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Genetic Variability Study in Bread Wheat (*Triticum aestivum* L.) under Normal and Late Sown conditions

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ABSTRACT: Wheat is a temperate crop that is susceptible to high temperature. Its different growth stages have different temperature requirements and when exposed to extreme temperature, physiological behaviour and yield are affected negatively. Therefore, choosing a suitable genotype for particular climatic and sowing conditions is very important. In crop species, phenotypes are controlled mainly by genetic make-up of such crop coupled with kinds of environments where they are being grown and the interactions exist between the genotypes and environments. Therefore, it is necessary to divide the observed phenotypic variability into heritable and non-heritable components with parameters *viz*., phenotypic and genotypic coefficient of variation, heritability and genetic advance. Looking to these, the present study was conducted under normal (E_1 and E_3) and late sown condition (E_2 and E_4) during *rabi* 2019-20 and *rabi* 2020-21 by keeping objectives of estimation of variability parameters for sixteen different characters including grain yield per plant. Most of the characters studied displayed ample range of variation under late sown conditions than normal sown conditions. Wide range of variation was showed by all the characters studied except flag leaf area and canopy temperature depression, which showed modest phenotypic range under both the sowing conditions. Phenotypic coefficient of variation were higher than their corresponding genotypic coefficient of variation under normal (E_1 and E_3) and late sown (E_2 and E_4) conditions in both the years (*rabi* 2019-20 and *rabi* 2020-21), signifying the influence of environmental factors. However, the differences between phenotypic and genotypic coefficient of variation were not considerable. In normal as well as late sown conditions, based on modest to high values of different variability parameters, especially modest to high value of heritability accompanied by modest to high genetic advance as percentage of mean, the characters *viz*., grain yield per plant, harvest index, productive tillers per plant, spikelets per main spike, grains per main spike, plant height, days to 50 per cent heading, spike length, grain filling period, days to anthesis, SPAD-chlorophyll meter reading and days to maturity, which might also be ascribed to additive gene action controlling the expression of these traits and that phenotypic selection for improvement of these traits could be made under normal as well as late sowing conditions.

Keywords: Bread wheat, Variability, Heritability, Genetic advance.

INTRODUCTION

Wheat is widely grown all over the world and stands first among the cereals both in area and production. It has been described as the "King of Cereals" because of the growing area it occupies, and high productivity and top position it holds in the international food grain trade. Wheat is a crop of global significance grown in diversified environments. It is an important cereal crop of cool weather and plays vital role in food and nutritional security of world. It provides food for 40 per cent of the worldwide population and contributes 20 per cent of the food calories (Bhutto *et al*., 2016). The nutria-rich cereal is grown in diversified environments; internationally wheat occupies around 217 million hectares holding the position of maximum acreage among all crops with an annual production hanging around 731 million tonnes (Anon., 2018).

Before initiating any form of improvement programme in any agricultural crop, including wheat, a sound knowledge pertaining to the amount of genetic variability existing in such crop species for various traits is essential. Estimation of the variation in grain yield determining quantitative traits of the crop is a pre-requisite in breeding to improve yield. In crop species, phenotypes are controlled mainly by genetic make-up of such crop coupled with kinds of environments where they are being grown as well as the interactions between the genotypes and the environments. Therefore, it is necessary to divide the observed phenotypic variability into heritable and non-heritable components with parameters *viz*., phenotypic and genotypic coefficient of variation, heritability and genetic advance. Estimates of genetic parameters offers an indication of the relative importance of the various types of gene effect, that affecting the total variation of a plant character. In fact, genotypic and phenotypic coefficient of variation and heritability accompanied with genetic advance are very important parameters in improving traits. Genotypic and phenotypic components of variance, heritability and genetic advance for different yield traits revealed that selection was effective for a population with broad genetic variability and characters with high heritability.

