Journal of Animal & Plant Sciences, 33(4): 2023, Page: 936-948
ISSN (print): 1018-7081; ISSN (online): 2309-8694
https://doi.org/10.36899/JAPS.2023.4.0687

ASSESSMENT OF STABILITY PARAMETERS FOR MULTIPLE TRAITS IN NEWLY DEVELOPED SINGLE CROSS HYBRIDS OF MAIZE (*Zea mays* L.)

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ABSTRACT

Due to climatic changes around the world, maize is currently exposed to a variety of biotic and abiotic pressures in time and place that affect the performance of maize hybrids. Plant breeders need genotypes that respond consistently and preferentially to different environmental conditions. The present investigation was carried out with seven inbred lines, twenty-one F_1 hybrids which were developed through a diallel matting scheme, and three hybrid checks at six environments which comprise three locations and two crop growing seasons. The pooled analysis of variance indicated highly significant mean squares due to environments, genotypes, and genotype by environment interactions (GEI) for all the traits like Days to 50 per cent anthesis, days to 50 per cent silk, anthesis-silking interval, days to 50 per cent physiological maturity, plant height, ear height, ear length, ear diameter, kernel rows per ear, kernels per row, grains per plant, 1000-kernel weight, shelling per cent and grain yield per plant. The mean squares of analysis of variance for all the studied traits in maize over the six environments revealed highly significant due to genotypes, Env. + (G x Env.), environment (linear), and pooled deviation. The significant to highly significant mean squares due to G × E (linear) were observed for all the traits under study except for days to 50% anthesis and silking, plant height, ear length, kernels per row, and grains per plant. The higher magnitude of mean squares due to environment (linear) than the corresponding G × E (linear) were recorded for all the studied traits indicating that the linear response of environment accounted for a major part of the total variance. The estimates of environmental indices revealed that environment, E4 (Rabi 2019-20, BAU, Sabour) had highly positive, therefore E4 is considered the most favorable environment amongst the six environments for the expression of all the studied characters. The estimates of stability parameters for grain yield per plant revealed nine hybrids, namely, P1 × P2, P1 × P4, P1 × P5, P2 × P4, P2 × P5, P3 × P4, P3 × P5, P4 × P7, and P5 × P6 had high mean grain yield, unit regression coefficient (bi=1) and non-significant deviation from regression ($S^2di=0$) indicating these hybrids were stable for this trait over the test environments.

Keywords: G × E Interactions, Multiple traits, Maize, Stability parameters, and Single cross hybrids

Published first online April 18, 2023 Published final August 04, 2023

INTRODUCTION

Maize (*Zea mays* L., 2n=20) also known as corn literarily means "that which sustains life" (Raj *et al.,* 2019) and belongs to the family Poaceae. The world's population will hit 9.1 billion by 2050, 34% higher than it is today. Nearly all of this rise in population will happen in developing countries. Urbanization will proceed at an accelerated pace and nearly 70% of the world's population will be urban. Income levels are going to be many multiples of what they now are. Food production needs to boost by 70% to feed this bigger, more urbanized, and wealthier population (FAO, 2009) and the demand for corn in developing nations will double between now and 2050 (Rosegrant *et al.*, 2009).

Currently, maize is exposed to dynamic environmental conditions which include several biotic and abiotic stresses in time and space due to global climate changes that influence the performance of maize hybrids. In addition, maize growing areas are changing because of their replacement by higher-value crops like vegetables from its traditional production belts. It is increasingly grown in much more challenging and marginal production environments, characterized by declined soil organic matter, reduced soil fertility, and low water-holding soils among other challenges in tropical regions and developing nations. In India, the production of maize is also dominated by marginal and small farmers who lack the means to condition the environment (India maize summit, 2014). Therefore, this reveals the need for the development of high-yielding stable genotypes (Nyombayire *et al*., 2018).

Stability refers to the suitability of a variety for general cultivation over a wide range of environments. The most important objective of the plant breeder is to develop varieties with high yields and stable performance. Stability analysis helps the breeder to identify adaptable genotypes that can grow over a wide range of environments and predict the varietal response under different environments. It requires multi-environment testing to obtain a reliable estimate of the productivity of the genotypes under study and to evaluate them for phenotypic stability over the environments. According to Eberhart and Russell (1966), a stable variety is one with a regression coefficient of unity (b=1) and a minimum deviation from the regression line ($S^2d=0$).

Genotype by environment interaction (GEI) is the differential performance of genotypes over environments, especially in tropics with wide seasonal and spatial variation. The consequences of G × E interactions in the selection and release of improved genotypes cannot be overlooked. For this rationale, plant breeders have been striving to create varieties with superior and stable grain yield, quality, and other desirable traits over an array of environments. Keeping in the view of above perspective, the present investigation was undertaken with the objectives to determine the stability parameters for multiple traits in newly developed single cross hybrids of maize (*Zea mays* L.).

MATERIALS AND METHODS

The experimental materials comprise twenty-one F_1 hybrids generated in half diallel fashion (Method II and Model I) suggested by Griffing 1956, their seven parental inbred and three commercial hybrids were evaluated in a randomized block design (RBD) with three replications over six environments comprising three locations and two consecutive crop growing seasons i.e., Kharif 2019 and Rabi 2019-20. The recommended package of practices was followed across the environments to raise the healthy crop. The pedigree of twenty-one single cross hybrids generated by Griffing's (1956) diallel mating design (Method II Model I) is presented in Table 1.

