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Effect of inter and intra seasonal variability in meteorological parameters on rice productivity in central Punjab*

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ABSTRACT

A study was conducted to ascertain the role of meteorological parameters on year to year variability in rice yield in Punjab using 12 years (2000-11) data of Ludhiana district. The rice growing season was divided into three stages (entire rice season, vegetative stage and reproductive stage) and the meteorological data during these stages were correlated with the rice yields. Highly significant (p=0.05) positive correlation was noticed between grain yield and sunshine hours received during entire rice season and vegetative stage of the crop. The maximum temperature during entire rice season and vegetative stage was significantly (p=0.10) and positively correlated with grain yield. During all three stages maximum relative humidity had significantly negative correlation with grain yield. Rainfall during vegetative stage and number of rainy days during reproductive stage were significantly and negatively correlated with grain yield. After studying the deviation of meteorological parameters from respective normals during high and low yield years and the correlation of meteorological parameters with rice yield it can be concluded that in the central parts of the Punjab sunshine hours play a major role in determining the productivity of rice.

Key words: Rice, Punjab, maximum, minimum, temperature, sunshine hours.

Rice (*Oryza sativa* L.) is one of the most important cereals cultivated in the world as well as in India and Punjab. It is a staple food of more than 50 per cent of the world's population (Fageria, 2007) and it supplied 20 per cent of calories required by world and 31 per cent required by the Indian population, in the year 2005 (Anonymous, 2011). More than one billion farmers from over a hundred countries make their living from rice. More than 90 per cent of the world's rice is grown and consumed in Asia alone (Sharma, 2003). On an average, an Indian consumes 83 kg rice per year. According to Agricultural Policy Vision 2020 of ICAR, India will need 112.4 million tonnes of rice in the year 2020.

The plants grow to their best under a range of abiotic factors and any deviation from optimum range will lead to aberrant changes in physiological processes in the plant and the plant may experience stress (Orcutt and Nilsen, 2000). Under changing climatic scenario, extreme of temperatures and rainfall events are predicted. These changes will most likely make the stresses even more common and severe. Increasing temperature may be a potential threat to rice production because high temperature can affect rice production at all stages of development, particularly during flowering, when it causes spikelet sterility. It also increases plant respiration, affects photosynthesis and shortens the grain-filling period, all of which leads to lower productivity (Peng *et al.*, 2004). Samui (1999) reported that in India the maximum rice yield was observed when rainfall ranged between 100-115 cm, sunshine hours between 250-350 hours for photo-insensitive varieties, maximum and minimum temperature ranged between 29-32°C and 23-25°C, respectively. These parameters vary yearly and intra and inter-seasonal variations play a pivotal role in determining the final crop yields (Prabhjyot-Kaur and Hundal, 2009). Therefore, the present study was conducted, to analyze the effect of variations in inter- and intra-seasonal meteorological parameters on rice yields in Punjab.

MATERIALS AND METHODS

The historical rice yields of district Ludhiana for the past twelve years (2000-2011) were taken from the "Statistical Abstracts" of Punjab. Meteorological data required for the study was collected from the Meteorological Observatory,

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Table 1: Weekly maximum and minimum temperature deviation from normal at Ludhiana the years of high (2004 & 2009) and low (2010 & 2011) rice yield