Among many abiotic and biotic stresses, terminal heat stress is one of the major constraint to the global wheat production, particularly in tropical and sub tropical regions of South Asia including large portion of India (Joshi *et al.*, 2007). Yield loss may be up to 40 per cent under severe heat stress (Hays *et al.*, 2007). It has been observed that a heat wave (35–37° C) for 3–4 days modifies grain morphology and reduces grain size (Wardlaw and Wrigley, 1994). Shew *et al.* (2020) found that, increase in 1°C temperature resulted in average wheat yield reduction of 8.5 per cent, which increases to 18.4 per cent and 28.5 per cent under increase of 2 and 3°C temperature. Hence, keeping in view the above facts and figures, it is the need of the hour that for identifying the heat tolerant wheat genotypes which can be utilized in crop improvement programme, first basic need is to study the variability in relation to high temperature. The present study was conducted in four different environments created by sowing dates in two different seasons (*rabi* 2019-20 and *rabi* 2020-21) to estimate the genetic variability parameters which may useful for the development of efficient cultivars adapted to high temperature conditions.

MATERIALS AND METHODS

Geographically Junagadh is situated at 21.5° N latitude and 70.5°E longitudes with an elevation of 60 meters above the mean sea level. The soil of trial site was medium black, alluvial in origin having pH 7.8. The weather of the area represents tropical situation with semi-arid nature. The experimental materials consisted of 52 genotypes of bread wheat obtained from Wheat Research Station, Junagadh Agricultural University, Junagadh. These genotypes were sown on 18th November and 18th December under timely and late sown condition, respectively during *rabi* 2019-20 and *rabi* 2020-21 in Randomized Block Design (RBD) replicated thrice at the Sagdividi Farm, Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh, which created four different environments. Each genotype was sown in a single row plot of 3.0 m length with a spacing of 22.5 cm. All the recommended crop production and protection practices were followed timely for the successful raising of crop. The detail sowing time and year of experimentation is given in Table 1. The field view of all the four environments is depicted in Figs.1 to 4. In each plot, five plants were randomly selected and tagged excluding terminal ones to minimize border effects. The observations were recorded on these five randomly selected plants in each genotype and in each replication for 16 different characters except days to 50 per cent heading, days to anthesis, grain filling period and days to maturity, which were recorded on plot basis. Mean values of all the characters studied were used for statistical analysis. The analysis of variance to test the variation among the trial material was carried out using Randomized Block Design (RBD) as per procedure outlined by Panse and Sukhatme (1985). The genotypic and phenotypic coefficient of variation, which measures the amount of genotypic and phenotypic variation, respectively present in a particular character, was estimated as per the formula suggested by Burton and De Vane (1953). Heritability in broad sense was calculated by using the formula suggested by Allard (1960). The expected genetic advance at 5% selection intensity was estimated by using formula as suggested by Allard (1960). The genetic advance expressed as per cent of mean was calculated as under:

$$\text{Genetic advance as per cent of mean} = \frac{\text{Genetic advance}}{\text{Mean of character}} \times 100$$

Table 1: The details of environments.

Year of experiment	Environments	Date of sowing
Rabi 2019-20	E_1 (Normal sowing)	18th November, 2019
	E_2 (Late sowing)	18th December, 2019
Rabi 2020-21	E_3 (Normal sowing)	18th November, 2020
	E_4 (Late sowing)	18th December, 2020

Fig. 1. Field view of normal sown conditions (E_1) of *rabi* 2019-20.

Fig. 2. Field view of late sown conditions (E_2) of *rabi* 2019-20.

Fig. 3. Field view of normal sown conditions (E_3) of *rabi* 2020-21.

Fig. 4. Field view of late sown conditions (E_4) of *rabi* 2020-21.

RESULTS AND DISCUSSION

Genetic variability is pre-requisite for any crop improvement programme, as it provides wider scope for selection. Genotypic coefficient of variation measures the total of variation present for a particular character. However, it does not determine the amount of heritable variation of the total variation present for particular character. Johnson *et al.* (1955) suggested that heritability and genetic gain when worked out together would be more useful in predicting the resultant effect of selection. Therefore, in the present investigation, mean values, phenotypic (PCV) and genotypic (GCV) coefficients of variation, heritability, genetic advance and genetic advance expressed as percentage of mean were estimated.

