Research Article

Characterization and Evaluation of Rice (*Oryza sativa L.*) Genotypes in Randomized Complete Block Design

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Abstract

To characterize, compare and evaluate rice yields and its attributing traits, two-season experimental trials were conducted in a randomized complete block design with a standard check Pant Dhan-4 in 2016 and 2017, respectively. The tested genotypes were statistically significant (p<0.05) based on traits such as days to flowering, days to maturity, number of effective tillers, panicle length, fertile and sterile grain number per plant and yield. The average grain yield of rice genotypes transplanted in 2016 (10153.85 kg/ha) was higher than 2017 (5598.38 kg/ha). The minimum night temperature during grain filling period in Kharif 2016 was lower than 2017 by as much as 3.41^{0}C and we conclude that the elevated night temperature was detrimental to rice productivity. The yield increment in 2016 might be due to favourable weather conditions and ideal night temperature during the crop growth and development phase. The findings confirm that climate variables have significant effects on yields but these effects vary among rice genotypes. The results also reveal that the Pantnagar crop is severely affected by extreme temperature. Only four genotypes were found completely resistant to bacterial leaf blight during both years of the experiment. The resistant genotypes showing promising yields were selected for further evaluation.

Keywords

Introduction

Rice is the most important crop commodity and staple food of about half of the world populations [1]. It is also the staple food of more than 65% of the Indian population and accounts for 46% of cereal production in the country. India is the 2nd largest rice producer in terms of acreage and is the biggest exporter in the world. The area, production and productivity of rice in India was 4, 33, 88,000 ha; 10, 43, 20,000 tonnes and 2,404 kg/ha in 2016-17, respectively [2]. Although rice is a mainstay food of the country, its productivity (2.4 metric ton/ha) is limited. Major constraints that affect the production and productivity are abiotic-biotic stresses, methods of agronomic management and seed quality [3]. Abiotic stress like weather factors (temperature, rainfall, humidity, solar radiation and wind velocity) exerts significant effects on productivity and disease severity [4]. The fast-growing Indian population's food demands can only be addressed with an increase in crop productivity. Therefore, the best way to boost crop productivity is to grow climate-resilient, high-yielding, and disease-resistant varieties with a full agronomic package of practices.

Indian agriculture is severely affected by abiotic stresses like drought, salinity, high temperatures, and soil acidity. Several reports show that the earth surface in the Indian peninsula is warming in an accelerated rate with a minimum (night time) temperature rising 0.025 ^{0}C per year during 1980-1990 and 0.056 ^{0}C per year during 1990-2000 [5,6]. The surface solar radiation was shown to fall by about 5 % during 1980-2004 [5]. *Rao et al.* [7] reported a minimum temperature rising at the rate 0.24 ^{0}C per decade over India, and warming during Ravi (October-March) was faster than Kharif (June-October) by 0.09 ^{0}C per decade. A slight but definite warming trend in the mean annual Indian temperature has already been reported [8].

Temperature and radiation have significant impacts during both the vegetative and ripening phases of the rice plant [9]. It has been observed that higher minimum temperatures reduce yield, whereas higher maximum temperatures raise it, and radiation impact varies by growth phase [10,11]. Mohammed and Tarp-

ley [12] reported that high night temperature is associated with reduced yield resulted from spikelet sterility and reduced grain length, width and weight. *Auffhammer et al.* [5] also reported that rice yield tends to be reduced by higher minimum temperature and lower solar radiation, especially during the latter part of growing season. Different simulated models have been also developed to test the effects of temperature on rice yields. The ORYZA1 and INFOCROP models predicted an average yield decline of 7.20 % and 6.66 %, respectively for every 1 °C increase in temperature at 380 ppm of CO_2 [13]. A field-based experiment also revealed a rice yield decline by 10% for each 1°C increase in minimum temperature in the dry season [14].

In addition to abiotic stress, biotic factors are also responsible for yield reduction. An economically important biotic factor destructive to rice is Bacterial leaf blight (BLB; *Xanthomonas oryzaepv. Oryzae*), the most serious bacterial disease in rice-producing countries like India [15,16]. It limits rice yield especially in irrigated lowland and rainfed conditions where predisposition factors favour disease development. This disease is widely prevalent among various rice varieties worldwide [17]. This disease could cause 15-25% of the yield loss each year, losses as high as 30-40% may also occur [18]. Suresh et al. [19] found that maximum temperature has a significant positive and rainfall has a negative correlation with BLB development. They also reported an increase in disease severity between the 3rd and 4th week of October. The most appropriate way of controlling BLB is to develop resistant varieties through successful breeding programs [20]. Scientists have also identified 38 genes that confer resistance to BLB and designated them in a series from Xa1 to Xa38 [21]. These resistance genes are not universally effective across all locations at all times due to the geographical structuring of the pathogen and its races. Therefore, continuous efforts are made to transfer genes from wild relatives (http://www.apsnet.org/publications/PlantDisease/BackIssues/Documents/1993Articles/PlantDisease77n01_5.PDF). Despite the economic importance of BLB, complete resistance has not been reported [22].