Month	SMW	Normal maximum temperature(^oC)	Normal minimum temperature(^oC)	Deviation from normal							
				Maximum temperature (^oC)				Minimum temperature (^oC)			
				2004	2009	2010	2011	2004	2009	2010	2011
June	22	39.7	24.0	-0.1	-0.6	0.5	-3.4	0.4	1.6	1.5	0.1
	23	39.4	25.1	-3.3	2.2	-4.9	1.3	-0.1	-0.1	-2.1	0.3
	24	38.2	25.5	-1.6	-0.5	0.7	-1.5	0.8	-1.3	-0.3	0.6
	25	37.4	26.1	-4.1	3.4	4.3	-2.2	-1.9	-1.5	3.0	0.0
	26	36.2	26.5	0.0	2.2	0.8	-5.2	-0.6	0.0	0.2	-1.5
July	27	35.3	26.0	2.0	1.1	-3.1	-1.1	2.8	0.5	-0.1	0.5
	28	34.3	26.2	1.1	-1.1	0.0	-0.2	1.0	0.5	0.7	1.0
	29	33.9	26.0	1.5	0.9	-2.4	-0.2	0.3	0.9	1.5	0.3
	30	33.6	26.0	2.3	-2.3	-0.4	-0.8	1.2	0.1	0.9	1.3
Aug	31	33.0	25.9	-1.4	1.3	-0.3	1.6	-1.3	1.3	1.6	0.8
	32	33.2	25.8	-0.1	2.8	0.1	-0.8	0.5	2.9	1.2	1.4
	33	33.5	25.4	-0.2	-0.1	0.5	-3.6	1.3	1.9	1.3	-1.4
	34	33.5	25.3	-1.8	0.1	-1.0	-0.6	0.0	0.2	0.6	0.9
	35	33.6	24.8	1.1	-0.7	-1.4	-0.6	1.0	0.1	1.0	2.1
Sep	36	33.5	24.0	1.9	-2.1	0.6	-2.0	0.2	-0.7	1.9	1.7
	37	33.3	23.1	0.2	-2.8	-0.7	-1.3	3.0	-0.7	0.9	2.3
	38	33.7	22.3	-0.1	0.6	-3.1	-1.9	1.3	2.0	-0.5	0.6
	39	33.4	20.7	1.1	1.3	-3.3	-0.7	-0.2	4.0	0.5	1.5
Average	34.9	24.9	-0.1	0.3	-0.7	-1.3	0.5	0.7	0.8	0.7	

Punjab Agricultural University, Ludhiana (30æ%562 N latitude, 75æ%522 longitude and at an altitude of 247 m above mean sea level). The normal meteorological data for Ludhiana were computed from daily weather data for the past 38 years (1970-2007). The weekly average values of different meteorological parameters were used during the study to calculate the deviations from the normal (actual - normal). These averages of actual meteorological data were also used for calculation of correlation coefficient with rice yield**.** Weekly deviations from normal meteorological parameters during each rice crop season were calculated to study the influence of deviation in meteorological parameter from its normal value on rice yield as these deviations directly affect the growth and final yield of crop.

RESULTS AND DISCUSSION

Amongst the twelve recent crop years under study maximum yield of 4692 kg ha^{-1} was recorded during *kharif* 2009. The deviation of weekly maximum and minimum temperature, sunshine hour and rainfall from normal are presented in Table 1 and 2. The inter and intra-seasonal deviation of the meteorological data for two highest and lowest yielding years revealed the following facts:

High rice yield years (2004 and 2009)

The perusal of the weekly meteorological data (Table 1) revealed that deviations in maximum and minimum temperature from normal were in the range of -4.1 to +2.3^oC and -1.9 to +3.0^oC, respectively. The high productivity of rice recorded during 2004 may be due to above normal

Table 2: Weekly sunshine hours and rainfall deviation from normal at Ludhiana during the years of high (2004 & 2009) and low (2010 & 2011) rice yield

Month	SMW	Normal Sunshine (hours)	Normal Rainfall (cm)	Deviation from normal							
				Sunshine hours (Hrs)				Rainfall (mm)			
				2004	2009	2010	2011	2004	2009	2010	2011
June	22	10.5	3.4	-1.3	-1.1	-1.6	0.0	-3.4	-3.4	0.4	29.4
	23	10.1	14.9	-0.8	-0.7	-1.0	0.0	5.1	-14.9	9.3	-6.1
	24	9.7	11.2	0.9	-3.2	0.4	-2.1	4.2	-5.2	-11.2	137.4
	25	7.8	17.1	-3.2	5.1	-0.2	-2.2	2.9	-17.1	-14.3	58.0
	26	8.2	33.3	0.5	2.1	-1.9	-5.3	-33.3	73.3	-22.6	71.3
July	27	7.9	53.8	2.6	2.4	-3.6	-1.2	-53.8	-53.8	102.4	-27.0
	28	6.9	58.6	-1.3	0.0	0.7	-1.0	-41.6	3.3	39.0	-34.6
	29	6.8	45.0	2.2	0.9	-6.1	-1.2	-44.4	57.6	66.2	0.4
	30	6.5	41.3	1.1	0.4	-1.9	-4.2	-41.3	268.3	-29.1	-22.5
Aug	31	6.2	58.2	-2.2	1.0	2.1	5.1	-5.4	-35.2	-55.8	-31.1
	32	6.3	46.8	1.3	1.7	-2.7	-2.3	17.0	-46.8	-39.0	397.0
	33	5.8	28.8	1.0	-2.4	-2.1	-0.9	59.5	-4.0	17.4	3.3
	34	8.1	42.8	-1.7	1.9	-3.3	-2.2	-7.8	-5.6	6.6	-38.8
	35	8.1	44.3	2.8	-2.8	-1.2	-4.0	-44.3	5.9	-35.5	-36.9
Sep	36	8.3	39.8	2.8	0.3	-2.8	-7.3	-39.8	-32.3	-9.8	12.7
	37	8.7	17.5	-1.1	1.4	-2.5	-3.0	-17.5	44.9	10.5	106.1
	38	9.1	23.0	-1.8	-0.2	-2.9	0.1	-23.0	-23.0	37.5	-23.0
	39	9.1	11.8	0.6	0.4	1.0	0.6	-9.2	-11.8	-11.8	-11.8
Seasonal total		1010	591.4	+17	+50	-208	-218	315.3	791.8	651.8	1175.4