The results of analysis of variance for experimental design in individual environments [*Rabi*-2019-20 (E_1 and E_2) and *Rabi*-2020-21 (E_3 and E_4)] carried out for 16 different characters, indicated that mean squares due to genotypes were significant for all the characters studied in all the environments, indicating presence of considerable genetic variation among the genotypes evaluated in the trial.

Most of the characters studied displayed ample range of variation under late sown conditions than normal sown conditions (Table 2), suggests that study material contained some heat tolerant genotypes. Wide range of variation was showed by all the characters studied except flag leaf area and canopy temperature depression, which showed modest phenotypic range under both the sowing conditions. Similar results were also reported by Zeeshan *et al.* (2014), Malav (2015); Rahman *et al.* (2016). Characters which exhibited large variation had more scope of improvement while making selection of genotypes under the respective sowing condition.

Due to influence of environment, the estimates of phenotypic coefficient of variation were of higher magnitude than the estimates of genotypic coefficient of variation for all the characters studied under normal (E_1 and E_3) and late sown (E_2 and E_4) conditions in both the years (*rabi* 2019-20 and *rabi* 2020-21) (Table 2). But the differences between them were not substantial, indicated that characters were comparatively stable to the environment (Majumdar *et al*. 1969). This also suggested that genetic cause was predominantly responsible for the expression of these traits and selection could be effectively made on the basis of phenotypic performance. Similar results have been reported by Amin *et al.* (2016); Sapi *et al.* (2017); Bhanu *et al.* (2018); Hossain *et al.* (2021).

In normal sown condition of *rabi* 2019-20 and *rabi* 2020-21 (E_1 and E_3), high genotypic coefficient of variation (32.90 % and 34.33 %) was observed for productive tillers per plant. The modest genotypic coefficient of variation was found for grains per main spike (18.21 % and 18.33 %), spikelets per main spike (15.22 % and 15.53 %), grain yield per plant (12.88 % and 12.87 %), spike length (12.13 % and 12.69 %), harvest index (11.26 % and 9.76 %), days to 50 per cent heading (10.97 % and 11.35 %) and grain filling period (10.35 % and 11.26 %). The modest GCV of 18.21 per cent was recorded in E_1 for harvest index, while it was low (9.76 %) in E_3 condition for harvest index. The estimated values of genotypic coefficient of variation were low in remaining traits studied in both the normal sowing conditions. In late sown condition (E_2 and E_4) of *rabi* 2019-20 and *rabi* 2020-21, the high genotypic coefficient of variation was observed for grain yield per plant (24.52 % and 24.78 %), harvest index (26.46 % and 24.45 %), number of productive tillers per plant (23.02 % and 23.36 %). The moderate genotypic coefficient of variation was found for number of spikelets per main spike (16.96 % and 16.85 %), number of grains per main spike (16.05 %and 16.39 %), plant height (14.94 % and 14.95 %), grain filling period (12.88 % and 15.09 %), spike length (12.62 % and

12.41 %) and days to 50 per cent heading (12.11 % and 12.35 %). The high GCV of 22.56 per cent was recorded in E_2 for canopy temperature depression, while it was low (9.76 %) in E_4 condition for canopy temperature depression. The estimated values of genotypic coefficient of variation were low in remaining traits studied in both the late sown conditions.

Table 2: Phenotypic range, mean, phenotypic and genotypic coefficient of variation, heritability, genetic advance and genetic advance expressed as per cent of mean for various characters of bread wheat in all the environments.

