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UNRAVELLING THE PHOTOPERIOD-DRIVEN PERFORMANCE OF KATARNI RICE LINES FOR YIELD AND QUALITY TRAITS

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Abstract
Yield and quality characteristics were described for 60 lines derived from the Katarni variety across four different sowing dates. A univariate analysis of variance (ANOVA), which showed 14 traits to have statistically significant ($p<0.01$) genotypic variance, showed excellent genotypic divergence for the traits. Early sowing (29 May 2021) gave yields comparable to the optimal 15 June 2021 planting, but late sowing (15 July 2021) reduced yields in photoperiod-insensitive lines. There was a yield decrease for the late plantings (15 July 2021) for lines that are photoperiod-insensitive, whereas several photoperiod-sensitive lines maintained comparatively higher grain yield under the same delayed sowing conditions. The Traditional Katarni lines were remarkable for their photoperiod sensitivity, as they did not flower until November regardless of sowing date. Across all environments, the number of grains, tillers, and 1000-g weight were positively correlated to yield which was true for the yield trait association analysis. of the traits that showed a non-significant positive direct effect on yield, the number of tillers. was the most important, followed by 1000 grain weight. Flag leaf length and days to flowering were traits that had positive indirect effects, but their direct effects were different. There was a dependable set of traits that correlated to yield irrespective of length of photoperiod. Breeding lines for photoperiod insensitivity will likely stabilize flowering and yield. A balance of target traits such as number of grains, productive tillers, and 1000-g weight would provide excellent breeding scope for varying sowing dates.

KEYWORDS: Aromatic rice, Correlation, Path analysis, Photoperiod sensitivity, Sowing date and Yield components

INTRODUCTION
Rice (*Oryza sativa* L.) (2n=24) is the primary food source of more than half of the world population and must undergo considerable improvements to keep up the skyrocketing demand [3]. Numerous landraces, including Katarni rice of Bihar, are very sensitive to photoperiod changes and thus, have restricted adaptability and yield potential [4, 5, 6, 7]. Katarni only flowers in November and results in prolonged vegetative growth, lodging, and low yield [2, 8]. New strategies in breeding focus on photoperiod insensitivity combined with semi-dwarf stature in order to widen the potential adaptability and increase overall yield [5, 9]. The improvement of traditional aromatic cultivars, like the rice in Myanmar, has been achieved with the introgression of photoperiod-insensitive alleles and yield QTLs [4, 10, 11, 12].
Sowing date has a significant effect on rice growth and yield since it changes the photoperiod and temperature regimes [13, 14]. In South Asia, yields drop for transplanting after early August, with the period of mid-July to mid-August being the best for Aman rice [15, 16, 17]. Excessive vegetative growth and lodging can also be a problem of early planting [22]. These challenges can be overcome with photoperiod-insensitive lines and can thus provide stable and flexible planting for all seasons [1, 10, 11, 19].
According to Zhang *et al.* (2023), yield is principally determined by the number of panicles, grains per panicle, and weight of the grains. Correlation and path analysis engage in exploring the direct and indirect effects of traits. Several studies indicate significant yield positive associations with panicle length, tillers, and grain weight. However, for lodging resistance, breeders prefer toward the semi-dwarf early-maturing ideotypes.
There is more furniture complexity in terms of quality traits. For instance, in aromatic rices, the length to bread ratio of grain quality may inversely correlate with yield. Thus, breeding should concentrate on enhancing grain quality while maintaining a superior yield. This study seeks to evaluate the lines derived from Katarni which show reduced photoperiod sensitivity over 4 sowing dates. The study aims to determine (1) Yield traits for which correlation and path analysis can be used to identification, and (2) To evaluate the smoothness of the indirect selection standards to aid in the breeding of photoperiod-insensitive, high-yielding Katarni while grain quality is preserved.

MATERIALS AND METHODS
The subject of study consisted of 60 rice genotypes (Katarni-derived F_6 lines plus checks: Katarni, IR-64, Sabour Surbhit) [47][48], that were assessed during four sowing dates such as 15 June 2020, 29 May 2021 (early), 15 June 2021 (optimal), and 15 July 2021 (late) to capture the variations within the season and the year. The tests were held in the irrigated lowlands of Bihar Agricultural University, Sabour, and were divided into an alpha-lattice with two replications [1], using standard management (100:50:50 NPK kg/ha, irrigation, and crop protection). The agronomic and quality traits recorded were flowering time, plant height, panicle and tiller traits, number of grains in each panicle, 1000- grain weight, size of

the grains, length-to-breadth ratio, and others. The data was analyzed using ANOVA for each environment, correlation estimates [51], path coefficient analysis to partition direct and indirect effects on yield (Wright, S., 1921) [26], and was to yield trait analysis and stability of the genotypes assessed over the sowing dates.

Weather condition during crop season

Weather during the crop season was normal with monsoon rains; monthly temperature, humidity, and rainfall are shown in Tables 1(a) &1(b), and Fig. A & B.

Results and Discussion

Genotypic Variation and Mean Performance across Environments

Most of the traits across all planting dates were significantly different in the ANOVA test. In the first planting, on June 15, 2020, 13 of the 14 traits were significantly different (with acceptable differences at $p<0.01$, except for plant height which was $p<0.05$) [2][52]. During the other planting dates: 2 (May 29, 2021), 3 (June 15, 2021), and 4 (July 15, 2021), all traits were significantly different, and they were mostly at $p<0.01$ [29, 30]. This confirms that the Katarni-derived lines exhibit significant variation for traits concerning yield and quality.