sunshine hours (+17 hours) coupled with below normal rainfall (-276 mm) as compared to normal during the crop season (Table 2). Also the timing of the rainfall (rainfall received during mid June and first three weeks of August) was an important contributing factor. During rest of the period the weather remained dry.

During the crop year 2009 the deviation in maximum and minimum temperature (Table 1) from normal was within the range of -2.8 to +3.4^{o}C and -1.5 to +4.0^{o}C, respectively. The higher productivity recorded during 2009 may be due to above normal sunshine hours (+50 hour) as compared to normal during the crop season (Table 2). A well distributed rainfall of +200 mm above normal was recorded during the crop season. Rainfall received during the months of end June and July, i.e., the transplanting and tillering phase of rice and during the second week of September (44.9 mm) which proved beneficial for grain filling of rice.

The perusal of the meteorological data during 2004, 2005 and 2009 (high yield crop years) revealed that clear sky conditions (i.e. sunshine hours more than 1010 hours from transplanting to maturity stage of rice) (Table 4) coupled with well distributed rainfall (dry weather from 2nd week of September onwards upto maturity stage) are the conducive weather conditions for obtaining high rice yields in Punjab state.

Low rice yield years (2010 and 2011)

The perusal of the meteorological data revealed that the sunshine hours were below normal by -208 hour (Table 2), i.e., cloudy weather was observed during the major part

Table 3: Crop stage wise sunshine hours during low rice yield (<4000 kg ha^{-1}) years at Ludhiana

Crop growth phase	Normal	2000	2001	2010	2011
Vegetative stage	609	529(-13%)*	526(-13%)	498(-18%)	508(-16%)
Reproductive stage	401	462(15%)	454(13%)	304(-24%)	284(-29%)
Transplanting to Physiological Maturity	1010	991 (-1.9%)	980 (-2.9%)	802 (-20.6%)	792 (-21.6%)

*Figures in parenthesis represent per cent deviation from the normal

Table 4: Crop stage wise sunshine hours during high rice yield (>4500 kg ha^{-1}) years at Ludhiana

Crop growth phase	Normal	2004	2005	2007	2009
Vegetative stage	609	608(-0.1%)*	612(0.4%)	568(-6%)	669(9%)
Reproductive stage	401	419(4%)	415(3%)	340(-15%)	391(-0.02%)
Transplanting to Physiological Maturity	1010	1027 (1.7%)	1027 (1.7%)	908 (-10.1%)	1060 (4.9%)

*Figures in parenthesis represent per cent deviation from the normal

Table 5: Correlation coefficients of rice yield with weekly meteorological parameters at Ludhiana (*Kharif* 2000 to 2011)

Crop Growth phase	Temperature		Sunshinehour	Relative humidity		Rainfall	Rainy Days
	Tmax	Tmin		RH max	RH min		
Vegetative Phase	0.54**	0.06	0.59*	-0.55**	-0.41	-0.50**	-0.46
Reproductive Phase	0.27	0.17	0.35	-0.49**	-0.32	-0.10	-0.53**
Transplanting to Physiological Maturity	0.54**	0.13	0.62*	-0.54**	-0.44	-0.44	-0.43

* Significant at 5% level of probability** Significant at 10% level of probability

of crop growing season. A well distributed rainfall of +60 mm above normal (received during the months of July, August and September). However, a rainfall of 10.5 and 37.5 mm during 37 and 38 Standard Meteorological Week (2nd and 3rd week of September), respectively were received which coupled with below normal sunshine hours were not beneficial for grain formation of rice. The temperature scenario, i.e., deviation in maximum and minimum temperature from normal was within the range of -4.9 to +4.3^{o}C and -2.1 to +3.0^{o}C, respectively may not be a major contributor towards the reduction in rice yield (Table 1).

