Impact and variability of meteorological parameters on rice crop at Siddharthnagar, Uttar Pradesh, India

ABSTRACT

The present study explores the impacts and variability of meteorological parameter on the rice yields at Siddharthnagar of Uttar Pradesh, India. This study that the maximum and minimum temperatures during the period 2011 to 2020 show increasing trends. Whereas the duration of sunlight increased in June and July. Whereas the rainfall data shows decreasing trends for the period August-September. Furthermore, this study suggests that there was a decrease in rainfall trends during the paddy growing period. A negative correlation was observed with rainfall, particularly during the duff stage, indicating that wetting during the flowering to maturity period may be decisive. This study suggests that taking into account the variability in annual or seasonal temperature and rainfall in the region, the warming trend along with the temporally erratic rainfall is likely to have a significant impact on the paddy crop. Consequently, there is a great need to devise plans capable of dealing with the impact of current variability of meteorological parameters on paddy yields in this district of Uttar Pradesh by developing suitable alternatives to increase production in the paddy crop.

Key words: Meteorological parameter, impacts, alternatives.

Introduction

Year-to-year variability of meteorological parameters and extreme weather conditions, such as floods, droughts, heat and cold waves are regarded as the primary causes of annual fluctuations in yield. Variations in weather at the time of critical phases of crop growth can also have a significant impact on yield. Climate prognostication arise for India for the 2050s show a 2-4 °C increase in average temperature and decrease in the number of rainy days (Kumar et al. 2006). It is predicted that by 2100, the kharif period (June to October monsoon period in India) temperature would warm by a minimum of 0.7 °C - 3.3 °C and rainfall would be 7% to 37% wetter (Birthal et al. 2015). Also, these are studies that say that if capacity to uphold the rice yields in India are not enacted immediately, by 2050, India would be more of ~~ana~~ a foreign buyer of rice than an exporter (Teng et al. 2016; van Oort and Zwart 2017).

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If right, then the rationale of this study is questionable.

Uttar Pradesh is the most populated (199.6 million; 17% of India) state and has distinguished itself as the 'agricultural hub' on account of its largest share of rice area and production. This state also faces enormous stress on its water holdings due to the huge agriculture industry (Mall et al. 2006). As long as the rainfall fluctuation and change remains a menace for the water availability, it would keep sling in difficulties to cultivate the water-intensive crops. The rising concerns like the high climate variability, decreasing per capita water availability and the rising food demands of the growing national population are yet to be explored for their inter-dependencies to combat the crisis. This crisis is a horrify challenge for the contributor and the

decision makers, and to holder, they must look for effective adaptive part capable of assure sufficient water and food supplies for all.

Therefore, the present study aimed to changes in meteorological parameters of Siddharthnagar, Uttar Pradesh, and its impact on rice growth and yields. Also, an attempt has been made to analyze the impact of maximum temperature and minimum temperature, solar radiation data of weather upon phonological phases of rice crop with a special allusion to better agronomic management of weather restraint to ensure sustainable production in the zone. Thus changes in weather related factors affect the growth and yield of paddy crop. Variation in various weather related factors during the paddy growing season is responsible for determining the yield of paddy due to changing climatic conditions. Thus, keeping in view the changes in meteorological parameters, the present study was carried out to assess the change in temperature, precipitation and photoperiod in Siddharthnagar and its effect on yield.

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MATERIALS AND METHODS

The observed daily long-term maximum temperature and minimum temperature, solar radiation data from and rainfall data from 2011 to 2020 were obtained from the Indian Meteorological Department (IMD), New Delhi. Rice yield data were obtained from Krishi Vigyan Kendra, Sohna, Siddharthnagar, Uttar Pradesh, [Latitude 27° 18' 7.98''N, Longitude: 82° 35' 29.88'' E] conducted by Acharya Narendra Dev University of Agriculture and Technology Kumarganj, Ayodhya, Uttar Pradesh, located in the trai belt of Himalaya. Daily station weather data is utilized for identification of the mean spatial patterns and rainfall intensity trends. From mean and standard deviation (SD), the coefficient of variation (CV) is calculated. 0.05% significance level was applied to detect the trend in both temperature and rainfall data. For rice or kharif season, temperature extremes were considered whenever the temperature rose beyond 40 °C and fell below 15 °C, which might have affected the crop growth and development, and thus the final yield. Rainy days are categorized with threshold of ≥2.5 mm per day as given by criteria of IMD. Climate of experimental site is characterized as subhumid with an annual rainfall of 1001.5 mm, out of which about 89% is received from June to September. (Table 3) The soil of the experiment site was clay–loam in texture.