Mean grain yield mentioned in **Table 2** was different for differing sowing dates. The earliest sowing date (May 29, 2021) and the optimum sowing date (June 15, 2021) had the highest yields of about (25-28 g/plant). The latest sowing on July 15, 2021, had a yield of about 14 g/plant, which was a 30% drop due to a shortened duration of grain filling, and stress [31]. The yields that were produced in Mid-June during the year 2020 were similar to the yields in Mid-June of 2021. This shows that the climatic effects per year, were minor in comparison to the effects of sowing date. The traditional Katarni had significant photoperiod sensitivity since it produced almost empty grains and had a low yield in late sowing. However, photoperiod-insensitive lines had relatively stable yields whether sowing was done in May or June, with no significant differences [1]. This shows that photoperiod insensitivity, which was bred into katarni, allows for early sowing without risks of losing yield. This also means that there is a possibility of having extra cropping, without late-season risks. The number of days until 50% flowering showed photoperiod sensitivity depending on the date of planting, with 133 days from planting on the 29-05-2021, 120 days from planting in mid-June, and 114 days from planting in late July [32, 33]. With early planting, the length of the vegetative phase prolonged while with later planting, the days until flowering was reached were shortened due to the daylengths becoming shorter. The trend was also evident in the average height of the plants with the tallest plants in the early planting group, measuring 87.6cm, and the plants measuring 87.0cm in the mid-June planting group. The shortest plants (~80cm) were in the late July group [34, 35]. The early planting group also displayed more tillering but with a decrease in yield. The photoperiod-insensitive plants were shorter, flowered earlier and did not exhibit the excessive vegetative growth phase, also referred as the "lag phase," in which Katarni was defined, which was also reported in Shinde *et al.* (2025).

The quality parameters, more specifically, the size of the kernels, amount of amylose, and the aroma, were consistent, regardless of the environment. Although amylose and Alkali spreading value (ASV) (%) only changed marginally, it shows that the cooking quality was not changed regardless of the sowing date. In late sowing (DOS-4) i.e.,(15-7-2021) there was marginally lower filling of grains and a decreased weight of the grains with weight reduced to 22 g for some lines. However, the means remained at approximately 23-24 g. The two checks (IR-64 and Sabour Surbhit) showed relatively stable grain weight and a lower yield reduction, thus confirming the insensitivity to photoperiod buffers the yield loss for the late sowing date under unfavourable photoperiod conditions. [19].

Correlation Analysis: Trait Associations with Yield under Different Photoperiods

Grain yield was positively linked with number of tillers per plant, Alkali spreading value and Kernal breadth across all sowing dates, showing these three traits are the main factors for yield. Table 3. (a) to Table 3. (d) is showing phenotypic correlation among 14 characters with yield per plant during all date of sowings.

Four sowing intervals conducted a phenotypic correlation analysis which confirmed observations regarding primary component observations were Number of tillers per plant and 1000 Grain weight which were strong correlated positive for all environments which confirmed the belief that these observations were primary yield determinants. In the ideal sowing of (15 June), grains produced per panicle was the phenotypic trait that were most positively correlated with yield at $r \approx +0.70$, $p<0.01$ while tiller number and grain weight were also positively correlated but moderately at $r \approx +0.45$ and $r \approx +0.40$, respectively. Other traits such as flag leaf length and plant height also positively correlated but with weaker associations of $r \approx 0.2$ to 0.3 with flag leaf length having a much weaker correlation of 0.02. Meanwhile, days to 50% flowering just had a positive, but minor correlation with yield, indicating that longer flowering durations did not significantly increase yield under these conditions. In the early sowing (29 May), yield and grains per panicle increased positive strong correlation of $r \approx +0.68$ while tiller number also positively correlated but weaker at $r \approx +0.35$. The decrease of positive correlation could be the effect of unproductive tillers that are common with photoperiod sensitive genotypes. In this study, the number of days to flowering had a small negative correlation with the overall yield produced by the genotype. This negative correlation indicates that the genotype that flowered first had a higher yield due to being able to maximize the growing period available. This observation is consistent with previous research done by Islam, M. S., 1986. Despite the negative correlation with overall yield, the flowering days showed a positive correlation with the number of grains produced and an abundance of grain weight due to the shortened growing season. This positive correlation in the other flowering day traits produced a positive correlation overall with the skyline grains. This positive flowering trait value was countered with the number of flowering tillers produced. There was a reduction in the overall yield produced when the flowering day tillers, with the addition of having no significant correlation with the overall yield produced. This reduction of flowering tillers is also consistent with a reduction of flowering days. Apparently, no other flowering characteristics had an overall positive correlation of flowering days. Contrary to other traits, quality characteristics showed no associations with yield (Faysal et al., 2022; Khan et al., 2016). To suggest that the very slender grains produced a negative correlation, fewer yields was also possible. The correlation of yield and Amylose content was absent also indicating yield has the potential to improve without cooking quality.

Grains per panicle proved to be the most stable and highest correlate of yield across all photoperiod conditions, followed by context-dependent contribution from tillers, and grain weight. Thus, with the obtained results, it is highly likely that choosing the derived population from Katarni, with big panicles, high grain numbers, optimal productive tillering, and stable grain weight will increase the yield across several sowing windows [36].

Path Coefficient Analysis: Direct and Indirect Effects on grain yield

The correlation analysis method that classifies variables according to their interaction with one another as either direct or indirect is critical for understanding the different types of relationships underlying the attributes of a body of interest. With this in mind, the impact of several significant phenotypic attributes on the crop yield per a single plant was analysed throughout the four different dates of sowing. These sowing periods were as follows: DOS-1 was 15th June 2020, DOS-2 was 29th May 2021, DOS-3 was 15th June 2021, and finally DOS-4 was 15th July 2021. The path coefficients were standardized for the traits of interest, namely, number of tillers for a single plant, and weight of 1000 grains. Overall, across the different climatic conditions given the panicle assemblage of the crop, the number of tiller positively impacted the yield as a direct cause (approximately +0.5 to 0.6) followed, in order, by the weight of 1000 grains weight. During the last sowing period, also known as DOS-4, the direct weight effect of the 1000 tillers was reduced significantly, implying that during this period, there were less effective to yield contributing tillers. More often than not, this is as a result of time and climatic variables bringing about stress in the plant.