Sr. No.	Characters	Environment	Phenotypic range	Mean	Genotypic coefficient of variation (%)	Phenotypic coefficient of variation (%)	Heritability in broad sense (%)	Genetic advance (GA)	GA (as percentage of mean)
1.	Days to 50 per cent heading	E_1	44.67 to 70.67	57.98	10.97	11.69	88.16	12.82	22.11
		E_2	44.67 to 76.67	58.37	12.11	12.34	96.37	19.29	24.94
		E_3	47.33 to 86.67	65.97	11.35	11.57	96.18	15.12	22.92
		E_4	44.67 to 77.33	58.21	12.35	12.44	98.40	14.68	25.23
2.	Days to anthesis	E_1	56.00 to 95.33	76.54	9.55	9.77	87.40	14.70	19.21
		E_2	52.33 to 84.33	68.58	9.50	9.88	92.40	12.90	18.81
		E_3	56.33 to 95.00	76.65	9.64	9.83	96.04	14.91	19.45
		E_4	52.33 to 86.00	68.50	9.47	9.60	97.13	13.16	19.22
3.	Days to maturity	E_1	94.33 to 134.67	112.01	7.17	7.53	90.59	15.75	14.06
		E_2	84.33 to 112.33	97.69	5.67	6.13	85.55	10.55	10.80
		E_3	94.33 to 134.67	112.22	7.31	7.60	92.53	16.26	14.49
		E_4	83.67 to 113.33	97.87	6.16	6.29	95.73	12.14	12.41
4.	Grain filling period	E_1	27.67 to 47.67	35.47	10.35	12.79	65.40	6.11	17.23
		E_2	20.33 to 38.67	29.11	12.88	16.41	61.51	6.05	20.80
		E_3	26.67 to 47.67	35.57	11.26	13.20	72.75	7.03	19.78
		E_4	18.67 to 39.33	29.37	15.09	16.10	87.70	8.54	29.10
5.	Number of productive tillers per plant	E_1	4.00 to 15.00	8.21	32.90	34.59	90.46	5.29	64.46
		E_2	3.33 to 9.67	6.21	23.02	26.41	75.93	2.56	41.32
		E_3	4.67 to 15.33	8.22	34.33	35.60	92.96	5.60	68.18
		E_4	3.33 to 9.67	6.33	23.36	24.81	88.63	2.86	45.31
6.	Plant height (cm)	E_1	63.50 to 101.00	81.68	9.69	10.55	84.41	14.98	18.35
		E_2	44.17 to 82.90	64.23	14.94	15.46	93.35	19.09	29.73
		E_3	63.47 to 100.27	82.08	9.90	10.76	84.65	15.40	18.76
		E_4	44.16 to 83.18	64.27	14.95	15.46	93.49	19.13	29.77
7.	Spike length (cm)	E_1	6.60 to 13.00	9.89	12.13	12.83	89.31	2.33	23.61
		E_2	5.67 to 10.67	8.25	12.62	13.31	89.75	2.03	24.62
		E_3	6.47 to 13.50	9.84	12.69	13.40	89.63	2.43	24.75
		E_4	5.67 to 10.52	8.24	12.41	13.09	89.70	1.99	24.23
8.	Number of spikelets per main spike	E_1	10.67 to 22.67	15.04	15.22	16.04	89.94	4.47	29.73
		E_2	8.33 to 16.67	11.85	16.96	18.81	81.21	3.73	31.50
		E_3	10.33 to 22.33	14.94	15.53	16.22	91.71	4.57	30.64
		E_4	8.33 to 16.33	11.83	16.85	18.38	83.94	3.76	31.79
9.	Number of grains per main spike	E_1	25.67 to 65.33	47.94	18.19	18.77	93.90	17.40	36.31
		E_2	21.67 to 42.67	31.42	16.05	17.25	86.75	9.67	30.80
		E_3	26.00 to 64.00	47.87	18.33	18.92	93.86	17.51	36.59
		E_4	21.67 to 43.00	31.41	16.39	17.21	90.43	10.10	32.16
10.	1000 grain weight (g)	E_1	36.33 to 46.60	41.09	5.10	5.42	88.38	4.05	9.88
		E_2	23.23 to 30.28	27.07	5.19	5.53	87.62	2.70	9.99
		E_3	36.17 to 46.63	41.04	5.31	5.66	87.76	4.20	10.23
		E_4	22.71 to 30.57	27.07	5.17	5.61	84.62	2.65	9.79
11.	Grain yield per plant (g)	E_1	14.68 to 29.31	20.50	12.88	14.70	76.68	4.76	23.24
		E_2	6.54 to 21.42	13.54	24.52	25.53	92.20	6.57	48.50
		E_3	14.45 to 29.24	20.72	12.87	14.38	80.04	4.91	23.72
		E_4	6.50 to 21.41	13.58	24.78	25.61	93.63	6.71	49.40
12.	Biological yield per plant (g)	E_1	34.23 to 55.28	45.93	6.25	8.86	49.68	4.16	9.07
		E_2	25.33 to 39.70	34.63	5.96	9.17	42.16	2.75	7.96
		E_3	34.48 to 53.89	46.10	5.85	8.68	45.32	3.73	8.11
		E_4	24.77 to 41.40	30.16	7.82	10.75	52.82	3.53	11.70
13.	Harvest index (%)	E_1	28.65 to 60.38	45.02	11.26	13.94	65.19	8.42	18.72
		E_2	18.31 to 57.19	39.15	26.46	26.97	96.26	21.13	53.48
		E_3	29.31 to 59.95	45.46	9.73	19.39	52.79	6.62	14.56
		E_4	22.13 to 70.81	45.64	24.45	26.44	85.47	21.45	45.56
14.	Flag leaf area (cm^2)	E_1	1.14 to 1.46	1.29	3.97	5.86	45.94	0.07	5.54
		E_2	1.08 to 1.43	1.24	5.15	6.72	58.57	0.10	8.11
		E_3	1.15 to 1.47	1.30	3.54	5.85	36.47	0.05	4.39
		E_4	1.04 to 1.43	1.19	4.92	7.54	42.51	0.07	6.60
15.	SPAD-Chlorophyll Meter Reading (SCMR-reading)	E_1	36.33 to 46.67	42.64	6.65	7.52	78.21	5.16	12.11
		E_2	33.33 to 46.33	41.74	6.53	8.04	66.00	4.52	10.94
		E_3	35.33 to 47.67	42.50	6.67	8.10	67.91	4.81	11.33
		E_4	31.00 to 46.33	41.33	6.54	8.04	65.99	4.52	10.94
16.	Canopy temperature depression (CTD)	E_1	4.26 to 8.80	6.08	9.80	14.70	44.44	0.81	13.46
		E_2	4.00 to 10.16	5.53	22.56	24.70	83.40	2.35	42.44
		E_3	4..83 to 8.00	6.03	8.82	13.42	43.24	0.72	11.95
		E_4	4.50 to 8.20	5.76	9.19	14.02	42.98	0.71	12.41