Similar to crop year 2010, during the crop year 2011 a consistently cloudy weather was observed and the sunshine hours were below normal by -218 hour (Table 2). The rainfall scenario was also not favourable as a very heavy rainfall of +584 mm above normal was recorded during whole crop season except in the month of July. Also a rainfall of 12.7 and 106.1 mm was received during 36 and 37 Standard Meteorological Week (Ist fortnight of September), respectively which coupled with a consistently cloudy weather proved unfavorable for grain development of the crop. The deviation in maximum and minimum temperature from normal was within the range of -5.2 to +1.6^{o}C and -1.5 to +2.3^{o}C, respectively (Table 1).

The perusal of the data revealed that the normal value of sunshine hours during the rice crop season is 1010 hour (609 hrs during vegetative stage and 401 hrs during reproductive stage) for Ludhiana. During the low rice yield years, i.e. 2000 and 2001 the sunshine hours were 13% less than normal during the vegetative stage of rice (Table 3). During the entire rice season of low rice yield years i.e. 2010 and 2011 the sunshine hours were 21 and 22% less than normal, respectively, and this could be the reason for low rice yields during these years. Sandhu *et al* (2012) observed at Ludhiana from a research trial conducted for two years i.e. 2009 (high yield year) and 2010 (low yield year) that the mean grain yield during 2010 was significantly (compared by t test at 5% level of probability) lower by 7.78% than that obtained during 2009, owing to unfavorable weather conditions that prevailed during 2010. The study revealed that that during 2010 average number of panicles m^{-2} were less by 2.69% than 2009. It might be due to less sunshine hours received during 2010 after transplanting of the crop to 90 days after transplanting. The lower sunshine hours after heading during 2010 might have reduced the supply of current photosynthates leading to a reduction in weight of grains $panicle^{-1}$ by 3.77%. These observations are supported from the findings of Mahajan *et al* (2009) who reported that rice receiving more sunshine hours at tillering stage produced more number of panicles m^{-2} and hence more grain yield. The results of present study also get support from Jadhav (1987). He reported from Maharashtra (India) that in rice, partial shading (45-50 % reduction in sunlight) resulted in reduction of grain yield, number of panicles $plant^{-1}$, number of filled grains $panicle^{-1}$ and harvest index whereas an increase in sterility per cent was reported.

Correlation analysis

The correlation analysis revealed that sunshine hours is positively and significantly (p=0.05) correlated with grain yield (Table 5). Maximum temperature also exhibited a similar trend but at 10% level of probability. During all three stages maximum relative humidity had significantly negative correlation with grain yield. Rainfall during vegetative stage and number of rainy days during reproductive stage were significantly and negatively correlated with grain yield.

CONCLUSION

The analysis of the data revealed that during high yield years range of deviation of maximum temperature from normal was less as compared to that in low yield years. However, in case of minimum temperature range of deviation from normal was slightly more in high yield years than low yield years. The maximum temperature during the entire growth period and vegetative stages was significantly (p=0.10) and positively correlated with grain yield. During all three stages maximum relative humidity had significantly negative correlation with grain yield. Rainfall during vegetative stage and number of rainy days during reproductive stage were significantly and negatively correlated with grain yield. Highly significant (p=0.05) positive correlation was noticed between grain yield and sunshine hours during entire growth period and vegetative stages of the crop. The perusal of the meteorological data during low yield crop years revealed that cloudy sky conditions (20 % or more reduction in actual sunshine hours from a normal of 1010 hours from transplanting to maturity stage of rice crop) coupled with heavy rainfall events especially during the month of September are the main contributing factors towards reduction in rice yields in during low yield years in the Punjab state.

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