To determine which traits directly affect yield under various sowing environments, previous research examined direct and indirect correlations [20]. All four environments showed that the number of grains per panicle positively affected grain yield the most, with standardized path coefficients of +0.50 to +0.60, and this showed that grain number was the most influential variable determining yield potential. This result coincides with previous findings in rice, such as those found in Zahid *et al.* (2006), of the strongest positive direct effect of grains per panicle [24, 25]. As shown in **Table 4.(a) to Table4. (d)**showing phenotypic path matrix of 14 characters studied under across sowing dates, the most influential trait was still number of tillers per plant with the 1000-grain weight and following alkali spreading value.

The impact of tiller numbers was moderately positive, ranging from 0.30 to 0.10, based on the timing of sowing. As sowing was done later, the positive impact on the number of tillers decreased, resulting in unproductive tillers and hence, corroborating the results of the shorter season, as reported by Rangare *et al*., (2012). 1000 grain weight and number of tiller per plant was positively impacted results from all different environments. It was also noted to positively impact the results more significantly from more grain filling under shorter season environments (0.30). The total number of days to 50% flowering negatively impacted all environments at a correlation of -0.08 to -0.10. Although a longer duration of flowering negatively impacted the overall yield of the crop, it positively impacted yield by indirectly influencing several other traits such as flag leaf length, panicle length, and grain weight. Based on the overall results, a slightly positive correlation was noted to exist between duration of flowering and yield. Plant height was noted to slightly negatively impact the results from a correlation standpoint. It was noted however, to indirectly positively impact the results by (grains per panicle) and panicle length. There was consensus that a greater plant height, even though it negatively impacted results, was not detrimental and could therefore, allows more height to be removed. Similarly, flag leaves impacted results slightly negatively as well (0.13) but positively by indirectly influencing the number of grains per panicle and the overall 1000 weight of the grains resulting in the noted positive correlation overall with yield. Furthermore, panicle length was noted to have slight negative as well as direct impacts from 0.05.

Traits such as grain number and weight had a direct, positive relationship with yield (0.09), while panicle length did not affect yield (0.09), suggesting that selection should focus on grain number and not panicle length [68]. There was negative (or negligible) direct effect on yield of quality-related traits (kernel L/B ratio, amylose content, aroma score); however, a negative direct relationship with yield potential was observed for excessively slender grains although kernel breadth had a small positive direct effect [22, 38]. Overall, among the environments, the number of tillers produced per plant and 1000 grain weight were the only key contributors to yield. With regards to the late-sowing condition, sink compensation was the primary factor, with findings supporting previous studies on alternative yield strategies where fewer panicles with more grains, as compared to many panicles filled with fewer grains, yielded better [23, 39]. While photoperiod insensitivity was not directly included in the path model, its positive effect was captured through stable flowering, and as observed in the high performing lines, better yield components were recorded across sowing environments [9]. Selection on key traits with high heritability, as in grains per panicle (~99%), indicates selection for these traits will not only be effective in improving yield, but will also be achieved with very little effort [28, 40]. In conclusion, the analysis shows that grains per panicle is the most important direct determinant of yield as well as the most consistent factor. Tiller number and grain weight depend on the sowing environment in their degree of contribution to yield, meaning that their contribution is more contextual. Thus, breeding should enhance yield stability across varying sowing windows in Katarni-derived rice by improving breeding traits, namely, maximizing grain number, maintaining productive tillers, sustaining grain weight, and synchronizing flowering time [10, 23, 31].

CONCLUSION

Present study highlighted that from Katarni rice derived lines were examined for their genetic variability ($p < 0.01$) in terms of yield and quality traits, as well as their response to different photoperiods. It was found that traditional Katarni rice is photoperiod-sensitive and especially unproductive if planted at non-optimal seeding dates, as it only flowers in short photoperiods. In contrast to traditional Katarni, several derived lines from Katarni became photoperiod-insensitive, flowering earlier in long day photoperiods while maintaining yields that were stable across early and optimal seeding dates. Yields were lower in all lines, however, if seeding was done very late (15 July 2021) as this reduced the flowering duration. It was found across all lines that the yield was determined mainly by the number of grains per panicle (r = 0.6-0.7, direct effect 0.5), followed by the number of productive tillers and the weight of the grain (thousand-grain weight), especially in cases of late seeding stress. Path analysis showed direct negative effects of late flowering and flag leaf length, while yield components provided an avenue for indirect positive effect of late flowering. It was evident that a moderate duration of flowering along with a large panicle size and an adequate number of productive tillers was optimum, especially if seeding was done late. In terms of quality traits, weakly positive yields were observed with aroma, grain shape and amylose traits, and so traits that adversely affect yield significantly could be improved concurrently with quality traits. Several derived lines were found to contain a Katarni-like aroma while possessing a yield that is the same as traditional Katarni rice. This was consistent with the introgression of dwarfing genes and yield QTLs. From a practical standpoint, photoperiod-insensitive lines deposited with at high yields when traditional lines were planted late. Breeding for these lines should focus on grains per.