In this study, two-season field experiment was conducted to observe the effects of temperature on yield and its attributing traits. Rice genotypes were also characterized and evaluated. We correlated the epidemics of disease with weather conditions. Statistical analyses of the resulting BLB epidemics, rice yield, and the rice yield components were used to develop the best explanation for the disease severity and crop loss relationship.

Material and Methods

Experimental trial set up

An experimental trial was set up in a randomized complete block design in two replications with a standard check Pant Dhan-4 in open field condition at Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar India during Kharif season 2016 and 2017, respectively. The trial was geographically located at a latitude 29°50'N, longitude

79° 30' E, and altitude 243.84 meters from mean sea level. The test entries were obtained from the International Rice Research Institute (IRRI) as an IRON (International Rice Observation Nursery) trial in 2016. Altogether 40 genotypes were used in the study where Pant Dhan-4 was used as a standard check, resistance to BLB (Table 1).

Seed sowing and crop management

Seeds were sown in well-prepared land at the last week of May, and 25 days old seedlings were transplanted at 15 X 15 cm spacing of row to row and plant to plant in a fine prepared puddled field each year. Each plot consisted of an area of 2.5-meter square. The amount of fertilizers was calculated based on the recommended doses of NPK@120:60:40. Half nitrogen and the full dose of phosphorus and potash fertilizers were applied as basal before transplanting of rice. The remaining half of nitrogen was applied into two equal splits first at tillering, and second at the flowering stage. Necessary intercultural operations like weeding and irrigation were carried out routinely.

Data recording and observation

Rice traits like days to flowering, days to maturity, effective tillers per plant, panicle length, fertile grain per panicle, sterile grain per panicle and yield per plot were taken according to the Standard Evaluation System for Rice (SES) IRRI 2013 protocol (http://www.clrri.org/ver2/uploads/SES_5th_edition.pdf). The parameter of days to flowering was calculated as the time from date of sowing until 80% of the rice genotypes per plot flowered, days to maturity was calculated as the time from date of sowing until 80% of the grains per plot ripened, effective tiller per plant was obtained by counting the mean of total tillers of five plants per plot at the crop maturity stage, panicle length was measured as the mean length of selected five panicles per plot, fertile grain per panicle was calculated as the mean number of fertile grains of five panicles, sterile grain per panicle was calculated as the mean number of sterile grains of five panicles, and yield was calculated as the total weight of grains per plot expressed in Kg/ha. The fresh grain yield was weighed after five days of sun drying in the field, including moisture percentage.

Artificial inoculation of Bacterial leaf blight (BLB)

Artificial inoculation of BLB was done by the clipping method. Bacterial leaf blight (*Xanthomonas oryzae pv. Oryzae*) infected leaves were taken and cut into small pieces with scissors. The leaves were dipped in a small bucket half filled with water. It was left undisturbed for 24 hours. The prepared inoculums were taken to the field and a sickle was chopped in bacterial suspension, used to cut about 1-2 cm of leaf tips per plant per plot. The inoculation was done after 55 days of transplantation, in the morning on cloudy days. The inoculums were prepared as described by Bonman and Mackill [23].

Rice genotypes were screened against BLB following SES IRRI 2013 protocol. The BLB scoring was done twice, first, two weeks

Treatment	Pedigree name	Replication-I	Replication-II	Replication-I	Replication-II
1	TP30437	R	MR	MR	R
2	IRRI 146	R	R	R	R
3	TP30034	MR	R	MR	MR
4	TP29631	MR	R	R	R
5	TP30431	MR	R	MR	R
6	IRRI 154	R	R	MR	R
7	TP29409	R	MR	S	R
8	TP30436	MS	R	S	R
9	TP 30432	MS	MR	MS	R
10	Pant Dhan-4	MR	R	R	R
11	TP 30439	MR	R	MS	MS
12	IRRI 104	R	R	R	R
13	TP 30440	MS	MS	R	R
14	TP 30015	MR	MR	R	R
15	TP 30433	R	MR	R	R
16	TP 30039	MS	R	R	R
17	TP 30441	MS	MS	MR	MR
18	IRRI 181	R	R	MR	MR
19	IRRI 180	MR	MR	MR	MR
20	TP 29632	R	R	R	R
21	IRRI 105	MR	R	R	MR
22	TP 30438	MR	R	MR	MR
23	TP 30078	MR	R	R	R
24	TP 30025	MS	MS	R	R
25	TP 30017	MR	R	MR	R
26	TP 30082	MR	R	MR	R
27	IRRI 179	R	MR	R	MR
28	TP 29759	R	R	R	MR
29	IRRI 156	MR	MS	R	R
30	TP 29737	R	MR	MR	R
31	TP 30022	R	R	R	MS
32	TP 30035	R	R	MR	R
33	TP 29651	R	R	R	R
34	TP 29637	R	R	R	MR
35	TP 30430	MS	MS	MR	R
36	IRRI 123	MR	MR	R	R
37	TP 30047	R	R	MR	MR
38	TP 30011	R	R	R	MR
39	TP 29654	R	R	MR	MR
40	IRRI 174	R	MR	R	R

Table 1: IRON rice genotypes and their Bacterial leaf blight scoring done in 2016 and 2017.

after inoculation and second three weeks after inoculation.

