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Short Communication

Variability in meteorological parameters during *kharif* season and its impact on rice crop at Ludhiana, Punjab, India

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Climate as whole and prevailing weather conditions like temperature, rainfall and sunshine hours directly influence agricultural production. The variability in extreme temperatures at different crop stages has significant impact on the growth of the crop. Temperature, sunshine hours and rainfall are important meteorological parameters which affect rice growth and production. Under Punjab conditions, the temperature range required for germination and optimum growth of rice is 25-30°C and 30-42°C, respectively (Singh *et al*., 2010). Temperature and sunshine duration together play a significant role in rice production. High temperature during grain filling or reproductive stage declines the yield. The most important temperature effects are generally found during the ear development stage. If the temperature is extremely high, the grain development stage is affected. Increased temperature above normal has been observed to interfere in the maturity of rice and decrease the grain yield under Ludhiana conditions (Kaur, 2016). Therefore, sowing time of rice must be selected so that the critical stages of rice crop coincide with the favourable weather conditions (Dari *et al.,* 2017). Hundal *et al.* (2005) also reported the increasing trend in minimum temperature (0.4-1.4 °C) over past 30 years for Ludhiana. Sunshine hours play an important role in central parts of Punjab in determining rice productivity and phenology (Aggarwal and Mall, 2002). An increase in the number of cloudy days and rainfall especially during grain filling stage induces a significant loss in yield and results in poor grain quality. The combined effect of increased temperature, altered pattern of rainfall and water stress would lead to decrease in rice productivity. Thus, variability in meteorological parameters affects the growth and yield of rice crop. Under changing climatic conditions, variations in different meteorological parameters during rice growing season are responsible for determining the rice yield. Keeping all this in view, the present study was undertaken to assess the changes in temperature, rainfall and sunshine hours at Ludhiana and its impact on yield and yield attributing attributes of rice crop.

The historical data on maximum and minimum temperatures, sunshine hours and rainfall of Ludhiana district (2007-2017) were collected from the Agrometerological Observatory, Punjab Agricultural University Ludhiana and compiled to study the effect different meteorological parameters (temperature, sunshine hours and rainfall) on rice yield. The normal were taken from past 30 years data. The weekly sunshine hours and rainfall were correlated with rice yield.

Variability in meteorological parameters during June to October

Variability in climatic parameters (temperature, rainfall and solar radiation) effects crop growth and yield. Under Punjab conditions, the favourable range of temperature which affects the rice yield was 20-40 °C. The annual variability in maximum and minimum temperatures recorded for the last 30 years demonstrated that with an increase in temperature the rate of leaf senescence hastened which leads to less leaf area index and total biomass and ultimately yield reduced. For the past 20 years, it can be inferred that while temperatures depict an increasing trend, rainfall has shown a decreasing one.

Maximum and minimum temperatures

Analysis of the historical data for the period 2007-2017 illustrates an increase in the trends of both the maximum and minimum temperatures in Ludhiana. The maximum temperature showed the increasing trend at the rate of 0.1 °C $year^{-1}$ from June to October while the minimum temperature showed increasing trend at the rate of 0.14 °C $year^{-1}$ for the same period (Table 1). Gill *et al*. (2010) had also reported that during August month (three-yearly moving averages), the maximum temperature displayed an increasing trend and values remained close to normal at Ludhiana.

Sunshine hours

Sunshine hours (SSH) during the rice growing period

Table 1: Rate of change in different meteorological parameters at Ludhiana during *rice* growing season (2007-2017)

Month	Maximum temperature (ºC year^{-1})	Minimum temperature (ºC year^{-1})	Sunshine hours (hours year^{-1})	Total rainfall (mm year^{-1})
June	0.10	0.14	0.08	-3.7
July	0.06	0.09	0.01	-9.3
August	0.03	0.01	-0.03	-10.6
September	0.14	0.12	-0.02	-5.27
October	0.08	0.13	-0.15	-1.78