The investigated variables included panicle, productive tillers, grain weight, and screening for photoperiod insensitivity, where traits such as grains per panicle displayed very high heritability (~99%) and hence, they served as a good candidate for indirect selection; as a whole, photoperiod insensitive Katarni-derived lines showcased better yield potentials while keeping the grain yield quality intact, thus coordinating photoperiod reaction genes with the critical yield determining components for the formulation of superior cultivars for Bihar and other comparable agro-ecologies

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Authors' contributions

D Mahto formulated the concept of the research work, carried out the research work, data collection, data analysis and writing of manuscript. MK, AK and NKS and helped in writing and proofreading of manuscript. NR helped in proofreading of manuscript. All the authors read and agreed for the final shape of manuscript.

Compliance with ethical standards

Competing interests: The authors declare that they have no competing interests.

Ethical issues: None

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Table 1(a): Monthly weather data of Sabour location during May -November, 2020

Month	Temp Max (°C)	Temp Min (°C)	RH 7 AM (%)	RH 2 PM (%)	Rainfall (mm)	Sunshine Hours	Wind Velocity (km/h)
May-20	33.3	23.4	86.8	70.0	34.2	7.2	7.3
June-20	33.7	26.1	86.2	69.2	5.2	4.0	6.8
July-20	33.1	25.9	83.7	66.0	11.4	2.8	5.6
Aug-20	34.1	26.3	82.5	68.7	3.6	5.4	8.0
Sep-20	32.9	25.7	81.2	68.8	7.9	4.3	3.0
Oct-20	33.8	22.6	85.5	74.3	0.7	6.9	2.5
Nov-20	30.5	15.4	85.5	75.2	0.0	3.5	3.2

Table 1(b): Monthly weather data of Sabour location during May -November, 2021

Month	Temp Max (°C)	Temp Min (°C)	RH 7 AM (%)	RH 2 PM (%)	Rainfall (mm)	Rainy Days	Sunshine Hours
May-21	34.1	24.3	84.5	61.8	59.1	9.7	5.4
June-21	33.8	26.1	89.2	63.5	298.6	6.8	4.1
July-21	33.0	26.4	88.7	68.4	331.2	8.0	4.0
Aug-21	32.4	27.3	91.5	77.1	104.7	9.2	3.4
Sep-21	32.7	27.3	91.6	75.4	119.4	9.8	5.1
Oct-21	31.9	24.4	94.1	73.1	210.0	4.4	5.6
Nov-21	28.0	16.3	94.0	73.4	0.0	2.5	4.9

Table 2: Mean Value of Morphological Traits at Four Date of Sowing (DOS)

Traits	DOS-1 (15/06/2020)	DOS-2 (29/05/2021)	DOS-3 (15/06/2021)	Dos-4 (15/07/2021)
D 50% flower	119.52	133.44	120.05	113.97
Plant height	87.70	87.70	87.70	87.70
Flag leaf length	25.05	26.10	25.06	23.99
Panicle length	22.84	23.00	22.58	21.19
Number of tillers	16.77	16.04	15.31	13.08
Grains/panicle	197.29	188.05	206.33	148.55
1000 grain weight	19.18	19.01	19.16	16.27
Gelatinization temperature	3.71	3.68	3.72	3.79
Amylose	17.99	24.29	23.45	21.97
Leaf aroma score	0.91	0.91	0.91	0.91
Kernel length	8.31	8.41	8.38	8.19
Kernel breadth	1.79	1.81	1.83	1.76
Length breadth ratio	4.64	4.66	6.53	4.65
Grain yield	28.72	28.60	28.88	17.11

Note-: DOS-Date of sowing, DOS-1 (15-6-2020), DOS-2(29-5-2021), DOS-3(15-6-2021), DOS-4(15-72021)

Table 3(a): Phenotypic correlation among 14 characters with yield per plant during DOS-1

TRAITS	PH	DOF	FLL	PL	NTPP	NGPP	1000GWT	ASV	AMYLOSE	LAS	KL	KB	L/ B	GY
PH	1	0.1309	0.2742*	0.3418**	-0.2335*	0.1112	0.1046	0.0119	0.2280*	0.137	-0.1378	-0.1285	-0.0929	-0.1656
DOF	0.1309	1	-0.1307	-0.2209*	0.1267	0.3207**	-0.2949*	-0.1928*	-0.0737	0.1166	-0.4036**	-0.1199	-0.3629**	0.0359
FLL	0.2742*	-0.1307	1	0.3675**	-0.2321*	0.2162*	-0.0963	0.1873*	0.1871*	0.0616	-0.1167	-0.1614	-0.0493	-0.2535**
PL	0.3418**	-0.2209*	0.3675**	1	-0.1533	-0.1977*	0.2770*	0.2843*	0.3477**	0.2062*	0.1900*	0.1388	0.133	-0.2328**
NTPP	-0.2335*	0.1267	-0.2321*	-0.1533	1	-0.1914*	-0.2167*	0.0322	0.1248	-0.0476	-0.067	0.1183	-0.1219	0.2003*
NGPP	0.1112	0.3207**	0.2162*	-0.1977*	-0.1914*	1	-0.4459**	-0.1724	-0.1577	-0.0144	-0.6102**	-0.3602**	-0.4550**	-0.072
1000GWT	0.1046	-0.2949*	-0.0963	0.2770*	-0.2167*	-0.4459**	1	0.0481	0.1282	0.0593	0.4827**	0.3648**	0.3157**	0.0303
ASV	0.0119	-0.1928*	0.1873*	0.2843*	0.0322	-0.1724	0.0481	1	-0.0613	-0.0563	-0.0321	0.3398**	-0.1778	0.0664
AMYLOSE	0.2280*	-0.0737	0.1871*	0.3477**	0.1248	-0.1577	0.1282	-0.0613	1	-0.0785	0.1914*	0.0886	0.137	0.0177
LAS	0.137	0.1166	0.0616	0.2062*	-0.0476	-0.0144	0.0593	-0.0563	-0.0785	1	-0.029	0.1633	-0.1155	-0.0623
KL	-0.1378	-0.4036**	-0.1167	0.1900*	-0.067	-0.6102**	0.4827**	-0.0321	0.1914*	-0.029	1	0.2485*	0.9006**	-0.0345
KB	-0.1285	-0.1199	-0.1614	0.1388	0.1183	-0.3602**	0.3648**	0.3398**	0.0886	0.1633	0.2485*	1	-0.1881*	0.1341
L/ B	-0.0929	-0.3629**	-0.0493	0.133	-0.1219	-0.4550**	0.3157**	-0.1778	0.137	-0.1155	0.9006**	-0.1881*	1	-0.1064