Scale	Disease Leaf Area (%)	Description
1	1-5	R
3	6-12	MR
5	13-25	MS
7	26-50	S
9	>50	S

Disease assessment

The percentage of disease incidence was calculated using the formula

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plant}}{\text{Total number of plates rated}} \times 100\ \%$$

$$\text{Disease incidence (\%) in 2016} = \frac{36}{2 \times 40} \times 100\ \% = 45\ \%$$

$$\text{Disease incidence (\%) in 2017} = \frac{33}{2 \times 40} \times 100\ \% = 41.25\ \%$$

The disease index (DI) was determined using formula

$$\text{Disease severity index (\%)} = \frac{\text{Sum of all numerical rating}}{\text{number of plates rated} \times \text{Highest rating scale}} \times 100\ \%$$

$$= \frac{(0 * X0 + 1 * X1 + 2 * X2 + ...n * Xn)}{(X1 + X2 + ...Xn)} \times 100\ \%$$

where,

0-n=Number of the rating scale

X0-Xn=Number of plants

$$\text{Disease index (\%) in 2016} = \frac{(44 * 1 + 24 * 3 + 12 * 5 + 0 * 7 + 0 * 9)}{(2 * 40) * 5} \times 100\ \% = 44$$

$$\text{Disease index (\%) in 2017} = \frac{(1 * 47 + 27 * 3 + 4 * 5 + 2 * 7 + 0 * 9)}{(2 * 40) * 5} \times 100\ \% = 28.92$$

Weather data

Weather parameters like maximum and minimum temperature (⁰C), total rainfall (mm), number of rainy days, average number of sunshine hours, average wind velocity (Km/hr) and relative humidity (%) of Kharif 2016 and 2017 were obtained from the weather station of the Department of Meteorology, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar.

Statistical analysis

Statistical analysis of two seasons experimental trials transplanted in the randomized complete block design with two replications was done through MSTAT-C statistical software program. Correlation and regression analysis were done by correlating the mean yield of rice genotypes with the average temperature of that year through MS-Excel 2003 software program. Similarly, other traits of the rice including days to flowering, days to maturity, effective tiller per plant, fertile and sterile grain per plant were also correlated with average temperature. The Pearson correlation coefficient was also calculated [14]. The formula used for calculating correlation coefficient was

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{\left(n\sum x^2 - (\sum x)^2\right)\left(n\sum y^2 - (\sum y)^2\right)}}$$

Where x and y are the value of variables, and n is the size of the sample.

Results

Characterization of rice genotypes

The tested rice genotypes were statistically highly significant (p<0.05) based on rice traits days to flowering, days to maturity, effective tillers per plant, panicle length, fertile and sterile grain number per panicle and grain yield per plot in 2016 and 2017 (Table 2). The mean grain yield of rice genotypes in 2016 and 2017 was 10153.85 kg/ha and 5598.38 kg/ha respectively. The mean yield difference between the two seasons was 4555.5 kg/ha. The average yield of rice genotypes in 2016 was 44.86 % higher than 2017. Genotype yields were found more consistent in 2016, with a coefficient of variation 16.34 % than 2017 (coefficient of variation 21.45 %). The least significant difference of the yield in 2016 and 2017 was 3356 kg/ha and 2429 kg/ha at 5% level of significance (Table 3).

Compared with the check Pant Dhan-4, only 31 genotypes flowered earlier in 2016 and 2 genotypes in 2017 whereas 28 genotypes matured earlier in 2016 and 2 genotypes in 2017. Similarly, 15 genotypes were observed higher tillers in 2016 and 11 genotypes in 2017. The longer panicle length was observed in 16 genotypes in 2016 and 11 genotypes in 2017. Fertile grain number was also high (32 genotypes) in 2016 than 2017 (23 genotypes). But only 22 genotypes had higher yield in 2016 than in 2017 (38 genotypes) (Figure 1)

We found maximum grain yield in IRRI 154 (12696 kg/ha), followed by TP 30433 (12568 kg/ha), IRRI 174 (12212 kg/ha) and minimum in TP 30438 (0 kg/plot) in 2016. Similarly, TP 30430 (8281.28 kg/ha) had maximum yield followed by TP 30432 (8260.39 kg/ha), TP 30441 (8103.09 kg/ha) and minimum in IRRI 180 (3000.09 kg/ha) in 2017 (figure 1). TP 30438 did not flower in 2016, so it had zero yields (table 3).