Geographical Location for Experimentation: The present investigation was carried out during Kharif 2019 and Rabi 2019-20 at three different zones of Bihar under Bihar Agricultural University, Sabour, Bhagalpur (Bihar) namely, Bihar Agricultural College (BAC), Sabour (Zone-IIIA); Bhola Paswan Shastri Agricultural College (BPSAC), Purnea (Zone-II) and Pulse Research Centre (PRC), Mokama (Zone-IIIB) with an eye to full fill the objectives of the work (Table 2). The meteorological data which cover the average data monthly wise over the six environments are presented in Table 3

Geographically, the experimental area of Bihar Agricultural College, Sabour is situated at the latitude between 25° 07' - 25° 30' N, longitude between 86° 37' - 87° 30' E, and altitude of 42.98 meters above the mean sea level. The experimental area falls under the sub-tropical zone and is characterized by a hot summer, moderate to heavy rainfall, and cold winter. The average rainfall is about 1100 mm distributed between the second fortnight of June and to first fortnight of October. The hottest and coldest month of the year is May to June and January, respectively. The maximum average temperature goes beyond 40 °C from May to June whereas, the minimum and maximum average temperatures go 8 °C and 21.8 °C, respectively in January.

The experimental farm, BPSAC, Purnea is situated at a latitude between 25º 21'-26º 05' N, longitude between 86º 59' - 87º 51' E, and altitude of 35.97 meters above the mean sea level. The experimental area falls under a moist humid climate with an average rainfall of 1411.5 mm. The winter season starts in November and lasts until February. The month of January was the coldest of the year with the mean daily minimum and maximum temperature ranging from 5 - 10 ºC and 20 - 25 ºC. Summer season commences in March and lasts up to June followed by the monsoon season which lasts until September. About 82% of the total annual rainfall is received during the monsoon season of June to September.

The experimental area, PRC, Mokama, falls under the district of Patna which is situated at the latitude and latitude between 25°13′ - 25º 45' N and 84°43′ - 86º44' E, respectively, and an altitude of 53 meters above the mean sea level. Geographically, the district of an experimental area is characterized by a quite hot summer, fairly cold during the winter, and the coldest month January. Rain starts sometime in the middle of June and lasts until mid of September. The average annual rainfall receives in the district is around 1076 mm. The monsoon months namely, July and August receive maximum rains whereas, sometimes winter rains also receive from January to February.

Data Collection on Morpho-physiological Traits: Data were recorded on morpho-physiological traits on a plot basis in each plot and each replication for days to 50% anthesis, days to 50% silk, and days to 50% physiological maturity. However, plant height, ear height, ear length, ear diameter, kernel rows per ear, kernels per row, grains per plant, and grain yield per plant were recorded on ten randomly selected competitive plants from the middle of each row in each plot and each replication. Anthesis-silking interval was recorded as a difference between days to 50% anthesis and silk. 1000-kernel weight was calculated from the bulked seeds of all the ears of ten competitive plants in each plot and each replication. The shelling percentage was calculated from the kernels weight and ear weight of ten randomly selected plants using the formula given below:

$$\text{Shelling (\%)} = \frac{\textbf{Weight of kernels}}{\textbf{Weight of ear}} \times 100$$

For estimation of grain yield per plant, the weight of ears of ten plants after harvest was taken in grams for each plot using an electric weighing balance and at the same time all the ears of sampled plants from each plot were shelled and the moisture percentage in grains at harvest was taken using electronic moisture tester for each representative sample. The grain yield for every entry from the data of fresh ear weight per plot was adjusted to uniform grain moisture content at 15%. The following modified formula is used to calculate grain yield per plant (g) at 15% moisture (Mafouasson *et al.,* 2018).

$$\text{Grain yield per plant (g)} = \text{Fresh ear weight (g)} \times \frac{100 - \text{Grain moisture at harvest}}{100 - 15} \times \frac{0.80 \times 1.176}{10}$$

Here,
0.80 is the shelling coefficient
1.176 is a constant factor to adjust grain yield at 15% moisture content
10 is the number of randomly selected representative plants
15 is the moisture percentage required in maize grain at the storage

Statistical Analysis: Stability analysis was carried out on thirty-one genotypes including twenty-one single cross hybrids, seven parental inbred lines, and three commercial hybrids as checks under six environments during Kharif-2019 and Rabi 2019-20 following Eberhart and Russel's model (1966). This analysis was based on the following mathematical model

$Y_{ij} = \mu + \beta_i I_j + \delta_{ij} + \varepsilon_{ij}$, i=1,……..g, j=1……….n

Here,
Y_{ij} is the mean of the $_i$th genotypes in the j^{th} environment,
μ is the mean of all the genotypes over all the environments,
β_i is the regression coefficient of the i^{th} genotypes to the varying environment.
I_j is the environments index (EI) i.e., the mean of all genotypes at the j^{th} environments minus the grand mean
δ_{ij} is the deviation from the regression of i^{th} genotype in j^{th} environment.
ε_{ij} is the experimental error
g and n are numbers of genotypes and environments, respectively

Stability parameters such as the regression coefficient (bi) and deviation from the linear regression (S^2d) were estimated as follows.

$$bi = \frac{\sum j \ Yij \ Ij}{\sum j \ \ Ij2}$$

$$S^2 di = \frac{\sum j \ \ \delta ij2}{n-2} - \frac{S^2 e}{r}$$

Here,
bi =is the regression coefficient of the i^{th} genotype
S^2di is the mean square deviation of the i^{th} genotype from regression
S^2e/r = pooled error

$$\delta_{ij}^2 = \sum j Y_{ij}^2 - \frac{Y_i^2}{n} - \frac{(\Sigma j Y_{ij} I_j)^2}{\Sigma j I_j^2}$$

The 'F' test was used to find out the significance of differences among genotypes, regression values, and deviations from the regression line.