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RESULTS AND DISCUSSION

Variability in meteorological parameters during June to October

Variability in climatic parameters (temperature, rainfall and solar radiation) effects crop growth and yield. Under Siddharthnagar conditions, the favorable range of temperature which affects the rice yield was 15-40 ^{o}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. High temperature, especially during the night, leads to loss of reserved food through greater respiration (Peng et al. 2004). For higher grain yield, a day temperature of 25 to 32 °C and night temperature of 15 to 20 °C is preferable. Temperature beyond 35 °C influences both the pollen shedding as well as the grain filling. It is well known that moderate temperature of night and clear sunny weather during daytime is better

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for huge yield of rice, but temperature less than 15 °C is neither conducive for the panicle initiation nor for the crop growth (Rao et al. 2014).

Maximum and minimum temperatures

Analysis of the historical data for the period 2011-2020 illustrates an increase in the trends of both the maximum and minimum temperatures in Siddharthnagar. The maximum temperature showed the increasing trend at the rate of 0.3^{o}C year^{-1} from June to October while the minimum temperature showed increasing trend at the rate of 0.11 ^{o}C year^{-1} for the same period (Table 1). Increase in maximum temperature may cause cellular injury, lipid membrane per-oxidation, increase rate of respiration and photosynthesis. Rise in minimum temperature may cause poor growth, decline in photosynthesis rate which may finally culminate in negatively affecting the yield. This type of change in temperature influence the crop production through factors such as raised respiration, higher metabolism, evaporation failure and altering plant reaction to biotic stresses in different agro-climatic zones of the region (Rezaei et al. 2015).

Table 1: Change in different meteorological parameters at Siddharthnagar during *kharif season of paddy crop* (2011-2020)

Month	Maximum temperature(ºC year^{-1})	Minimum temperature (ºC year^{-1})	Sunshine hours (hours year^{-1})	Total rainfall (mm year^{-1})
June	0.03	0.11	0.06	-2.7
July	0.04	0.06	0.07	-4.2
August	0.02	0.01	-0.03	-6.4
September	0.07	0.08	-0.02	-4.12
October	0.06	0.11	-0.12	-2.24

Table 2: Analysis of correlation coefficients between rice yield and photoperiod with phenological stages (2011-2020)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Correlation coefficient (r)
Yield (q ha^{1})	44.8	46.4	46.8	46.9	42.0	42.6	45.6	44.2	44.6	46.8	
Tillering											
SMW 25	5.6	6.2	11.38	8.28	4.9	8.64	8.82	4.78	6.51	8.32	0.70*
SMW 26	8.77	5.01	10.30	4.30	6.72	7.38	4.04	8.48	6.78	5.04	0.24
SMW 27	8.03	6.30	6.95	7.65	5.98	6.48	7.20	9.42	7.04	7.18	0.20
SMW 28	8.90	6.51	7.68	0.74	5.58	8.58	6.4	6.02	7.92	6.02	-0.27
SMW 29	8.37	8.92	4.32	4.69	2.34	6.72	9.68	1.74	7.38	5.16	0.22
Booting											
SMW 30	4.82	4.78	7.22	8.28	7.20	4.58	5.98	6.22	4.6	6.26	0.62*

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SMW 31	5.98	6.30	8.02	3.68	4.02	3.88	3.22	6.38	5.98	3.78	-0.16
Panicle initiation											
SMW 32	8.99	5.51	6.46	4.69	4.88	6.78	4.22	8.48	6.98	7.02	0.08
SMW 33	8.71	9.49	8.98	4.86	5.88	2.08	6.58	10.08	6.72	4.85	-0.11
SMW 34	7.62	9.12	6.32	6.88	5.09	4.57	9.22	4.38	7.68	5.92	0.12
Soft dough											
SMW 35	6.39	9.94	8.38	5.52	1.08	6.48	7.88	3.18	5.38	10.36	0.48
SMW 36	8.14	9.78	7.05	6.24	5.8	7.04	8.68	6.76	8.14	8.22	0.68*
SMW 37	5.98	6.08	8.98	6.22	9.28	7.42	8.68	8.98	6.98	4.38	-0.52
Hard dough											
SMW 38	6.12	8.95	10.54	10.27	9.78	10.22	6.8	9.68	7.12	2.38	0.58*
SMW 39	9.34	6.28	8.24	6.84	9.56	9.98	4.85	2.88	10.34	2.08	0.42
SMW 40	9.48	8.48	9.36	6.14	7.36	9.4	2.08	8.34	9.48	8.78	0.32
SMW 41	8.12	8.26	8.14	3.88	8.88	7.54	9.05	8.82	8.15	8.85	0.18
SMW 42	8.16	8.25	8.14	3.88	8.88	7.54	9.06	8.82	8.15	8.85	0.18

*Significant at 5% level

Sunshine hours

Sunshine hours during the paddy growing season from June-October were analyzed and presented in Table 1. During June, there was an increasing trend in Sunshine hours 0.06 hours year^{-1}. In the following month of July, there was an increasing trend in Sunshine hours at the rate of 0.07 hours year^{-1}. During month of August, September and October, the data indicated there was decreasing trend of Sunshine hours 0.03 hours year^{-1}, 0.02 hours year^{-1} and 0.12 hours year^{-1}, respectively.