2016		DTF			DTM			TILN			PANL		
Source	Df	MSS	F value	Prob.	MSS	F value	Prob.	MSS	F value	Prob.	MSS	F value	Prob.
Block	1	7.2	0.49		105.8	4.62*	0.0378	0.16	0.02		21.73	8.60**	0.0056
Treatment	39	700.94	47.98**	0	1088.44	47.58**	0	20.5	2.47*	0.0 029	33.03	13.07**	0
Error	39	14.61			22.87			8.31			2.52		
2017													
Block	1	1.51	0.27		0.1	0.01		0.11	0.04		0	0	
Treatment	39	26.41	4.72*	0	13.9	2.69*	0.0013	8.98	2.93*	0. 0005	11.54	3.00*	0.0004
Error	39	5.59			5.2			3.06			3.84		

2016		FGN			SGN			GYLD		
Source	Df	MSS	F value	Prob.	MSS	F valve	Prob.	MSS	F valve	Prob.
Block	1	3030.72	17.25**	0.0002	21.63	0.44		340605	0.12	
Treatment	39	1505.19	8.57**	0	315.7	6.39**	0	10474596.67	3.80*	0
Error	39	175.66			49.43			2753041.51		
2017										
Block	1	110.45	0.80		96.8	2.62	0.1138	651417.11	0.45	
Treatment	39	554.43	4.00**	0	103.97	2.81*	0.0008	3731047.60	2.59*	0.0019
Error	39	138.73			37.00			1442277.94		

Table 2: Analysis of variance statistics of traits of forty IRON rice genotypes transplanted during Kharif 2016-2017.

(Significant codes: all treatments show significant value at 0.05 level of significance, *=significant; **=highly significant)

(a: DTF=Days to flowering, DTM=Days to maturity, TILN=Tiller number per five plants, PANL=Mean panicle length per five plants, FGP= Fertile grain number per five panicles, SGP=Sterile grain number per five plants and GYLD= Grain yield in kg/ha; Df=Degree of freedom, the MSS=mean sum of a square; Prob.=probability)
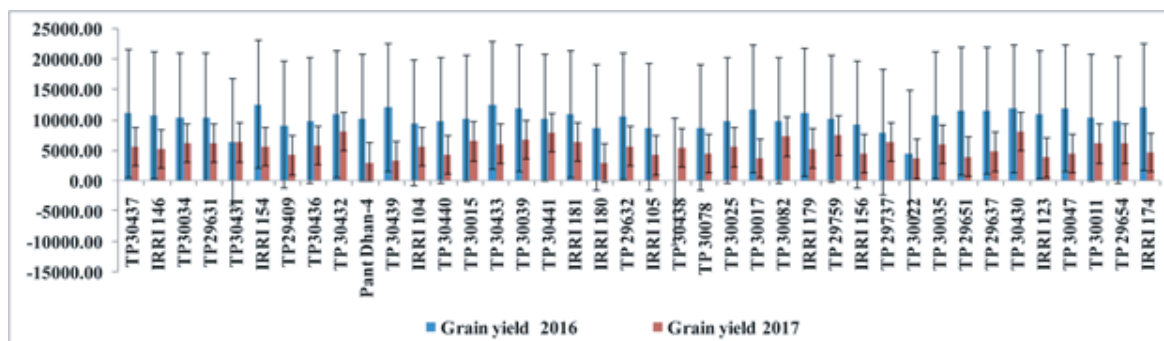

Figure 1: Comparison of rice genotypes based on yield with Pant Dhan-4, a check variety through error bars diagram.

The average days to flowering of all genotypes in both years were the same (105 days), but the average days to maturity of rice genotypes in 2016 (140 days) was higher than 2017 (128 days) (table 3). The longest period of days to flowering and maturity were observed in TP 29632 (126 days) and TP 30022 (153 days) in 2016, and TP 30082 (112 days) and TP 29654 (137 days) in 2017 respectively. Similarly, minimum maturity days was observed in TP 30034 (120 days) in 2016 and TP 30436 (124 days) in 2017.

The average effective tillers were higher in 2016 (16 tillers) than 2017 (10 tillers). On a genotype basis, effective tillers (20 tillers) was found maximum in TP 30017, IRRI 179, TP 29631 and IRRI 123 and longest panicle size was observed in IRRI 181 (26.95 cm) in 2016. In the same way, IRRI 179 (18 tillers) had maximum tillers per genotypes and TP 30078 (25.9 cm) had longest panicle size in 2017 respectively. The average panicle size was also found higher in 2016 (26.25 cm) than 2017 (22.1 cm). Similarly, the