RESULTS AND DISCUSSION

The present study entitled "Assessment of stability parameters for multiple traits in newly developed single cross hybrids of maize (*Zea mays* L.)" presented and discussed as follows

Pooled Analysis of Variance for the Design of the Experiment: The pooled analysis of variance for the design of the experiment over six environments indicated highly significant mean squares due to environments, genotypes, and genotype by environment interactions (GEI) for fourteen quantitative traits in maize, namely, days to 50 per cent anthesis, days to 50 per cent silk, anthesis-silking interval, days to 50 per cent physiological maturity, plant height, ear height, ear length, ear diameter, kernel rows per ear, kernels per row, grains per plant, 1000-kernels weight, shelling percentage and grain yield per plant (Table 4). These results indicated that significant differences existed among the environments and genotypes, and environment played an important role in the expression of characters. Hence, there is great scope for the identification of promising genotypes used in crop breeding programs for improvement in grain yield and yield contributing characters. These findings are in close conformity with the finding of Hefny (2010) for grain yield per plant, 100-grain weight, number of kernels per row, number of kernel rows per ear, days to 50% silking, and days to 50% anthesis; finding of Werle *et al.* (2014) for grain yield; finding of Oliveira *et al.* (2016) for grain yield, plant height, and ear height; finding of Akaogu *et al.* (2017) for grain yield (kg/ha), days to anthesis, days to silking, anthesis-silking interval, plant height, and ear position; finding of Murtadha *et al.* (2018) for days to anthesis, days to silking, anthesis-silking interval, 1000-kernel weight, and grain yield; finding of Hemlata (2019) for grain yield per plant, 1000-kernel weight, number of grains per plant, days to 75% physiological maturity, ear height, plant height, anthesis-silking interval, days to 50% silk and days to 50% anthesis.

Genotype by Environment Interactions (GEI): The performance of a genotype mainly depends on environmental interaction. The estimates of genotype by environment interactions give an idea of the buffering capacity of the genotypes under study. The analysis of variance for the stability of fourteen quantitative characters in maize is presented in Table 5. The estimates of mean squares due to genotypes were highly significant for all the characters. This suggested that there were significant variations among genotypes. These results are in close conformity with the findings of Shanthi *et al.* (2010), Patel (2015), Bharathiveeramani *et al.* (2016), *Dar et al.* (2017), Synrem *et al.* (2017), Sserumaga *et al.* (2018), Hemlata (2019), Pavani *et al.* (2019), Hemlata *et al.* (2020) and Rezende *et al*. (2020). The mean squares (MS) due to Env. + (G × Env.) were highly significant for all the traits under study indicating the interaction of genotype with the environment and the distinct nature of the environment and GEI in phenotypic expression *i.e.,* differential behavior of genotypes under different environments. Further partitioning the MS due to Env. + (G × Env.), the MS due to environment (linear) was highly significant for all the characters under study indicating the presence of micro seasonal differences under Kharif and Rabi crop growing seasons. The significant to highly significant MS due to G × E (linear) were observed for the majority of studied traits except for days to 50% anthesis, days to 50% silk, plant height, ear length, kernels per row, and grains per plant indicated significant linear response of genotypes for these traits. A higher magnitude of MS due to environment (linear) than the G × E (linear) indicated that the linear response of environment accounts for a major part of the total variance for all the traits and might be responsible for the high adaptation of the genotype to yield and its attributes. The MS due to pooled deviation was highly significant for all the characters under study indicating that both linear and non-linear components may be contributing to G × E interactions observed for these characters.

Environmental Indices (EI): The varietal performance is a function of the genotype and environment where it grows. Different environments are not equally favorable/unfavorable for the performance of the genotypes grown under them. The environmental index directly reflects the environment through positive and negative values (Table 6). The estimates of environmental indices for fourteen quantitative characters ranged from -77.15 (1000-kernel weight) to 4.02 (plant height) for E1, -119.42 (grains per plant) to 1.84 (ear height) for E2, -34.56 (days to 50 per cent physiological maturity) to 23.25 (plant height) for E3, 0.34 (anthesis-silking interval) to 117.88 (grains per plant) for E4, -24.01 (ear height) to 66.39 (1000-kernel weight) for E5 and -3.27 (plant height) to 29.72 (days to 50 per cent silk) for E6. Almost all the characters showed positive environmental indices in environments, E4, E5, and E6 with an exceptional of plant height and ear height had negative environmental indices in both environments, E5 and E6. Based on environmental indices, the environment, E4 (Rabi 2019-20, BAU, Sabour) exhibited highly positive environmental indices for all the traits under study. Hence, E4 was considered the most favorable environment amongst the six environments for the expression of characters. Two environments, namely, E5 (Rabi 2019-20, BPSAC, Purnea) and E6 (Rabi 2019-20, PRC, Mokama) also exhibited highly positive environmental indices for all the characters except plant height and ear height. Therefore, these two environments are also considered favorable environments for the expression of traits. The environments, namely, E4, E5, and E6 had positive environmental indices, and E1, E2, and E4 had negative environmental indices for grain yield per plant, respectively. This suggested that the environments E4, E5, and E6 were favorable, while E1, E2, and E3 were unfavorable environments for the expression of this trait. Lker *et al*. (2009), Nahar *et al.* (2010), Ararsa *et al.* (2016), Matin *et al.* (2017), Hemlata (2019) and Kumar *et al.* (2020) also observed positive and negative environmental indices for the expression of several characters.