Under normal sown condition of *rabi* 2019-20 and *rabi* 2020-21 (E_1 and E_3), the phenotypic coefficient of variation was observed high for number of productive tillers per plant (34.59 % and 35.60 %). The phenotypic coefficient of variation was found medium for number of grains per main spike (18.77 % and 18.92 %), number of spikelets per main spike (16.04 % and 16.22 %), grain yield per plant (14.70 % and 14.38 %), canopy temperature depression (14.70 % and 13.42 %), harvest index (13.94 % and 19.39 %), grain filling period (12.79 % and 13.20 %), spike length (12.83 % and 13.40 %), days to 50 per cent heading (11.69 % and 11.57 %) and plant height (10.55 % and 10.76 %). While the estimated values of phenotypic coefficient of variation were noted low in remaining traits in both the normal sown conditions. Under late sown condition of *rabi* 2019-20 and *rabi* 2020-21 of experimentation (E_2 and E_4), the high phenotypic coefficient of variation was observed for harvest index (26.97 % and 26.44 %) followed by number of productive tillers per plant (26.41 % and 24.81 %), grain yield per plant and (26.53 % and 25.61 %). The phenotypic coefficient of variation was found moderate for number of spikelets per main spike (18.81 % and 18.38 %), number of grains per main spike (17.25 % and 17.21 %), grain filling period (16.41 and 16.10 %), plant height (15.46 % and 15.46 %), spike length (13.31 % and 13.09 %) and days to 50 per cent heading (12.34 % and 12.44 %). The value of PCV was high (24.70 %) for canopy temperature depression in E_2 late sowing condition, while it was moderate for canopy temperature depression (14.02 %) and biological yield per plant (10.75 %) in E_4 late sown condition. The estimated values of phenotypic coefficient of variation were found low in remaining traits in respective late sown conditions.