SN	Treatment name	DTF		DTM		TILN		PANL		FGP		SGP		GYLD	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
1	TP30437	98	102	144	126	17	6	22.5	20.45	131	105	20	25	11228.01	5729.96
2	IRRI 146	99	103	134	127	15	8	21.5	20.5	139	109	25	20	10868	5440.65
3	TP30034	91	100	120	125	15	8	24	18.9	133	104	62	14	10600.1	6301.5
4	TP29631	96	99	145	125	17	10	24.1	17.5	132	65	20	20	10616.2	6371.11
5	TP30431	94	102	143	126	18	10	23.7	22.2	140	114	14	13	6432.02	6472.2
6	IRRI 154	107	108	143	131	18	10	25.55	26	98	79	17	29	12696.19	5783.74
7	TP29409	106	102	143	127	12	10	21.85	20.05	70	59	32	16	9284.35	4364.66
8	TP30436	105	106	145	124	14	9	25.2	23.65	86	84	29	16	9928.41	5957.93
9	TP 30432	112	108	144	133	18	12	25.3	24.9	79	87	40	20	11104.71	8260.39
10	Pant Dhan-4	111	99	146	125	16	10	23.75	23.7	74	75	15	29	10412.12	3189.92
11	TP 30439	107	106	145	127	15	9	23.5	21.5	105	96	18	23	12144	3381.01
12	IRRI 104	113	101	150	128	17	11	23.05	20.95	85	69	25	19	9564.03	5781.31
13	TP 30440	99	108	142	127	16	8	22.2	20.45	93	76	34	14	9910.05	4411.15
14	TP 30015	103	104	146	127	15	10	22.75	22.6	90	79	21	16	10352.5	6651.9
15	TP 30433	106	108	147	129	14	9	26.35	22.8	128	94	21	8	12568.31	6214.33
16	TP 30039	103	108	145	129	17	9	26.4	22	114	67	12	10	12028.4	6940.41
17	TP 30441	106	109	144	133	15	7	26.1	25.1	89	84	28	13	10420.03	8103.09
18	IRRI 181	108	107	145	129	18	9	26.95	24.05	109	81	25	16	11108.1	6522.7
19	IRRI 180	109	101	145	125	14	9	21.3	19.3	78	65	27	17	8824.57	3000.09
20	TP 29632	126	100	147	126	14	13	23.55	20.9	103	61	20	22	10688.32	5851.25
21	IRRI 105	98	103	132	127	13	9	24.65	21.4	125	85	23	17	8904.61	4356.33
22	TP 30438	0	109	0	131	0	11	0	23.05	0	53	0	20	0	5581.5
23	TP 30078	108	106	142	129	15	8	0	25.9	84	83	0	39	8828.34	4634.53
24	TP 30025	121	108	146	128	15	9	23.4	20.6	89	74	33	17	10016.21	5681.53
25	TP 30017	104	107	143	127	20	10	23.15	21.25	84	75	23	11	11948.14	3889.95
26	TP 30082	119	112	145	132	16	11	22.3	25.6	94	96	9	22	10012.72	7395.18
27	IRRI 179	106	108	144	128	20	18	25.35	21	71	61	50	10	11380.42	5447.13
28	TP 29759	107	106	145	132	15	9	21.75	23.05	91	92	14	26	10244.05	7630.5
29	IRRI 156	106	108	143	128	16	9	22.8	18.85	87	56	15	13	9320.09	4655.73
30	TP 29737	94	97	141	127	16	13	23.65	18.85	91	72	29	19	8060.81	6532.38
31	TP 30022	124	102	153	128	18	10	23.7	25.85	27	46	42	40	4680.62	3824.41
32	TP 30035	108	108	142	127	14	11	22.75	21.3	73	68	52	11	10948.21	6153.88
33	TP 29651	110	103	145	124	16	9	23.85	19.45	85	64	28	15	11576.18	4134.16
34	TP 29637	115	107	146	125	20	6	23.5	22.15	93	82	22	11	11628.26	4961.61
35	TP 30430	109	106	145	129	15	9	25.05	25.4	89	87	50	28	11980.64	8281.28
36	IRRI 123	109	104	148	127	20	13	24.1	17.6	69	44	20	14	11044.19	4014.15
37	TP 30047	121	105	148	127	17	10	21.7	21.35	92	69	21	17	12096.44	4620.5
38	TP 30011	109	108	145	129	18	11	25.55	23.9	81	69	22	26	10464.35	6277.53
39	TP 29654	117	112	152	137	19	7	24.55	24.8	60	96	32	19	10040.3	6281.3
40	IRRI 174	105	101	144	128	15	13	25.1	25.35	90	84	44	24	12212.27	4852.44
	Mean	105	105	140	128	16	10	26.25	22.1	91	77	32	19	10153.85	5598.38
	CV (%)	3.66	2.26	3.41	1.78	18.21	18.34	6.82	8.87	14.53	15.21	26.46	32.27	16.34	21.45
	LSD value at alpha 0.05	7.73	4.78	9.67	4.6	5.83	3.53	3.21	3.96	26.81	23.82	14.22	12.3	3356	2429

Table 3: IRON rice genotypes and their characterization based on different traits transplanted in 2016 and 2017.
(Abbreviations: DTF=Days to flowering, DTM=Days to maturity, TILN=Tiller number per five plants, PANL=Mean panicle length per five plants, FGP= Fertile grain number per five panicles, SGP=Sterile grain number per five plants and GYLD= Grain yield in kg/ha; CV (%) =coefficient of variation, LSD=least significance difference)

average fertile grain per panicle was also higher in 2016 (91) than 2017 (77). TP 30431 had the highest fertile grain per panicle in both 2016 (140) and 2017 (113). In the same way, the average highest observed sterile grain per genotype was in 2016 (32) than 2017 (19). Maximum sterile grain was reported in TP 30034 (62) and TP 30022 (40) in 2016 and 2017 respectively (table 3).