Stability Parameters: According to Eberhart and Russell's model (1966), a stable variety was defined as those having high mean yield, regression coefficient (bi) = 1, and deviation from regression (S^2di) =0. The regression coefficient (bi) measures the varietal response to the environments, whereas deviation from regression (S^2di) measures the stability. These three parameters of stability for all the fourteen characters under study are presented in Table 7. Among twenty-one newly developed single cross hybrids, nine hybrids, namely, P1 × P2, P1 × P4, P1 × P5, P2 × P4, P2 × P5, P3 × P4, P3 × P5, P4 × P7, and P5 × P6 had high mean grain yield, unit regression coefficient (bi = 1) and non-significant deviation from regression (S^2di = 0) for grain yield per plant indicated that these hybrids were stable for this trait over the environments studied. The stable phenotypic performance over test environments for grain yield attributing traits was recorded for the hybrid, P1 × P2 for grains per plant, kernels per row, kernel rows per ear, ear diameter and ear length; the hybrid, P1 × P4 for shelling per cent, grains per plant, kernels per row, kernel rows per ear, ear diameter and ear length; the hybrid, P1 × P5 for shelling per cent, grains per plant, kernels per row and kernel rows per ear; the hybrid, P2 × P4 for shelling per cent, 1000-kernel weight, kernels per row, kernel rows per ear, ear diameter and ear length; the hybrid, P2 × P5 for shelling per cent, grains per plant, kernel rows per ear and ear diameter; the hybrid, P3 × P4 for shelling per cent, 1000-kernel weight, grains per plant, kernels per row, kernel rows per ear and ear diameter; the hybrid, P3 × P5 for shelling per cent, 1000-kernel weight, grains per plant, kernels per row and ear length; the hybrid, P4 × P7 for grains per plant, kernels per row, kernel rows per ear, ear diameter and ear diameter; the hybrid, P5 × P6 for shelling per cent, 1000-kernel weight, kernel rows per ear and ear length. Hence, these hybrids may be recommended for general cultivation over the test environments for these traits. The parent, P6 exhibited a high mean for yield attributing traits like shelling percentage, unit regression coefficient (bi = 1), and non-significant deviation from regression ($S^2di = 0$), indicating the stable performance of this parent for this trait over the test environments. These results are largely in agreement with those reported by Shanthi *et al.* (2010), Gami *et al.* (2017), Matin *et al.* (2017), Synrem *et al.* (2017), Sowmya *et al.* (2018), Oliveira *et al.* (2019), Pavani *et al.* (2019), Raj *et al.* (2019) and Kumar *et al.* (2020). The hybrid namely, P1 × P7 had a high mean grain yield and regression coefficient (bi) significantly greater than one characterizing it as a hybrid adapted to favorable environments (rich environments). For 1000-kernel weight, the hybrids, P1 × P2, P1 × P4, P1 × P5, and P2 × P5 exhibited high mean and regression coefficients significantly greater than unity indicating the responsiveness of the hybrids for favorable environments, while the hybrid P6 × P7 had high mean and regression coefficient significantly smaller than unity indicated the responsiveness of this hybrid for unfavorable environments. For kernel rows per ear, the hybrids P1 × P3, P2 × P3, and P3 × P5 had high mean and regression coefficients significantly smaller than unity indicating the adaptability of these hybrids for unfavorable environments (poor environments). Similar results were obtained by Sowmya *et al.* (2018), Oliveira *et al*. (2019), Raj *et al.* (2019), and Hemlata *et al.* (2020).

In the present study, the stability analysis for grain yield per plant revealed that hybrids P1 × P5 and P1 × P2 were promising experimental hybrids that had a stable phenotypic performance for grain yield per plant over test environments. The estimates on the mean performance of grain yield per plant revealed that the hybrids namely, P1 × P7, P2 × P5, P3 × P6, P2 × P3, P1 × P5, P1 × P6, P3 × P7, P1 × P2, and P6 × P7 had significantly higher grain yield per plant than the best commercial check, DMRH-1308. Hence, these hybrids can be exploited commercially under test environments for grain yield per plant.

Table 1: Pedigree of twenty-one F1s generated by Griffing's (1956) diallel mating design (Method II Model I).