In general, harvest index, productive tillers per plant, grain yield per plant, canopy temperature depression, spikelets per main spike, grains per main spike, grain filling period, plant height, spike length and days to 50 per cent heading possessed high to modest magnitude of phenotypic and genotypic coefficients of variation under both the normal sown as well as late sown conditions.

High genotypic and phenotypic coefficient of variation was observed for harvest index by Kumar *et al.* (2014); Singh *et al.* (2018); for grain yield per plant by Kumar *et al.* (2014); Amin *et al.* (2016); Bhanu *et al.* (2018); Singh *et al.* (2018) and Poudel *et al.* (2021); and for productive tillers per plant by Kumar *et al.* (2013), Degewione *et al.* (2013); Desheva and Kyosev (2015). Moderate GCV and PCV values were noted by Dhananjay *et al.* (2012) for biological yield per plant, ear length, tillers per plant and grains per spike. Similarly, Nukasani *et al.* (2013) recorded moderate GCV and PCV values for 1000 grain weight, spike length, grains per spike, plant height and spikelets per spike; Desheva and Kyosev (2015) for 1000-grain weight and plant height; Malav (2015) for plant height, grain filling period and days to maturity; and Poudel *et al.* (2021) for thousand grain weight and grains per main spike.

The coefficient of variation does not offer full scope to estimate the heritable variation. The relative amount of heritable portion of variation is assessed with the help of heritability estimates and genetic advance expressed as percentage of mean (genetic gain). The success of selection depends on the breeding value of a genotype recognized from its phenotypic appearance. The degree of correspondence between phenotypic value and breeding value for a character is measured by heritability, which indicates reliability of former as a guide to the later. The heritability is a good index of transmission of characters from parents to their off-springs (Falconer, 1981). High values of heritability in broad sense are helpful in recognizing the proper character for selection and facilitating the breeder to select superior genotypes on the basis of phenotypic look of quantitative traits (Johnson *et al*., 1955).

High estimates of heritability (> 60 %) were observed for all the traits studied including grain yield per plant under normal and late sown conditions in both the years except for biological yield per plant (49.68 %), flag leaf area (45.94 %) and canopy temperature depression (44.44 %) in E_1; flag leaf area (58.57 %) and biological yield per plant (42.16 %) in E_2; harvest index (52.79 %), biological yield per plant (45.32 %), canopy temperature depression (43.24 %) and flag leaf area (36.47 %) in E_3; and biological yield per plant (52.82 %), canopy temperature depression (42.98 %) and flag leaf area (42.51 %) in E_4; which expressed modest heritability.

In general, heritability values did not differ much under both the sowing conditions for all the characters which may be due to the less influence of environment on the expression of traits. High to modest heritability estimates indicated that the characters were least influenced by the environmental effects, also suggested that the phenotypes were the true representative of their genotypes for these traits and selection based on phenotypic values could be reliable. Characters showing high heritability values indicate that they have more number of additive factors (Panse, 1957; Majumdar *et al*., 1969).

Rapid progress in selection can be achieved when high heritability is accompanied with the high genetic advance, which forms the most reliable index for selection (Burton, 1952). Since the magnitude of genetic advance is influenced by the units of measurement, it was further expressed as percentage of mean (genetic gain) and considered as an important selection parameter. The genetic gain reveals the genetic potential of the character under selection and effectiveness of selection. If the heritability was mainly due to additive effects, it would be associated with high genetic advance and if it was due to non-additive (dominance and epistasis) effects, the genetic advance would be low (Panse, 1957). The characters exhibiting high heritability along with high genetic gain possess selective value and offer ample scope for competent selection.