Relationship between temperature, yield and its attributing traits

The mean yield of rice genotypes (10153.85 kg/ha in 2016 and 5598.38 kg/ha in 2017) and average temperature (26.89 °C in 2016 and 27.67 °C in 2017) were negatively correlated (-1). The Pearson correlation coefficient value was also negative (-0.99) in both years of the experiment. Similar to the yield and temperature relationship, other rice traits including days to maturity, effective tiller, panicle length, fertile and sterile grain per panicle were negatively correlated to temperature. But days to flowering was positively correlated with the average temperature of that season; meaning that the higher the temperature, is the higher the chance of fast flowering. The 2016 rice genotypes showed delayed flowering and maturity compared to 2017 genotypes potentially due to the effect of temperature. The average temperature of 2016 was lower than 2017. The regression equation is expressed in logarithm because yield is a dependent variable, the value is expressed in a relative term5. Regression coefficient (R^2 =1) was positive in both year of experiments, revealed the fact that all values of yield lie near the value of temperature, means the temperature is highly correlated with yield components (Figure 2).
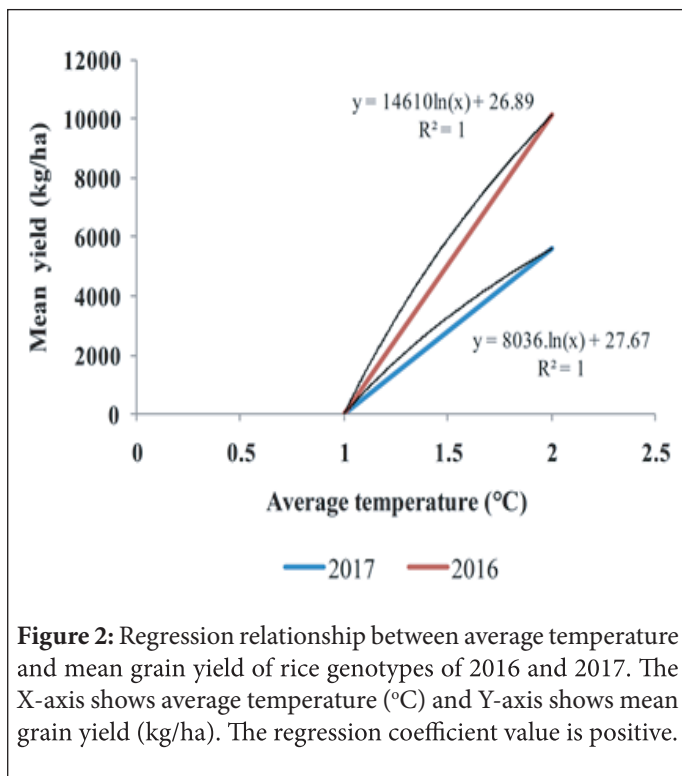

Figure 2: Regression relationship between average temperature and mean grain yield of rice genotypes of 2016 and 2017. The X-axis shows average temperature (°C) and Y-axis shows mean grain yield (kg/ha). The regression coefficient value is positive.

BLB infestation and disease assessment

BLB scoring of rice genotypes was done based on disease leaf area. Only 4 genotypes were found completely resistant in both years of BLB scoring (table 1). A combined 2-year analysis of data showed that 56.87 % genotypes were resistant, 31.87 % moderately resistant, 10 % moderately susceptible, and only 2.50 % were susceptible (Figure 3). The common genotypes which were screened with the same scoring value from two replications were, 13 resistant, 3 moderately resistant and 4 moderately susceptible in the initial year of experiment whereas 15 resistant, 7 moderately resistant and, 1 moderately susceptible of total 40 genotypes in the second year of the experiment. TP 29409 and TP 30436 was scored as susceptible in one replication whereas both were scored resistant in another replication in 2017. Only four genotypes were common which were found completely resistant in both years of screening. On yield basis, IRRI 146 (8154.33 kg/ha) had maximum average yield followed by TP 29651 (7855.08 kg/ha), TP 29632 (8269.63 kg/ha) and IRRI 104 (7672.65 kg/ha) etc.

Disease incidence was calculated based on the number of infected plants to the total plants per plot. The disease index and percentage of disease incidence were 44 and 45% in 2016 and 28.92 and 41.25% in 2017 respectively.
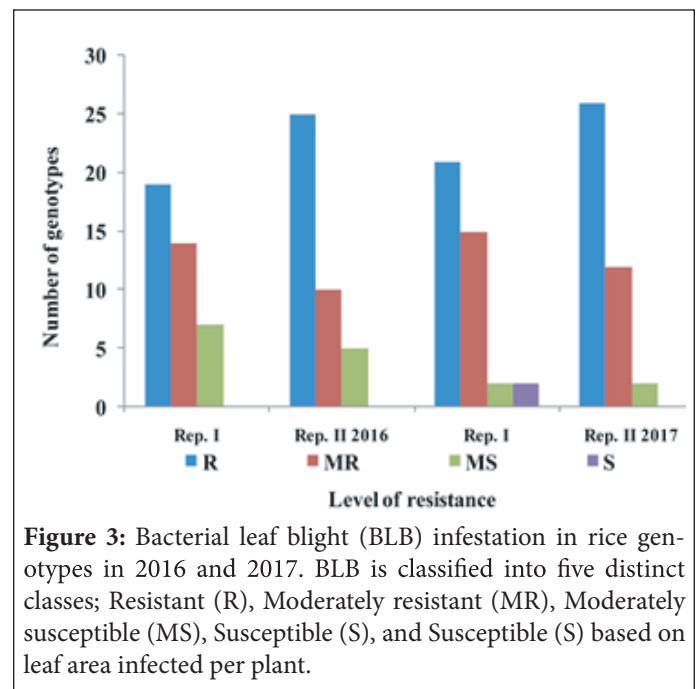

Figure 3: Bacterial leaf blight (BLB) infestation in rice genotypes in 2016 and 2017. BLB is classified into five distinct classes; Resistant (R), Moderately resistant (MR), Moderately susceptible (MS), Susceptible (S), and Susceptible (S) based on leaf area infected per plant.