SL NO.	CODE	PEDIGREE
1	P1 × P2	DTPYC9-F46-3-1-1-2-3-2-2-B*9 × BML-7
2	P1 × P3	DTPYC9-F46-3-1-1-2-3-2-2-B*9 × VL-1055
3	P1 × P4	DTPYC9-F46-3-1-1-2-3-2-2-B*9 × ZL-14501
4	P1 × P5	DTPYC9-F46-3-1-1-2-3-2-2-B*9 × [CML-161/CML-165]-BBB-11- BBB/CML-193
5	P1 × P6	DTPYC9-F46-3-1-1-2-3-2-2-B*9 × ZL-145312
6	P1 × P7	DTPYC9-F46-3-1-1-2-3-2-2-B*9 × CML-117-3-4-1-1-4-1
7	P2 × P3	BML-7 × VL-1055
8	P2 × P4	BML-7 × ZL-14501
9	P2 × P5	BML-7 × [CML-161/CML-165]-BBB-11-BBB/CML-193
10	P2 × P6	BML-7 × ZL-145312
11	P2 × P7	BML-7 × CML-117-3-4-1-1-4-1
12	P3 × P4	VL-1055 × ZL-14501
13	P3 × P5	VL-1055 × [CML-161/CML-165]-BBB-11-BBB/CML-193
14	P3 × P6	VL-1055 × ZL-145312
15	P3 × P7	VL-1055 × CML-117-3-4-1-1-4-1
16	P4 × P5	ZL-14501 × [CML-161/CML-165]-BBB-11-BBB/CML-193
17	P4 × P6	ZL-14501 × ZL-145312
18	P4 × P7	ZL-14501 × CML-117-3-4-1-1-4-1
19	P5 × P6	[CML-161/CML-165]-BBB-11-BBB/CML-193 × ZL-145312
20	P5 × P7	[CML-161/CML-165]-BBB-11-BBB/CML-193 × CML-117-3-4-1-1-4-1
21	P6 × P7	ZL-145312 × CML-117-3-4-1-1-4-1

Table 2: List of environments for conducting experiments.

SL. NO.	ENVIRONMENT CODES	CROP GROWING SEASONS	LOCATIONS	ZONES
1	E1	Kharif, 2019	Bihar Agricultural College, BAU, Sabour, Bhagalpur, Bihar	Zone-IIIA
2	E2	Kharif, 2019	Bhola Paswan Shastri Agricultural College, Purnea, Bihar	Zone-II
3	E3	Kharif, 2019	Pulse Research Centre, Mokama, Patna	Zone-IIIB
4	E4	Rabi, 2019-20	Bihar Agricultural College, BAU, Sabour, Bhagalpur, Bihar	Zone-IIIA
5	E5	Rabi, 2019-20	Bhola Paswan Shastri Agricultural College, Purnea, Bihar	Zone-II
6	E6	Rabi, 2019-20	Pulse Research Centre, Mokama, Patna	Zone-IIIB

Table 3: The average monthly weather observations on all six environments.

Parameters Months	E1				E2				E3			
	Temperature (º C)		Relative Humidity (%)	Rainfall (mm)	Temperature (º C)		Relative Humidity (%)	Rainfall (mm)	Temperature (º C)		Relative Humidity (%)	Rainfall (mm)
	Max	Min			Max	Min			Max	Min		
June-2019	37.88	25.47	61.35	85.00	34.29	25.60	61.93	184.60	47.77	28.25	43.5	36.91
July-2019	34.24	25.14	74..47	380.30	32.64	26.42	60.84	274.90	40.65	25.65	76.75	300.59
August-2019	34.69	26.58	75.24	65.60	33.57	26.70	61.99	150.10	35.65	25.68	81.50	116.02
September-2019	32.55	26.18	81.15	371.30	31.09	25.42	69.02	365.30	34.30	22.93	83.44	358.59
October-2019	30.77	21.67	83.95	23.40	30.06	22.77	67.02	13.20	30.56	17.88	83.25	0.00
November-2019	28.93	16.15	81.82	0.00	28.99	17.63	62.92	0.00	29.88	12.85	79.62	0.00
Parameters	**E4**				**E5**				**E6**			
	Temperature (º C)		**Relative**	**Rainfall**	**Temperature (º C)**		**Relative**	**Rainfall**	**Temperature (º C)**		**Relative**	**Rainfall**
Months	**Max**	**Min**	**Humidity (%)**	**(mm)**	**Max**	**Min**	**Humidity (%)**	**(mm)**	**Max**	**Min**	**Humidity (%)**	**(mm)**
December-2019	21.22	9.27	83.65	2.50	21.70	10.85	64.99	5.60	26.34	2.65	74.81	21.09
January-2020	21.89	8.76	81.98	6.00	19.87	10.20	64.70	15.40	27.65	4.56	69.38	5.27
February-2020	24.05	9.54	77.57	3.69	24.98	12.23	51.07	10.20	29.64	5.88	55.75	15.82
March-2020	30.25	16.61	72.95	48.00	28.54	17.74	50.35	63.30	38.02	13.60	50.75	47.46
Aprial-2020	33.14	20.02	76.65	2.38	30.66	19.86	53.20	148.20	40.87	17.29	39.31	31.64
May-2020	33.85	23.58	77.69	136.80	32.06	22.92	58.68	201.00	47.04	23.3	44.00	63.28
June-2020	33.21	25.84	74.81	354.50	32.40	25.87	62.53	406.00	40.91	24.89	66.50	284.77

The details on environments E1, E2, E3, E4, E5, and E6 are presented in table 2. Max: Maximum, Min: Minimum, and mm: millimeters.

Table 4: A pooled analysis of variance for the design of the experiment over six environments for fourteen quantitative characters in maize.