High values of genetic advance expressed as percentage of mean was exhibited by productive tillers per plant (64.46 % and 68.18 %), grains per main spike (36.31 %

and 36.59 %), spikelets per main spike (29.73 % and 30.64 %), spike length (23.61 % and 24.75 %), grain yield per plant (23.24 % and 23.72 %) and days to 50 per cent heading (22.11 % and 22.92 %) under normal sowing (E_1 and E_3) of both the seasons. While moderate estimates were found for days to anthesis (19.21 % and 19.45 %), harvest index (18.72 % and 14.56 %), plant height (18.35 % and 18.76 %), grain filling period (17.23 % and 19.78 %), days to maturity (14.06 % and 14.49 %), SPAD-chlorophyll meter reading (12.11 % and 11.33 %) in E_1 and E_3, and 1000 grain weight (10.23 %) in E_3. Under late sowing (E_2 and E_4) of both the seasons, high estimates of genetic gain was found for harvest index (53.48 % and 45.56 %), grain yield per plant (48.50 % and 49.40 %), number of productive tillers per plant (41.32 % and 45.31 %), number of spikelets per main spike (31.50 % and 31.79 %), number of grains per main spike (30.80 % and 32.16 %), plant height (29.73 % and 29.77 %), days to 50 per cent heading (24.94 % and 25.23 %), spike length (24.62 % and 24.23 %) and grain filling period (20.80 % and 29.10 %) in both the years, while for canopy temperature depression (42.44 %) in E_2 only. Canopy temperature depression had moderate estimates (12.41 %) for genetic gain in E_4. Moderate values were recorded for genetic advance as per cent of mean for days to anthesis (18.81 % and 19.22 %), SPAD-chlorophyll meter reading (10.94 % and 10.94 %) and days to maturity (10.80 % and 12.41 %) in both E_2 and E_4 environments. Overall, moderate to high value of heritability accompanied by moderate/high genetic advance as percentage of mean was expressed by grain yield per plant, harvest index, productive tillers per plant, spikelets per main spike, grains per main spike, plant height, days to 50 per cent heading, spike length, grain filling period, days to anthesis, SPAD-chlorophyll meter reading and days to maturity, which might also be ascribed to additive gene action controlling the expression of the traits and that phenotypic selection for improvement of these traits could be brought about.

High heritability couples with high genetic advance as per cent of mean was observed for days to anthesis by Amin *et al*. (2016) ; Bhanu *et al.* (2018); for days to heading by Degewione *et al.* (2013), Amin *et al*. (2016) and Bhanu *et al.* (2018); for days to maturity by Amin *et al*. (2016); Bhanu *et al.* (2018); for grain filling period by Amin *et al*. (2016) and Gerema *et al.* (2020); for productive tillers per plant by Zeeshan *et al.* (2014); for plant height by Amin *et al*. (2016); for spike length by Singh *et al*. (2018); for spikelets per main spike by Amin *et al*. (2016) and Hossain *et al.* (2021); for grains per main spike by Gerema *et al.* (2020); Hossain *et al.* (2021); for harvest index by Zeeshan *et al.* (2014); Singh *et al*. (2018); for 1000-grain weight by Zeeshan *et al.* (2014); Rahman *et al.* (2016); Bhanu *et al.* (2018); Singh *et al*. (2018); Hossain *et al.* (2021); Poudel *et al.* (2021); and for grain yield per plant by Degewione *et al.* (2013); Zeeshan *et al.* (2014); Amin *et al*. (2016); Singh *et al*. (2018); Hossain *et al.* (2021); Poudel *et al.* (2021).

CONCLUSIONS

On the basis of variability parameters studied, it can be concluded that grain yield per plant, harvest index, productive tillers per plant, spikelets per main spike, grains per main spike, plant height, days to 50 per cent heading, spike length, grain filling period, days to anthesis, SPAD-chlorophyll meter reading and days to maturity, which might also be ascribed to additive gene action controlling the expression of the traits and phenotypic selection for improvement of these traits could be brought about under normal as well as late sowing conditions.

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Conflict of Interest. The authors declare that the present study, a part of Ph. D. study was conducted without any financial relationship, that could be construed as a potential conflict of interest.

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