Weather data interpretation

The average maximum (33.12 °C) and minimum temperature (22.22 °C) of Kharif 2017 were higher than the average maximum (31.81 °C) and minimum temperature (21.96 °C) of Kharif 2016 (Figure 4). The mean temperature difference between the two years was 0.78 °C. Similarly, the minimum (night time) temperature difference between two seasons was 0.26 °C only. But there was 3.41 °C rise in minimum night temperature dur-

ing grain filling period in Kharif 2017 (October) than the initial year of the experiment (figure 4). High rainfall (338.95 ml) and 13 rainy days recorded in 2017 as compared to 259.52 ml rainfall and 14 rainy days in 2016. Though high rainfall recorded in Kharif 2017 but most rainfall occurred at the time of transplanting only. Highest maximum and minimum temperature were recorded in June during which rice tillering starts. The soil moisture was below the field capacity during grain filling period in 2017. The average relative humidity of both seasons was nearly same (73.7 %).

25 °C for optimum yield. But we reported a rise in minimum night temperature by 3.41 °C and soil water below field capacity during grain maturity period in 2017 compared to 2016 (figure 4). The yield decline in 2017 might be due to the rise in night temperature that decreases the percentage of ripened grains and increases the percentage of sterile spikelets [27-29,13,12]. Peng et al. [14] reported that grain yield declined by 10% for each 1 °C increase in minimum temperature, whereas the effect of maximum temperature on crop yield was insignificant. Welch et al. [10] and Cheng et al. [30] also said higher min-
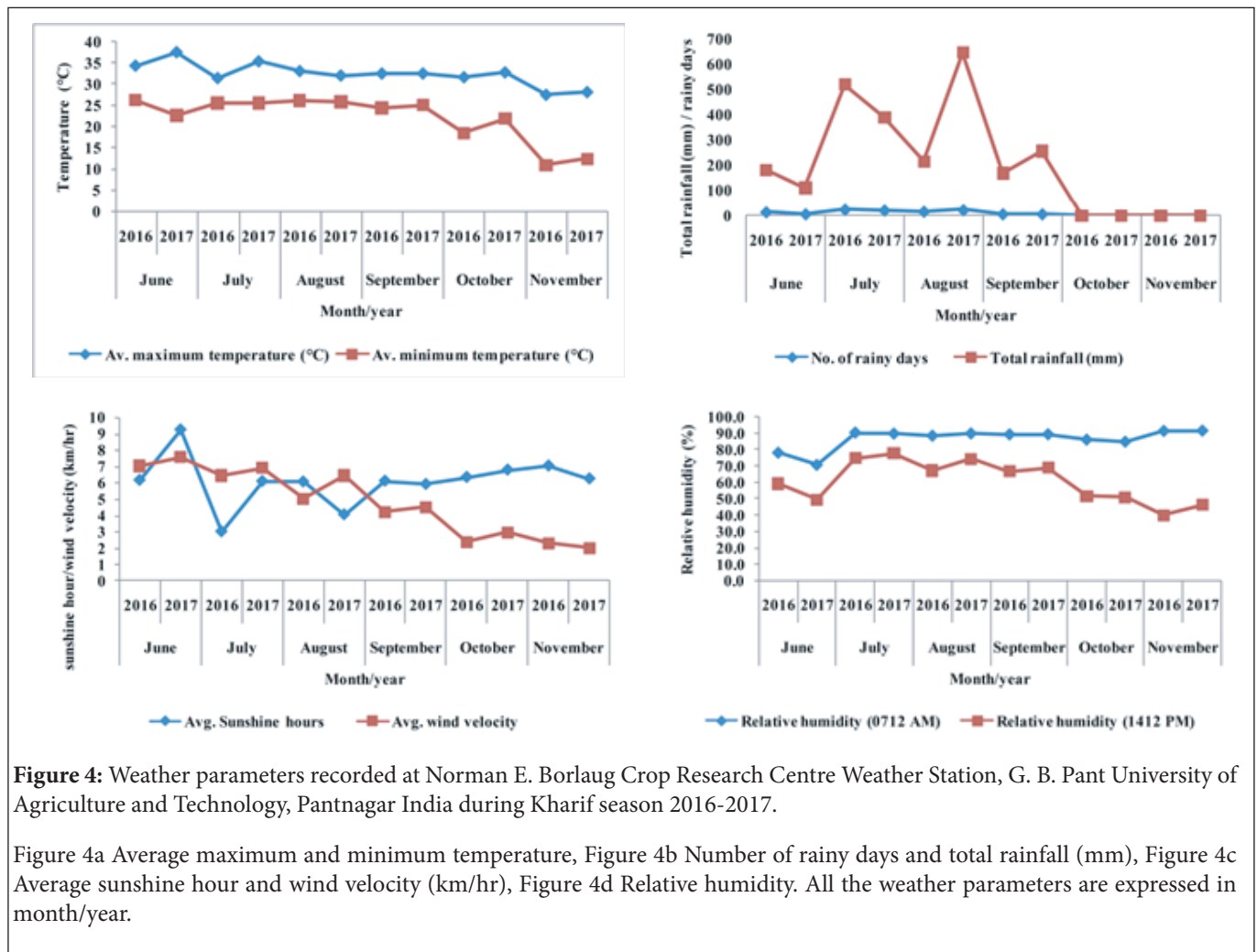