Table 2: Correlation coefficients between rice yield and sunshine hours at different phenological stages (2007-2017)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Correlation coefficient (r)
Yield (q ha-1)	43.7	45.3	44.7	46.9	44.0	42.5	45.4	44.2	43.5	45.9	48.1	
Tillering												
SMW 26	5.5	6.1	10.36	6.26	2.9	7.63	7.81	4.77	5.50	6.34	6.01	0.69*
SMW 27	6.77	4.01	10.29	4.29	6.71	7.36	4.03	8.47	6.77	5.03	7.83	0.23
SMW 28	7.03	6.29	6.94	7.64	5.99	6.46	7.19	9.40	7.03	7.17	7.06	0.19
SMW 29	7.90	6.53	7.66	0.73	5.57	8.57	5.3	6.00	7.90	6.00	6.30	-0.26
SMW 30	7.37	8.91	4.30	4.59	2.33	5.71	8.67	1.71	7.37	5.14	7.24	0.21
Booting												
SMW 31	4.80	4.77	7.21	8.29	7.10	4.59	5.99	6.21	4.8	6.24	3.57	0.60*
SMW 32	5.96	6.29	8.01	3.66	4.00	3.86	3.21	6.36	5.96	3.77	5.34	-0.15
Panicle initiation												
SMW 33	6.99	4.51	3.46	3.69	4.86	6.77	4.21	8.47	6.99	7.01	9.03	0.06
SMW 34	6.71	8.49	9.97	4.84	5.89	2.07	6.56	10.07	6.71	4.84	5.63	-0.12
SMW 35	7.66	9.13	5.30	6.87	4.09	4.56	9.20	4.37	7.66	5.91	6.10	0.11
Soft dough												
SMW 36	5.39	9.93	8.36	5.51	1.06	6.49	7.86	3.16	5.39	10.35	9.50	0.46
SMW 37	8.13	9.76	7.04	6.23	5.7	7.03	8.66	7.74	8.13	9.21	7.89	0.69*
SMW 38	5.96	6.07	8.96	6.21	9.26	7.40	8.67	8.93	5.96	4.39	8.06	-0.50
Hard dough												
SMW 39	7.11	9.94	9.53	10.26	9.76	10.21	6.7	9.67	7.11	2.37	9.03	0.56*
SMW 40	10.33	6.27	8.23	6.83	9.54	9.97	4.84	2.87	10.33	2.09	9.93	0.41
SMW 41	9.46	8.47	9.34	5.16	8.34	9.3	2.06	8.33	9.46	8.76	7.10	0.31
SMW 42	8.14	8.24	8.13	3.87	8.86	7.53	9.04	8.80	8.14	8.84	8.40	0.19
SMW 43	8.14	8.24	8.13	3.87	8.86	7.53	9.04	8.80	8.14	8.84	8.40	0.19

*Significant at 5% level

from June-October were analyzed and presented in Table 1. During June, there was an increasing trend in SSH (0.075 hours year^{-1}). In the following month of July, there was an increasing trend in SSH at the rate of 0.009 hours year^{-1}. Further during month of August, September and October, the data indicated there was decreasing trend of SSH @ 0.02 hours year^{-1}, 0.034 hours year^{-1} and 0.15 hours year^{-1}, respectively.

Table 3: Correlation coefficients between rice yield and rainfall at different phenological stages (2007-2017)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Correlation coefficient (r)
Yield (q ha-1)	43.7	45.3	44.7	46.9	44.0	42.5	45.4	44.2	43.5	45.9	48.1	
Tillerng												
SMW 28	68.6	54.5	61.9	140.8	47.7	36.7	31.5	0.0	68.6	29.8	9.8	0.53*
SMW29	0.0	55.6	102.6	68.0	10.9	21.6	2.2	6.8	0.6	28.5	25.0	0.43
SMW 30	1.2	9.6	309.6	1.7	3.7	7.1	34.4	110	1.2	104.2	37.4	0.62*
Total	69.8	119.7	474.1	210.5	62.3	65.4	68.1	116.8	69.8	162.5	72.2	
Booting												
SMW31	53.2	85.2	23.0	2.4	46.7	33.1	78.4	67.8	53.2	3.0	20.6	-0.24
SMW 32	6.2	47.4	0.0	7.8	23.8	0.5	66.8	38.4	0.0	8.0	0.0	0.75*
Total	59.4	132.6	23.0	10.2	70.5	33.6	145.2	106.2	53.2	11.0	20.6	
Panicle initiation												
SMW 33	29.0	23.8	24.8	46.2	176.8	12.0	130.6	0.0	6.2	27.4	15.0	0.43
SMW 34	38.2	6.2	37.2	49.4	11.7	39.9	4.5	0.0	29.0	45.2	11.6	-0.27
SMW 35	16.1	49.0	50.2	8.83	0.6	18.6	252.1	11.2	38.2	6.0	100	-0.45
Total	83.3	79.0	112.2	104.4	189.1	70.5	387.2	11.2	73.4	78.6	126	
Soft dough												
SMW 36	3.6	24.9	6.8	28.0	1.6	33.2	12.2	81.8	16.1	0.0	2.4	-0.15
SMW 37	23.1	0.0	62.4	60.5	293	28.9	0.0	48	3.6	0.0	0.0	-0.10
SMW 38	0.0	19.8	0.0	0.0	23.2	17.4	0.0	0.0	23.1	2.4	7.4	0.36
Total	26.7	44.7	69.2	88.5	317.8	79.5	12.2	48	26.7	2.4	7.4	
Hard dough												
SMW 39	0.0	0.0	0.0	0.0	0.0	0.0	25.3	0.0	0.0	12.6	0.0	-0.34
SMW 40	0.0	19.8	26.2	0.0	0.0	0.0	22.4	4.8	0.0	0.0	0.0	0.36
SMW 41	0.0	0.0	0.0	0.0	1.0	0.0	1.8	5.6	0.0	0.0	0.0	0.06
SMW 42	0.0	19.2	0.0	0.0	15.2	0.0	0.0	0.0	0.0	0.0	0.0	-0.09
SMW 43	0.0	0.0	0.0	8.8	0.0	3.8	0.0	2.5	0.0	0.0	0.0	-0.24
Total	0.0	39.0	26.2	8.8	16.2	3.8	49.5	12.9	0.0	12.6	0.0	