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Total rainfall

The historical rainfall data of Siddharthnagar (from 2011 to 2020) were analyzed during the rice-growing period i.e. from June to October and indicated a decrease in rainfall from 2013 to 2017 (Table 1) at the rate of - 2.7 mm year^{-1}. Variability in rainfall during July (from 2013 to 2017) illustrated a decreasing trend at the rate of -4.2 mm year^{-1}. Similar decreasing trend was observed in August month where the rate of decrease was -6.4 mm year^{-1}. Thus, rainfall was below normal in 2013, 2014, 2015 and 2016. Variability in rainfall from 2011 to 2017 during September showed decreasing trend at the rate of -4.12 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 -2.24 mm year^{-1}. Thus overall the rainfall from June to October (2011 to 2020) showed a decreasing trend of rainfall in Siddharthnagar during the rice- growing season. It can be seen that the district gets highest rainfall (34% of south west monsoon rainfall) in July month followed by August (31% of the south west monsoon rainfall). June and September receive 14% and 21% of south west monsoon rainfall,

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respectively. About 89% of annual rainfall receives during the southwest monsoon season only. The variability of monsoon and annual rainfall is 21% and 19% respectively.

Table 3: Rainfall statistics for the districts of Siddharthnagar, Uttar Pradesh for the four monsoon months, southwest monsoon season and annual.

DISTRICT	June		July		August		September		Monsoon		Annual	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
SIDDHARTH NAGAR	149.9	71	340.7	91	266.2	44	154.3	65	911.1	47	1001.5	58

Relationship of rice yield and yield contributing attributeswith meteorological parameters

Sunshine hours

Sunlight hours are one of the most important factors to estimate the production of paddy. Therefore, it is very important to have bright sunny weather during the pre~~i~~ and post-flowering of paddy. In paddy the grain is stressed due to low light intensity at the time of grain formation, hence low light intensity is the major determinant for paddy production. Keeping this in mind, the weekly sunlight hours were correlated with the paddy yield of different phenological stages. (Table 2). Shows a positive relationship between paddy yield and sunshine hours during the tailoring phase except in 28 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 30 SMW. It was also noticed that the number of spikelets per meter square was expanded with bright sunshine hours. Mahajan (2009) had also noted that low radiation during the flowering stage led to spikelet sterility and hence reduced grain yield. There was a positive correlation between sunlight hours and yield during the soft duff and hard duff stages. Which indicates that the hours of sunshine were beneficial and important during this time. Thus, due to the short sunshine hours led to grain loss, dry matter reduction and unfilled grain formation were observed in the earrings. 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 factor for the growth of paddy. The water requirement for paddy crop is very high, at different stages of the crop, sufficient water for irrigation proves beneficial for its growth and development. It is observed that a positive correlation has been observed during the tillering stage of the crop (Table 3). During 27-29 SMW, A positive correlation has been observed between rainfall and paddy yield, which indicates that rainfall

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during the tillering stage is pre-requisite and beneficial. 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. A negative correlation was observed between the yield of paddy with the rainfall during the soft duff stage (35 and 36 SMW). This indicates that the wet spell is crucial from the time of inflorescence to maturity. Heavy rainfall at the maturity stage shows a negative correlation between yield and the number of rainy days.