Note:- PH-Plant Height, DOF: Days To 50% Flowering, FLL: Flag Leaf Length, PL: Panicle Length, NTPP: Number of Tiller per Plant, NGPP: No of Grains per Panicle, 1000GWT: 1000Grain Weight, ASV: Alkali spreading value, AMYLOSE: Amylose Content, LAS: Leaf aroma score, KL: Kernel Length, KB: Kernel Breadth, L/B: Length Breadth Ratio, GY: Grain Yield per Plant.

Table 3.(b): Phenotypic correlation among 14 characters with yield per plant during DOS-2

TRAITS	PH	DOF	FLL	PL	NTPP	NGPP	10000GWT	ASV	AMYLOSE	LAS	KL	KB	L/ B	GY
PH	1	0.0602	0.2467*	0.0685	-0.3038**	0.0704	0.16	0.064	0.0899	0.0717	-0.0781	-0.042	-0.0716	-0.2556**
DOF	0.0602	1	-0.1862*	-0.2553*	0.097	0.3064**	-0.3747**	-0.2871*	-0.1467	0.0747	-0.4549**	-0.1402	-0.4165**	0.0299
FLL	0.2467*	-0.1862*	1	0.3287**	-0.2702*	0.1806*	-0.028	0.2189*	0.2076*	-0.0091	-0.0265	-0.0665	-0.0107	-0.2171*
PL	0.0685	-0.2553*	0.3287**	1	-0.1101	-0.2813*	0.3244**	0.3222**	0.2991**	0.1562	0.2663*	0.1116	0.2322*	-0.0482
NTPP	-0.3038**	0.097	-0.2702*	-0.1101	1	-0.2940*	-0.2604*	-0.0453	0.0135	-0.0042	0.0399	0.0117	0.0428	0.3115**
NGPP	0.0704	0.3064**	0.1806*	-0.2813*	-0.2940*	1	-0.3894**	-0.1898*	-0.2061*	0.002	-0.5822**	-0.2508*	-0.5098**	-0.0184
1000GWT	0.16	-0.3747**	-0.028	0.3244**	-0.2604*	-0.3894**	1	0.0069	0.1196	-0.0104	0.5321**	0.4334**	0.3816**	-0.0103
ASV	0.064	-0.2871*	0.2189*	0.3222**	-0.0453	-0.1898*	0.0069	1	0.2117*	-0.0568	-0.0083	0.2117*	-0.0823	0.0698

AMYLOSE	0.0899	-0.1467	0.2076*	0.2991**	0.0135	-0.2061*	0.1196	0.2117*	1	-0.1521	0.2749*	0.2052*	0.2097*	-0.0553
LAS	0.0717	0.0747	-0.0091	0.1562	-0.0042	0.002	-0.0104	-0.0568	-0.1521	1	-0.0464	0.018	-0.0611	-0.0739
KL	-0.0781	-0.4549**	-0.0265	0.2663*	0.0399	-0.5822**	0.5321**	-0.0083	0.2749*	-0.0464	1	0.2492*	0.9357**	-0.0527
KB	-0.042	-0.1402	-0.0665	0.1116	0.0117	-0.2508*	0.4334**	0.2117*	0.2052*	0.018	0.2492*	1	-0.1049	0.1447
L/ B	-0.0716	-0.4165**	-0.0107	0.2322*	0.0428	-0.5098**	0.3816**	-0.0823	0.2097*	-0.0611	0.9357**	-0.1049	1	-0.105

Note-: PH-Plant Height, DOF: Days To 50% Flowering, FLL: Flag Leaf Length, PL: Panicle Length, NTPP: Number of Tiller per Plant, NGPP: No of Grains per Panicle, 1000GWT: 1000Grain Weight, ASV: Alkali spreading value, AMYLOSE: Amylose Content, LAS: Leaf aroma score, KL: Kernel Length, KB: Kernel Breadth, L/B: Length Breadth Ratio, GY: Grain Yield per Plant.

Table 3.(c): Phenotypic correlation among 14 characters with yield per plant during DOS-3