Characters	Mean squares				
	Replication d.f. = 10	Environment (E) d.f. = 5	Genotypes (G) d.f. = 30	Genotype by Environment (G × E) d.f. = 150	Error d.f. = 360
Days to 50 per cent anthesis	21.01	95,351.52**	220.86**	20.95**	3.70
Days to 50 per cent silk	21.80	98,660.40**	261.49**	21.03**	3.61
Anthesis-silking interval	1.66	30.69**	7.99**	1.39**	0.05
Days to 50 per cent physiological maturity	21.19	1,18,224.49**	175.20**	24.61*	11.25
Plant height	871.73	20,265.23**	6,463.32**	355.87*	138.71
Ear height	401.46	19,011.38**	2,746.26**	206.19**	67.69
Ear length	2.83	260.36**	47.01**	3.19*	1.32
Ear diameter	0.07	10.31**	2.78**	0.15**	0.03
Kernel rows per ear	0.37	30.14**	38.32**	4.32**	0.53
Kernels per row	9.54	1,861.03**	593.15**	21.96**	5.32
Grains per plant	4,734.75	6,82,164.40**	1,71,887.98**	7,444.37**	2007.90
1000-kernel weight	1,624.46	2,65,199.44**	25,810.16**	2,323.88**	650.99
Shelling %	6.60	140.64**	524.24**	50.01**	5.77
Grain yield per plant	963.36	1,75,632.28**	21,089.51**	1,162.19**	274.80

* & **: level of significance at 5 % and 1 %, respectively.

Table 5: Analysis of variance for the stability of fourteen quantitative characters in maize.

Characters	Mean squares					
	Genotypes (G) d.f. = 30	Env. + (G × Env.) d.f. = 155	Env. (Linear) d.f. = 1	G × E (Linear) d.f. = 30	Pooled deviation d.f. = 124	Pooled error d.f. = 360
Days to 50 per cent anthesis	73.62**	1032.04**	158919.20**	7.82 ns	6.56**	1.23
Days to 50 per cent silk	87.16**	1067.65**	164434.00**	7.16 ns	6.75**	1.20
Anthesis-silking interval	2.66**	0.78**	51.15**	1.32**	0.24**	0.02
Days to 50 per cent physiological maturity	58.40**	1279.17**	197040.82**	2.41*	6.92**	3.75
Plant height	2154.44**	332.70**	33775.37**	147.37 ns	107.84**	46.24
Ear height	915.42**	270.94**	31685.63**	99.65*	59.03**	22.56
Ear length	15.67**	3.83**	433.93**	1.26 ns	0.98**	0.44
Ear diameter	0.93**	0.16**	17.18**	0.12**	0.03**	0.01
Kernel rows per ear	12.77**	1.72**	50.23**	3.64**	0.86**	0.18
Kernels per row	197.72**	27.10**	3101.72**	4.69 ns	7.72**	1.78
Grains per plant	57295.99**	9736.51**	1136940.65**	2360.16 ns	2430.75**	669.31
1000-kernel weight	8603.39**	3601.24**	441999.01**	2111.44**	426.22**	216.99
Shelling (%)	174.75**	17.64*	234.40**	30.60**	12.76**	1.92
Grain yield per plant	7029.85**	2263.44**	292724.07**	645.34**	312.50**	91.60

* & **: level of significance at 5 % and 1 %, respectively. ns: non-significant.

Table 6: Environmental indices for grain yield and its attributes in maize across the environments.

Sl. No	Characters	Environmental Indices					
		E1	E2	E3	E4	E5	E6
1	Days to 50 per cent anthesis	-26.93	-30.52	-30.13	30.82	27.64	29.12
2	Days to 50 per cent silk	-27.63	-30.95	-30.53	31.17	28.22	29.72
3	Anthesis-silking interval	-0.70	-0.43	-0.40	0.34	0.58	0.60
4	Days to 50 per cent physiological maturity	-29.90	-32.46	-34.56	39.62	27.34	29.95
5	Plant height	4.02	-5.06	23.25	3.13	-22.07	-3.27
6	Ear height	3.39	1.84	20.54	1.06	-24.01	-2.81
7	Ear length	-1.46	-2.57	0.99	1.89	0.38	0.76
8	Ear diameter	-0.39	-0.32	-0.15	0.43	0.27	0.15
9	Kernel rows per ear	-0.50	-0.79	-0.09	0.73	0.29	0.36
10	Kernels per row	-3.31	-6.64	0.67	6.30	1.91	1.07
11	Grains per plant	-77.15	-119.42	17.06	117.88	44.57	17.07
12	1000-kernel weight	-64.81	-38.55	-26.24	58.79	66.39	4.42
13	Shelling per cent	-1.82	0.20	-0.31	0.93	1.68	-0.68
14	Grain yield per plant	-45.00	-50.12	-3.33	63.45	28.82	6.19

Note E1: Bihar Agricultural University, Sabour, Kharif-2019; E2: Bhola Paswan Shastri Agricultural College, Purnea, Kharif-2019; E3: Pulse Research Centre, Mokama, Kharif-2019; E4: Bihar Agricultural University, Sabour, Rabi, 2019-20; E5: Bhola Paswan Shastri Agricultural College, Purnea, Rabi, 2019-20 and E6: Pulse Research Centre, Mokama, Rabi, 2019-20.

Table 7: Estimate of stability parameters for fourteen quantitative characters in maize.