Figure 4: Weather parameters recorded at Norman E. Borlaug Crop Research Centre Weather Station, G. B. Pant University of Agriculture and Technology, Pantnagar India during Kharif season 2016-2017.

Figure 4a Average maximum and minimum temperature, Figure 4b Number of rainy days and total rainfall (mm), Figure 4c Average sunshine hour and wind velocity (km/hr), Figure 4d Relative humidity. All the weather parameters are expressed in month/year.

Discussion

The mean yield of total rice genotypes in 2016 was higher than 2017, though disease epidemics were high in the initial year of the experiment (table 3). The increase in yield might be due to favourable weather conditions, optimum temperature during grain filling period, more days of sunshine, and the minimum night temperature which causes less loss of photosynthates [24]. The maximum and minimum temperature of Kharif 2016 was 31.81 °C and 21.96 °C which were ideal for rice productivity. Nyangau and Samui [25,26] suggested the ideal maximum and minimum temperature for rice ranges of 29-32 °C and 23-

imum temperature reduced yield, and the higher maximum temperature raised it. Rao et al. [7] found 57.2 % Indian rice area was influenced by the rise in minimum temperature, and rice yields declined by 411 to 859 kg/ha/°C rise from the 1971-2009 period. Krishnan et al. [31] support the above facts that high temperature limits rice productivity, causing reductions in grain weight and quality. Rice productivity decreased due to increase in temperature could be overcome by altering the sowing time, maintaining the soil water level up to field capacity at grain filling period and by the selection of genotypes that possess a higher potential of spikelet fertility at high temperatures [13]

The mean days to maturity of the crop in 2016 (139 days) was higher than 2017 (128 days). The increase in maturity days of the crop in the initial year of experiment might be due to lower weather temperature than 2017 (figure 4) [9,14]. Similarly, other rice traits such as effective tillers, panicle length, and fertile grain were also higher in the initial year of the experiment which might be due to the favourable temperature obtained during the rice growing stage [25]. *Ohe et al.* [32] and Yang et al [27] also reported that plant height was taller, and the maximum tillering stage was earlier at higher temperatures and the photosynthetic rate was lower because of the acceleration of leaf senescence. *Cheng et al.* [30] also found larger enhancement of photosynthesis at a higher temperature and elevated CO_2. However, increased night temperature can counter this because of the heavier respiratory cost, increased by the larger biomass [29]. We found that some rice genotypes (heat tolerant) performed very well and had higher productivity even at higher minimum temperature, but most genotypes showed a negative response to rise in minimum night temperature. The findings confirm that climate variables exert significant effects on rice yields but these effects vary among rice genotypes [33]. *Cao et al.* [11] also found relatively high yield in heat tolerant genotypes under high-temperature stress was associated with low leaf temperature, high root activity, and high ATPase activity in grains.

The disease index and disease incidences were 15.08 and 3.75% higher in 2016 than 2017. It might be due to more rainy days followed by maximum temperature, humidity and wind run [34]. Disease epidemics depend on the type of genotypes, weather condition and agronomic management, provided host and inoculum are present. *Suresh et al.* [19] found a significant positive correlation between disease development and maximum temperature, but minimum temperature and relative humidity had no much impact on it. Epidemics that began before panicle initiation significantly reduced grain yield, panicle fertility and kernel weight [35]

Conclusion

Temperature exerts a profound effect on crop production and productivity. Rice productivity could be reduced not only due to improper agronomic management and biotic factors but might also be due to elevated night-time temperatures. Each year, rice productivity fluctuates and one of the major reasons is elevated minimum temperature. We found a slight rise in night temperature was more detrimental to rice productivity than moderate BLB infestation. Rice productivity could be enhanced by altering sowing time and minimizing night temperature by maintaining soil water level up to field capacity at grain filling period. BLB might be a serious problem in rice-growing areas, especially if high temperature is followed by longer rainy days. The results also reveal that Pantnagar, Uttrakhand rice is severely affected by extreme temperature, thus selection of heat tolerant varieties with good agronomic practices can help to achieve optimum productivity.

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Conflict of interest

We confirm that there are no known conflicts of interest associated with this publication. The manuscript has been read and approved by the named author.

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