TRAITS	PH	DOF	FLL	PL	NTPP	NGPP	1000GWT	ASV	AMYLOSE	LAS	KL	KB	L/ B	GY
PH	1	0.074	0.2876*	0.2966*	-0.2516*	0.1664	0.1357	0.0329	0.0971	0.0934	-0.1970*	-0.0251	-0.1908*	-0.1119
DOF	0.074	1	-0.1559	-0.2955*	0.0868	0.3297**	-0.4606**	-0.2196*	-0.1737	0.1109	-0.4608**	-0.0312	-0.4380**	0.0114
FLL	0.2876*	-0.1559	1	0.3779**	-0.2912*	0.2271*	0.0853	0.1994*	0.1917*	-0.0755	-0.0174	-0.0823	-0.0003	-0.1058
PL	0.2966*	-0.2955*	0.3779**	1	-0.2524*	-0.2208*	0.3040**	0.3468**	0.3446**	0.0404	0.2723*	0.0597	0.2305*	-0.1353
NTPP	-0.2516*	0.0868	-0.2912*	-0.2524*	1	-0.2165*	-0.1951*	-0.0852	-0.0551	-0.0461	0.0114	-0.2095*	0.0328	0.2815**
NGPP	0.1664	0.3297**	0.2271*	-0.2208*	-0.2165*	1	-0.4388**	-0.1761	-0.2549*	-0.0306	-0.5806**	-0.0796	-0.5092**	-0.0252
1000GWT	0.1357	-0.4606**	0.0853	0.3040**	-0.1951*	-0.4388**	1	-0.041	0.1289	0.0233	0.5267**	0.0604	0.4448**	-0.0226
ASV	0.0329	-0.2196*	0.1994*	0.3468**	-0.0852	-0.1761	-0.041	1	0.1934*	-0.012	-0.0112	0.0453	-0.0204	0.0295
AMYLOSE	0.0971	-0.1737	0.1917*	0.3446**	-0.0551	-0.2549*	0.1289	0.1934*	1	-0.146	0.2960*	-0.1052	0.2744*	-0.073
LAS	0.0934	0.1109	-0.0755	0.0404	-0.0461	-0.0306	0.0233	-0.012	-0.146	1	-0.0555	0.0117	-0.0758	-0.0854
KL	-0.1970*	-0.4608**	-0.0174	0.2723*	0.0114	-0.5806**	0.5267**	-0.0112	0.2960*	-0.0555	1	0.0774	0.9376**	-0.0634
KB	-0.0251	-0.0312	-0.0823	0.0597	-0.2095*	-0.0796	0.0604	0.0453	-0.1052	0.0117	0.0774	1	0.0365	0.0893
L/ B	-0.1908*	-0.4380**	-0.0003	0.2305*	0.0328	-0.5092**	0.4448**	-0.0204	0.2744*	-0.0758	0.9376**	0.0365	1	-0.0744

Note-: PH-Plant Height, DOF: Days To 50% Flowering, FLL: Flag Leaf Length, PL: Panicle Length, NTPP: Number of Tiller per Plant, NGPP: No of Grains per Panicle, 1000GWT: 1000Grain Weight, ASV: Alkali spreading value, AMYLOSE: Amylose Content, LAS: Leaf aroma score, KL: Kernel Length, KB: Kernel Breadth, L/B: Length Breadth Ratio, GY: Grain Yield per Plant.

Table 3.(d): Phenotypic correlation among 14 characters with yield per plant during DOS-4

TRAITS	PH	DOF	FLL	PL	NTPP	NGPP	1000GWT	ASV	AMYLOSE	LAS	KL	KB	L/ B	GY
PH	1	0.0038	0.2633*	0.2185*	-0.1837*	0.1569	0.0451	0.0485	0.2118*	0.0717	-0.0796	-0.146	-0.0381	-0.0722

DOF	0.0038	1	-0.013	0.1425	0.0244	0.0477	-0.4096**	0.0408	-0.0537	0.0177	-0.1271	-0.2890*	-0.0264	-0.2975**
FLL	0.2633*	-0.013	1	0.4581**	-0.3872**	0.3131**	-0.091	0.2097*	0.2271*	-0.1229	-0.1837*	-0.1996*	-0.1344	-0.2345*
PL	0.2185*	0.1425	0.4581**	1	-0.2371*	-0.1026	0.146	0.4868**	0.3983**	0.1122	0.087	0.046	0.0727	-0.1843*
NTPP	-0.1837*	0.0244	-0.3872**	-0.2371*	1	-0.3131**	-0.0224	-0.1462	-0.0209	-0.0131	0.1169	0.0864	0.0945	0.1881*
NGPP	0.1569	0.0477	0.3131**	-0.1026	-0.3131**	1	-0.2825*	-0.1808*	-0.1556	-0.055	-0.5212**	-0.3216**	-0.4450**	0.0432
1000GWT	0.0451	-0.4096**	-0.091	0.146	-0.0224	-0.2825*	1	0.1222	0.1298	-0.1054	0.6207**	0.6190**	0.4397**	-0.0705
ASV	0.0485	0.0408	0.2097*	0.4868**	-0.1462	-0.1808*	0.1222	1	0.096	0.0252	-0.0097	0.2237*	-0.0836	0.0244
AMYLOSE	0.2118*	-0.0537	0.2271*	0.3983**	-0.0209	-0.1556	0.1298	0.096	1	-0.0689	0.1496	-0.0498	0.1743	-0.0537
LAS	0.0717	0.0177	-0.1229	0.1122	-0.0131	-0.055	-0.1054	0.0252	-0.0689	1	-0.0553	0.0294	-0.0757	0.0081
KL	-0.0796	-0.1271	-0.1837*	0.087	0.1169	-0.5212**	0.6207**	-0.0097	0.1496	-0.0553	1	0.3272**	0.9438**	-0.1148
KB	-0.146	-0.2890*	-0.1996*	0.046	0.0864	-0.3216**	0.6190**	0.2237*	-0.0498	0.0294	0.3272**	1	-0.0008	0.1683
L/ B	-0.0381	-0.0264	-0.134Y4	0.0727	0.0945	-0.4450**	0.4397**	-0.0836	0.1743	-0.0757	0.9438**	-0.0008	1	-0.1737

Note-: PH-Plant Height, DOF: Days To 50% Flowering, FLL: Flag Leaf Length, PL: Panicle Length, NTPP: Number of Tiller per Plant, NGPP: No of Grains per Panicle, 1000GWT: 1000Grain Weight, ASV: Alkali spreading value, AMYLOSE: Amylose Content, LAS: Leaf aroma score, KL: Kernel Length, KB: Kernel Breadth, L/B: Length Breadth Ratio, GY: Grain Yield per Plant.

