Chenab'	4.4	5.2	5.9	364.8	358.7	351.2	110.0	107.6	107.2	94.4	70.5	68.3	14.2	34.5	36.3
'Shalimar rice 1'	4.6	5.9	5.5	358.0	354.5	332.2	125.7	118.4	112.4	105.9	93.7	55.2	15.8	20.9	50.9
SEm+		0.03			4.09			2.96			1.75			1.14	
CD (P=0.05)		0.09			12.32			8.96			5.32			3.5	

Table 2. Yield, harvest index and days to maturity of rice genotypes as influenced by genotypes and transplanting dates (Data pooled over 2 years of study)

	Biological yield (t/ha)			Grain yield (t/ha)			Straw yield (t/ha)			Harvest index (%)			Days to maturity		
	25 May	10 June	25 June	25 May	10 June	25 June	25 May	10 June	25 June	25 May	10 June	25 June	25 May	10 June	25 June
'Jhelum'	18.25	18.06	13.01	8.46	7.05	4.06	9.79	11.01	8.95	46.35	39.03	31.21	145	141	138
'China-1039'	16.38	15.87	12.47	7.59	7.09	4.71	8.79	8.78	7.76	46.34	44.68	37.78	147	142	139
'Chenab'	16.21	16.07	12.12	7.34	7.28	4.56	8.87	8.79	7.56	45.28	45.30	37.62	148	145	140
'Shalimar rice 1'	18.59	16.12	14.10	8.66	6.34	3.98	9.93	9.78	10.12	46.58	39.33	28.23	149	147	141
SEm+		0.289			0.207			0.169			0.04			–	
CD P=0.05)		0.872			0.624			0.532			0.13			–	

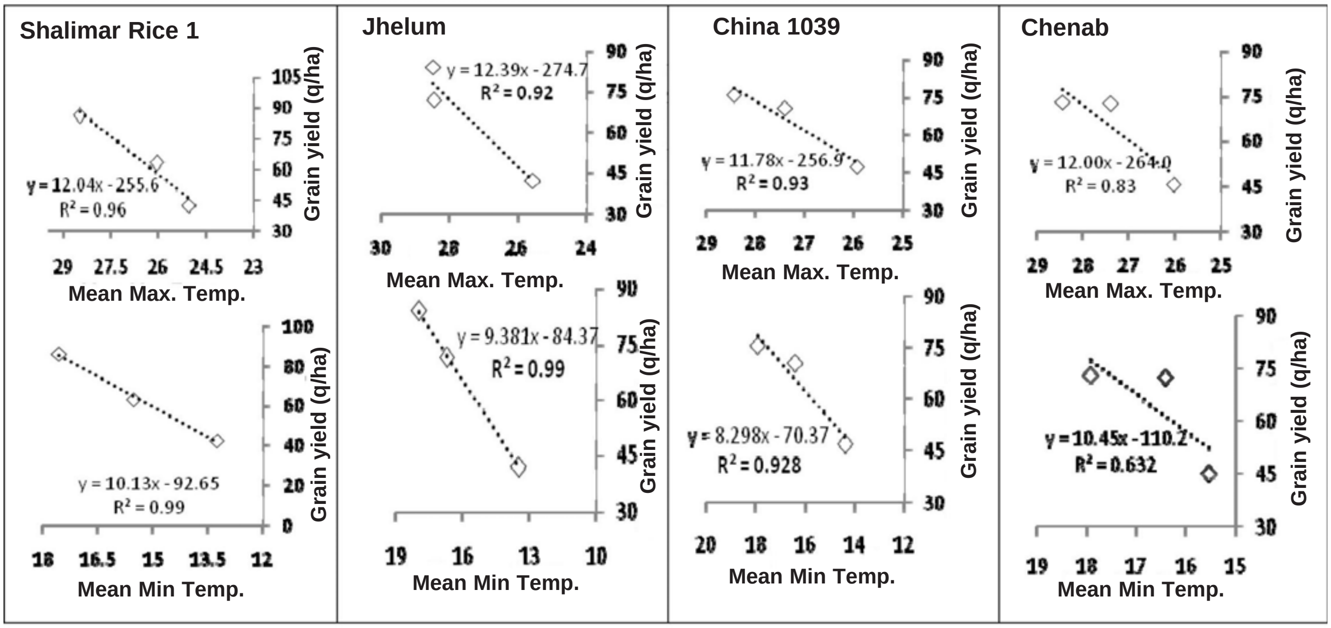

Fig. 3. Grain yield of different rice cultivars as influenced by mean maximum and minimum temperature at anthesis and grain filling stage (25 days window)

hood of encountering low temperature at later stages of rice crop. In all cultivars anthesis was delayed due to late transplanting (Fig.2).

Temperature and grain yield

In this study there was strong negative correlation between spikelet sterility and average temperature for 25 days during anthesis (10 days before flowering to 15 days after anthesis). Low temperature at anthesis decreased grain yield and response varied with cultivar (Singh *et al.*, 2006). The impact of temperature (both maximum and minimum) on grain yield showed linear response relationship among all cultivars. Response equations calculated due to regression analysis revealed that both maximum and minimum temperature has strong impact on grain yield (Fig 3). However minimum night temperature has comparatively higher impact. This is evident from higher intercept and slope in grain yield on minimum temperature response equations. This further supports the finding that reduction in harvest index due to late transplanting is mainly due to impact of low temperature at critical anthesis and grain filling stage.

Thus this study leads to the conclusion that there are two approaches for reducing losses from low temperature induced sterility in rice in Kashmir valley. Varieties with greater tolerance to low temperature would offer the simplest solution for the growers. The other possible solution is proper planting time,10 June or earlier. In the present study rice cultivar ‘Shalimar rice-1’ and ‘Jhelum’ showed the higher decrease in grain yield than ‘China-1039’ and ‘Chenab’ due to late planting.

Table 3. Heat susceptibility index and yield stability index of rice cultivars growing in temperate Kashmir. (Data pooled over 2 years of study)

Rice cultivars	Heat Susceptibility Index (S)	Yield Stability index
‘Jhelum’	1.13	47.99
‘China-1039’	0.83	62.06
‘Chenab’	0.82	62.13
‘Shaliamr rice 1’	1.17	46.28

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