Sl. No.	Genotypes	DA			DS			ASI			DPM			PH		
		$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d
1	P1 × P2	79.00	0.96 ^{ns}	4.83**	79.72	0.97 ^{ns}	5.41**	0.72	1.40 ^{ns}	0.01 ^{ns}	119.89	0.99 ^{ns}	2.69 ^{ns}	182.23	1.14 ^{ns}	28.66 ^{ns}
2	P1 × P3	81.56	1.01 ^{ns}	3.04*	83.22	1.02 ^{ns}	3.02*	1.67	2.01**	0.02 ^{ns}	121.89	1.01 ^{ns}	0.02 ^{ns}	170.17	0.81 ^{ns}	17.18 ^{ns}
3	P1 × P4	80.33	0.97 ^{ns}	7.54**	80.89	0.99 ^{ns}	10.43**	0.56	2.30 ^{ns}	0.43**	119.56	1.05 ^{ns}	8.50*	187.42	1.30 ^{ns}	35.78 ^{ns}
4	P1 × P5	80.22	0.96 ^{ns}	5.82**	80.61	0.98 ^{ns}	7.02**	0.39	2.07*	0.12**	121.33	1.04 ^{ns}	-1.60 ^{ns}	187.41	1.09 ^{ns}	31.45 ^{ns}
5	P1 × P6	81.00	0.99 ^{ns}	7.73**	81.17	1.01 ^{ns}	9.21**	0.17	2.01*	0.07*	121.17	1.02 ^{ns}	12.35**	191.98	0.90 ^{ns}	-17.03 ^{ns}
6	P1 × P7	83.28	1.01 ^{ns}	-0.22 ^{ns}	84.00	1.02 ^{ns}	-0.17 ^{ns}	0.72	1.40 ^{ns}	0.01 ^{ns}	124.06	1.03 ^{ns}	0.97 ^{ns}	185.83	1.04 ^{ns}	23.23 ^{ns}
7	P2 × P3	85.17	1.00 ^{ns}	-0.56 ^{ns}	86.94	1.00 ^{ns}	-0.89 ^{ns}	1.78	0.91 ^{ns}	0.33**	127.00	1.03 ^{ns}	-0.96 ^{ns}	177.31	1.00 ^{ns}	10.70 ^{ns}
8	P2 × P4	84.00	0.98 ^{ns}	1.14 ^{ns}	85.89	0.98 ^{ns}	0.82 ^{ns}	1.89	1.16 ^{ns}	0.17**	125.33	0.98 ^{ns}	-0.72 ^{ns}	195.05	1.49*	-34.34 ^{ns}
9	P2 × P5	83.00	0.95 ^{ns}	4.72**	84.22	0.96 ^{ns}	2.92*	1.22	1.63 ^{ns}	0.36**	123.83	0.99 ^{ns}	-2.90 ^{ns}	192.46	1.04 ^{ns}	38.36 ^{ns}
10	P2 × P6	83.44	0.98 ^{ns}	4.43**	85.00	0.98 ^{ns}	5.06**	1.56	1.10 ^{ns}	0.06*	125.33	1.02 ^{ns}	-2.70 ^{ns}	194.38	1.31 *	-44.93 ^{ns}
11	P2 × P7	85.67	0.99 ^{ns}	5.28**	87.22	1.00 ^{ns}	4.17**	1.56	1.72 ^{ns}	0.34**	125.50	1.00 ^{ns}	4.14 ^{ns}	179.99	0.59 ^{ns}	221.54**
12	P3 × P4	83.61	0.96 ^{ns}	0.78 ^{ns}	85.22	0.97 ^{ns}	0.27 ^{ns}	1.61	1.17 ^{ns}	0.04 ^{ns}	125.39	0.97 ^{ns}	-0.93 ^{ns}	176.46	1.29 ^{ns}	17.92 ^{ns}
13	P3 × P5	85.06	1.03 ^{ns}	2.56*	86.67	1.01 ^{ns}	2.09*	1.61	-0.07 ^{ns}	0.27**	127.17	1.01 ^{ns}	6.79*	177.20	1.07 ^{ns}	-29.85 ^{ns}
14	P3 × P6	83.22	0.97 ^{ns}	-0.33 ^{ns}	84.39	1.00 ^{ns}	-0.82 ^{ns}	1.17	2.12 ^{ns}	0.33**	124.17	0.99 ^{ns}	3.94 ^{ns}	179.27	1.20 ^{ns}	35.07 ^{ns}
15	P3 × P7	86.11	0.97 ^{ns}	4.36**	87.94	0.95 ^{ns}	5.35**	1.83	-0.15 ^{ns}	0.56**	126.61	1.00 ^{ns}	5.17 ^{ns}	170.02	0.68 ^{ns}	61.14 ^{ns}
16	P4 × P5	81.56	0.93 ^{ns}	6.18**	83.44	0.94 ^{ns}	5.64**	1.89	1.61 ^{ns}	0.10**	122.78	0.97 ^{ns}	-0.95 ^{ns}	189.03	1.01 ^{ns}	-18.25 ^{ns}
17	P4 × P6	87.44	0.97 ^{ns}	5.64**	88.50	0.96 ^{ns}	6.29**	1.06	0.30 ^{ns}	0.45**	124.06	0.93*	-1.80 ^{ns}	168.00	1.37 ^{ns}	78.92*
18	P4 × P7	85.22	0.98 ^{ns}	-0.08 ^{ns}	87.11	0.97 ^{ns}	0.15 ^{ns}	1.89	0.55 ^{ns}	0.10**	125.67	0.93*	-0.60 ^{ns}	183.50	1.15 ^{ns}	-20.67 ^{ns}
19	P5 × P6	82.17	0.98 ^{ns}	1.28 ^{ns}	83.67	0.99 ^{ns}	3.77**	1.50	1.72 ^{ns}	0.35**	124.78	0.92 ^{ns}	11.67**	187.06	1.65 ^{ns}	47.60 ^{ns}
20	P5 × P7	84.94	1.02 ^{ns}	4.05**	86.56	1.02 ^{ns}	2.72*	1.61	1.07 ^{ns}	0.19**	126.94	0.97 ^{ns}	-0.68 ^{ns}	180.91	1.18 ^{ns}	69.08 ^{ns}
21	P6 × P7	84.67	1.05 ^{ns}	2.77*	85.78	1.04 ^{ns}	2.87*	1.11	1.02 ^{ns}	0.13**	124.61	0.95 ^{ns}	8.97*	193.03	1.55*	-19.22 ^{ns}
22	P1	86.89	1.09 ^{ns}	16.83**	87.11	1.11 ^{ns}	15.67**	0.22	2.13**	0.02 ^{ns}	124.83	1.02 ^{ns}	1.08 ^{ns}	154.38	0.77 ^{ns}	31.47 ^{ns}
23	P2	89.28	1.03 ^{ns}	25.83**	90.94	1.01 ^{ns}	27.47**	1.67	0.05 ^{ns}	0.30**	131.22	1.07 ^{ns}	6.98*	149.37	0.61 ^{ns}	90.18*
24	P3	92.78	1.00 ^{ns}	14.47**	95.50	0.97 ^{ns}	15.56**	2.72	-0.24*	0.13**	130.06	1.02 ^{ns}	0.49 ^{ns}	105.04	0.02*	78.37*
25	P4	90.78	1.04 ^{ns}	8.62**	92.33	1.01 ^{ns}	9.58**	1.56	-0.61**	0.02 ^{ns}	127.50	0.95 ^{ns}	1.13 ^{ns}	151.87	1.22 ^{ns}	294.19**
26	P5	88.94	1.03 ^{ns}	-0.11 ^{ns}	89.50	1.05*	0.06 ^{ns}	0.56	2.30**	0.22**	127.72	1.01 ^{ns}	3.09 ^{ns}	145.86	0.49 ^{ns}	55.23 ^{ns}
27	P6	89.00	1.08*	2.48*	90.61	1.06 ^{ns}	2.80*	1.61	-0.08 ^{ns}	0.27**	128.72	0.96 ^{ns}	-0.50 ^{ns}	162.52	1.23 ^{ns}	336.37**
28	P7	89.56	1.06 ^{ns}	5.91**	91.78	1.04 ^{ns}	6.62**	2.22	-0.24*	0.26**	128.61	1.07 ^{ns}	14.96**	153.87	0.34 ^{ns}	113.62*
29	DMRH-1308(C1)	82.61	1.00 ^{ns}	5.92**	85.61	0.98 ^{ns}	4.88**	3.00	0.07 ^{ns}	0.47**	125.83	0.96 ^{ns}	8.71*	169.26	1.07 ^{ns}	55.44 ^{ns}
30	Deep Jowala(C2)	85.11	1.04 ^{ns}	9.47**	86.56	1.02 ^{ns}	8.68**	1.44	0.33 ^{ns}	0.24**	125.44	1.08*	-0.25 ^{ns}	177.94	0.50 ^{ns}	91.42*
31	SHM-1(C3)	78.17	0.97 ^{ns}	-0.69 ^{ns}	79.00	0.96*	-0.48 ^{ns}	0.83	0.24 ^{ns}	0.15**	116.78	1.08 ^{ns}	7.56*	169.01	0.87 ^{ns}	20.20 ^{ns}
	Mean	**84.64**			**86.04**			**1.40**			**124.96**			**173.80**		
	SE m(±)	0.69			0.69			0.15			0.91			3.35		
	CD at 5%	1.93			1.93			0.43			2.55			9.32		