Table 4.(c): Phenotypic path matrix of 14 characters studied under DOS-3

TRAITS	**PH**	**DOF**	**FLL**	**PL**	**NTPP**	**NGPP**	**1000GWT**	**ASV**	**AMYL**	**LAS**	**KL**	**KB**	**L/ B**	**GY**
PH	-0.0492	-0.0036	-0.0142	-0.0146	0.0124	-0.0082	-0.0067	-0.0016	-0.0048	-0.0046	0.0097	0.0012	0.0094	-0.1119
DOF	-0.0009	-0.0126	0.0020	0.0037	-0.0011	-0.0042	0.0058	0.0028	0.0022	-0.0014	0.0058	0.0004	0.0055	0.0114
FLL	-0.0022	0.0012	-0.0076	-0.0029	0.0022	-0.0017	-0.0007	-0.0015	-0.0015	0.0006	0.0001	0.0006	0.0000	-0.1058
PL	-0.0227	0.0226	-0.0289	-0.0764	0.0193	0.0169	-0.0232	-0.0265	-0.0263	-0.0031	-0.0208	-0.0046	-0.0176	-0.1353
NTPP	-0.0847	0.0292	-0.0980	-0.0850	0.3367	-0.0729	-0.0657	-0.0287	-0.0185	-0.0155	0.0038	-0.0705	0.0110	0.2815**
NGPP	0.0129	0.0255	0.0176	-0.0171	-0.0167	0.0773	-0.0339	-0.0136	-0.0197	-0.0024	-0.0449	-0.0061	-0.0394	-0.0252
1000GWT	0.0204	-0.0692	0.0128	0.0457	-0.0293	-0.0660	0.1503	-0.0062	0.0194	0.0035	0.0792	0.0091	0.0669	-0.0226
ASV	0.0031	-0.0208	0.0189	0.0329	-0.0081	-0.0167	-0.0039	0.0949	0.0184	-0.0011	-0.0011	0.0043	-0.0019	0.0295
AMYLOSE	-0.0003	0.0006	-0.0007	-0.0012	0.0002	0.0009	-0.0005	-0.0007	-0.0035	0.0005	-0.0011	0.0004	-0.0010	-0.0730
LAS	-0.0068	-0.0081	0.0055	-0.0029	0.0034	0.0022	-0.0017	0.0009	0.0106	-0.0729	0.0040	-0.0009	0.0055	-0.0854

KL	-0.0010	-0.0024	-0.0001	0.0014	0.0001	-0.0030	0.0028	-0.0001	0.0015	-0.0003	0.0052	0.0004	0.0049	-0.0634
KB	-0.0040	-0.0050	-0.0131	0.0095	-0.0334	-0.0127	0.0096	0.0072	-0.0168	0.0019	0.0123	0.1595	0.0058	0.0893
L/ B	0.0236	0.0541	0.0000	-0.0285	-0.0041	0.0629	-0.0550	0.0025	-0.0339	0.0094	-0.1159	-0.0045	-0.1236	-0.0744
Partial R^2	0.0055	-0.0001	0.0008	0.0103	0.0948	-0.0019	-0.0034	0.0028	0.0003	0.0062	-0.0003	0.0143	0.0092	

R SQUARE = 0.1383, RESIDUAL EFFECT = 0.9283

Note-: PH: Plant Height, DOF: Days To 50% Flowering, FLL: Flag Leaf Length, PL: Panicle Length, NTPP: Number of Tiller per Plant, NGPP: Grains per Panicle, 1000GWT: Thousand Grain Weight, ASV: Alkali spreading value, AMYLOSE: Amylose Content, LAS: Leaf aroma score, KL: Kernel Length, KB: Kernel Breadth, L/B: Length Breadth Ratio, GY: Grain Yield per Plant.

Table 4.(d): Phenotypic path matrix of 14 characters studied under DOS-4

TRAITS	PH	DOF	FLL	PL	NTPP	NGPP	1000GWT	ASV	AMYLOSE	LAS	KL	KB	L/B	GY
PH	0.054	0.0002	0.0142	0.0118	-0.0099	0.0085	0.0024	0.0026	0.0114	0.0039	-0.0043	-0.0079	-0.0021	-0.0722
DOF	-0.0017	-0.4447	0.0058	-0.0634	-0.0109	-0.0212	0.1822	-0.0181	0.0239	-0.0079	0.0565	0.1285	0.0117	-0.2975**
FLL	-0.0673	0.0033	-0.2555	-0.1171	0.0989	-0.08	0.0233	-0.0536	-0.058	0.0314	0.0469	0.051	0.0343	-0.2345**
PL	0.008	0.0052	0.0168	0.0366	-0.0087	-0.0038	0.0053	0.0178	0.0146	0.0041	0.0032	0.0017	0.0027	-0.1843*
NTPP	-0.0301	0.004	-0.0635	-0.0389	0.164	-0.0514	-0.0037	-0.024	-0.0034	-0.0021	0.0192	0.0142	0.0155	0.1881*
NGPP	0.0374	0.0114	0.0746	-0.0244	-0.0746	0.2384	-0.0673	-0.0431	-0.0371	-0.0131	-0.1242	-0.0766	-0.1061	0.0432
1000GWT	-0.0203	0.1844	0.041	-0.0657	0.0101	0.1272	-0.4502	-0.055	-0.0584	0.0474	-0.2794	-0.2787	-0.198	-0.0705
ASV	0.0054	0.0046	0.0235	0.0546	-0.0164	-0.0203	0.0137	0.1121	0.0108	0.0028	-0.0011	0.0251	-0.0094	0.0244
AMYLOSE	0.0106	-0.0027	0.0113	0.0198	-0.001	-0.0078	0.0065	0.0048	0.0498	-0.0034	0.0075	-0.0025	0.0087	-0.0537
LAS	-0.0024	-0.0006	0.0041	-0.0037	0.0004	0.0018	0.0035	-0.0008	0.0023	-0.033	0.0018	-0.001	0.0025	0.0081
KL	0.3227	0.5154	0.745	-0.353	-0.4738	2.1136	-2.5168	0.0393	-0.6066	0.2242	-4.055	-1.3268	-3.8271	-0.1148
KB	-0.2401	-0.4753	-0.3282	0.0757	0.1421	-0.5288	1.0181	0.3679	-0.082	0.0484	0.5381	1.6446	-0.0014	0.1683
L/ B	-0.1484	-0.1026	-0.5235	0.2833	0.3679	-1.733	1.7126	-0.3255	0.679	-0.2947	3.676	-0.0032	3.8948	-0.1737
Partial R^2	-0.0039	0.1323	0.0599	-0.0067	0.0309	0.0103	0.0318	0.0027	-0.0027	-0.0003	0.4656	0.2767	-0.6765	