*Significant at 5% level

Total rainfall

The historical rainfall data of Ludhiana (from 2007 to 2017) were analyzed during the rice-growing period i.e. from June to October and indicated a decrease in rainfall from 2011 to 2015 (Table 1) at the rate of - 3.7 mm year^{-1}. Variability in rainfall during July (from 2007 to 2010) illustrated a decreasing trend at the rate of 9.3 mm year^{-1}. Similar decreasing trend was observed in August month where the rate of decrease was -10.60 mm year^{-1}. Thus, rainfall was below normal in 2009, 2010, 2012, 2014, 2015 and 2016. Variability in rainfall from 2007 to 2010 during September showed decreasing trend at the rate of -5.27 mm year^{-1}. The rainfall remained below normal for most of the years. Variability in rainfall during October showed the decreasing trend at the rate of -1.78 mm year^{-1}. Thus overall the rainfall from June to October (2007 to 2017) showed a decreasing trend of rainfall in Ludhiana during the rice-growing season. Prabhjyot-Kaur *et al.* (2010) analyzed annual and seasonal variability in rainfall from historical daily meteorological data for Ludhiana. They reported that there were large variations in rainfall.

Relationship of rice yield and yield contributing attributes with weather variables

Sunshine hours

Sunshine hours is one of the most important factor in predicting rice yields, therefore, bright sunny weather during flowering is necessary as grain yield in rice comes from post-flowering photosynthesis. Low light intensity acts as a stress and is the major determinant for rice productivity. Keeping this in view, the sunshine hours (weekly) were correlated with rice yield at different phenological stages (Table 2). During the tillering phase, the relationship between grain yield and sunshine hours was positive except in 29 SMW. Gupta (2002) had reported that crop height and tiller number were positively correlated with sunshine hours.

From the time of booting till grain filling, sunshine hours were most important. Similarly there was significant positive correlation between sunshine hours and spikelet count during 31SMW. It was also observed that the number of spikelets per meter square was increased with bright sunshine hours. Mahajan (2009) had also reported that low radiation during the flowering phase led to spikelet sterility and hence decreased grain yield.

During soft dough and hard dough stage, there was positive correlation between sunshine hours and yield which signified that sunshine hours were important. Thus low sunshine hours led to a loss of grains per panicle, reduced dry matter accumulation and increased proportion of unfilled grains. Sattar *et al.,* (2017) had reported that bright sunshine hours up to 7 to 8 hours were necessary for the growth of rice.

Rainfall

Rainfall is an important weather parameter for the growth of rice. The water requirement for rice crop is very high and sufficient irrigation water to the crop at proper stages enhances its growth and development. It was observed that the correlation coefficient was found positive during the tillering phase of the crop (Table 3). During 28-30 SMW, positive correlations were observed between rainfall and rice yield which indicates that rainfall during the tillering stage is a prerequisite. Gupta (2002) had also reported that the number of rainy days during the tillering phase of the crop was led to an increase in the number of tillers per plant. During the booting and panicle initiation stage, the correlation was found to be positive. Balsubramaniam and Palaniappan (2004) reported that the panicle initiation stage and flowering stages were more sensitive to submergence. Negative correlation of grain yield with rainfall was observed during 36 and 37 SMW (soft dough stage). It signified that wet spells were detrimental for flowering till the time maturity was acquired. Heavy rainfall during the maturity phase reported a negative correlation between yield and the number of rainy days (Narayanan, 2004).

It can be concluded that the maximum and minimum temperatures depicted increasing trends during the period 2007-2017. While sunshine hours showed an increasing trend in June and July, rainfall depicted a decreasing trend for the period of August - September. Also, the trend in rainfall was decreasing during the rice-growing period. A negative correlation was observed with rainfall especially during the dough stage, which signifies that wet spells may prove detrimental during the flowering to maturity period.

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