Table 4: Analysis of correlation coefficients between rice yield and rainfall with phenological stages (2011-2020)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Correlation coefficient (r)
Yield (q ha-1)	42.3	44.5	45.6	46.6	43.0	40.4	44.3	43.3	44.6	46.6	
						Tillerng					
SMW 25	69.4	55.6	63.8	68.8	49.9	46.6	49.4	1.1	69.7	32.9	0.55*
SMW26	2.2	56.7	75.6	69.0	20.8	20.7	2.4	6.9	2.8	35.6	0.45
SMW 27	2.4	10.2	85.6	02.7	4.6	8.2	36.5	90.2	2.2	90.2	0.64*
Total	74.0	122.1	225.0	142.4	75.3	75.5	88.3	98.2	74.7	158.7	
						Booting					
SMW 28	54.3	88.4	25.0	2.6	48.8	34.2	79.6	68.9	55.4	6.0	-0.27
SMW 29	8.3	49.6	1.1	8.9	29.4	0.6	65.8	39.2	2.2	9.0	0.77*
Total	62.6	138.0	26.1	11.5	78.2	34.8	145.4	108.1	57.6	15.0	
						Panicle initiation					
SMW 30	30.0	24.9	26.8	48.2	120.8	14.0	125.6	0.0	12.0	28.6	0.46
SMW 31	39.2	8.4	38.4	51.6	12.8	40.8	6.6	0.0	30.0	46.4	-0.28
SMW 32	18.1	48.0	51.2	6.83	2.6	20.6	152.1	12.4	40.4	8.0	-0.48
Total	87.3	81.3	116.4	106.6	136.2	75.4	284.3	12.4	82.4	83.0	
						Soft dough					
SMW 33	4.6	26.9	8.8	30.0	2.6	34.2	14.2	84.8	18.1	0.0	-0.16
SMW 34	24.1	0.0	63.4	62.5	29.0	30.9	0.0	50	6.6	0.0	-0.9
SMW 35	0.0	20.8	0.0	0.0	24.4	18.4	0.0	0.0	24.1	4.4	0.38
Total	28.7	47.7	72.2	92.5	56.0	83.5	14.2	48.0	48.8	4.4	
						Hard dough					
SMW 36	0.0	0.0	0.0	0.0	0.0	0.0	26.3	0.0	0.0	13.6	-0.33
SMW 37	0.0	20.6	28.2	0.0	0.0	0.0	24.4	4.9	0.0	0.0	0.35
SMW 38	0.0	0.0	0.0	0.0	2.0	0.0	2.8	4.8	0.0	0.0	0.07
SMW 39	0.0	20.2	0.0	0.0	16.2	0.0	0.0	0.0	0.0	0.0	-0.08

SMW 40	0.0	0.0	0.0	8.6	0.0	3.8	0.0	4.6	0.0	0.0	-0.26
Total	0.0	40.8	28.2	8.6	18.2	3.8	53.5	14.3	0.0	13.6	

*Significant at 5% level

CONCLUSION

It can be concluded from this study that the maximum and minimum temperatures during the period 2011 to 2020 show increasing trends. Whereas the duration of sunlight increased in June and July. Whereas the rainfall data shows decreasing trends for the period August-September. Furthermore, this study suggests that there was a decrease in rainfall trends during the paddy growing period. A negative correlation was observed with rainfall, particularly during the duff stage, indicating that wetting during the flowering to maturity period may be decisive. This study suggests that taking into account the variability in annual or seasonal temperature and rainfall in the region, the warming trend along with the temporally erratic rainfall is likely to have a significant impact on the paddy crop. Consequently, there is a great need to devise plans capable of dealing with the impact of current variability of meteorological parameters on paddy yields in this district of Uttar Pradesh by developing suitable alternatives to increase production in the paddy crop.

REFRENCES

Balasubramanian, P. and Palaniappan, S.P. (2004). *Principles and Practices of Agronomy*. p.84-85. Agrobios, India.

Birthal PS, Negi DS, KhanMd T (2015) Is Indian agriculture becoming resilient to droughts? Evidence from rice production systems. Food Policy 56:1–12.

Gupta, R.K., Hobbs, P.K. and Ladha, J.K. (2002) Resource conserving technologies: Transforming the rice wheat- system of Indo Gangetic plains. *Rice-wheat consortium***,** APAARI Publications pp:1-42.

Kumar KK, Sahai AK, Kumar KK, Patwardhan SK, Mishra PK, Revadekar JV, Pant GB (2006) High-resolution climate change scenarios for India for the 21st century. Curr Sci 90:334–345.

Mahajan, G., Bharaj, T.S. andTimsina, J. (2009). Yield and water productivity of rice as affected by time of transplantingin Punjab, India. *Agric. Water Manage.*, 96: 525-532.

Mall RK, Singh R, Gupta A, Srinivasan G, Rathore LS (2006) Impact of climate change on Indian agriculture: a review. Clim Chang 78:445–478.

Peng S, Huang J, Sheehy JE, Laza RC, Visperas RM, Zhong X, Khush GS, Cassman KG (2004) Rice yields decline with higher night temperature from global warming. Proc Natl Acad Sci U S A 101:9971–9975.

Rao BB, Chowdhary PS, Rao VUM, Venkateswarlu B (2014) Rising minimum temperature trends over India in recent decades: implications for agricultural production. Glob Planet Change 117:1–8.

Rezaei EE,Webber H, Gaiser T, Naab J, Ewert F (2015) Heat stress in cereals: mechanisms and modelling. Eur J Agron 64:98–113.

Sattar, A., Kumar, M., Vijaya Kumar P. and Khan, S.A. (2017). Crop weather relation in *kharif* rice crop. *J. Agrometeorol.*, 19(1)**:** 71-74.

Teng PPS, Caballero-Anthony M, Lassa JA (2016) The future of rice security under climate change, NTS report no. 4. Centre for Non Traditional Security Studies, Nanyang Technological University, Singapore, pp 4.

Van Oort PAJ, Zwart SJ (2017) Impacts of climate change on rice production in Africa and causes of simulated yield changes. Glob Change Biol 24:1029–1045.