R SQUARE = 0.3201, RESIDUAL EFFECT = 0.8245

Note-: PH: Plant Height, DOF: Days To 50% Flowering, FLL: Flag Leaf Length, PL: Panicle Length, NTPP: Number of Tiller per Plant, NGPP: Grains per Panicle, 1000GWT: Thousand Grain Weight, ASV: Alkali spreading value, AMYLOSE: Amylose Content, LAS: Leaf aroma score, KL: Kernel Length, KB: Kernel Breadth, L/B: Length Breadth Ratio, GY: Grain Yield per Plant.

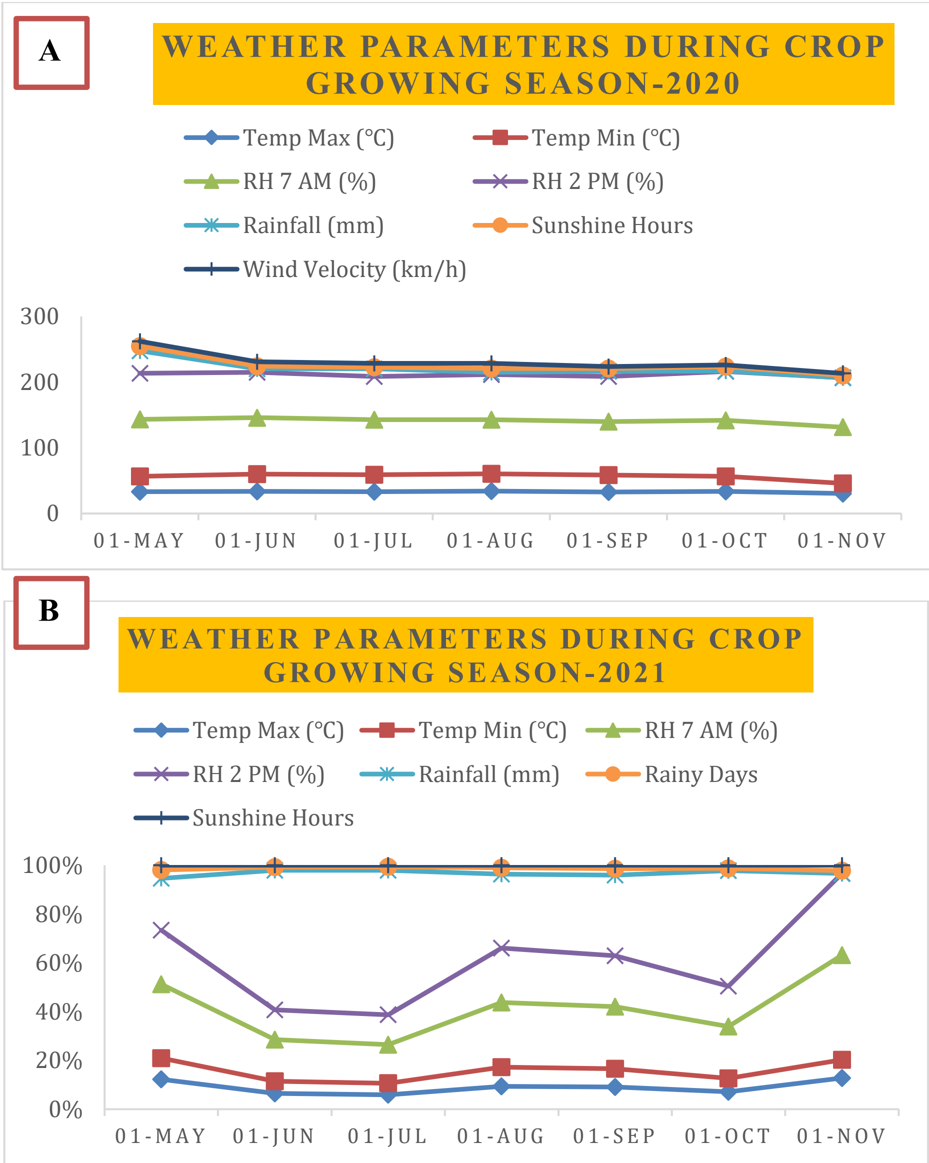

Fig: A and B Weather parameters during crop growing period [May-November, 2020 and2021, respectively.]