Note * & **: level of significance at 5 % and 1 %, respectively. ns: non-significant. DA: Days to 50 per cent anthesis, DS: days to 50 per cent silk, ASI: anthesis-silking interval, DPM: days to 50 per cent physiological maturity, PH: plant height, EH: ear height, EL: ear length, ED: ear diameter, KRPE: kernel rows per ear, KPR: kernels per row, GPP: grains per plant, 1000-KW: 1000-kernel weight, SP: shelling per cent and GYP: grain yield per plant.

Contd. Table 7: Estimate of stability parameters for fourteen quantitative characters in maize.

Sl. No.	Genotypes	EH			EL			ED			KRPE			KPR		
		$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d
1	P1 × P2	80.18	1.10^{ns}	-1.78^{ns}	14.22	0.80^{ns}	-0.31^{ns}	4.51	1.39^{ns}	0.01^{ns}	13.76	0.29^{ns}	-0.04^{ns}	26.59	0.75^{ns}	2.48^{ns}
2	P1 × P3	73.00	1.01^{ns}	6.99^{ns}	14.89	1.08^{ns}	-0.04^{ns}	4.40	1.23^{ns}	0.00^{ns}	14.07	0.02^{ns}	-0.12^{ns}	27.54	0.98^{ns}	0.07^{ns}
3	P1 × P4	86.55	1.15^{ns}	34.03^{ns}	15.44	0.74^{ns}	0.22^{ns}	4.13	1.04^{ns}	0.00^{ns}	13.11	0.79^{ns}	-0.01^{ns}	27.49	0.62^{ns}	2.08^{ns}
4	P1 × P5	85.26	0.93^{ns}	13.33^{ns}	16.14	1.08^{ns}	0.69*	4.17	1.31^{ns}	0.02*	14.23	0.74^{ns}	0.19^{ns}	27.81	0.93^{ns}	0.77^{ns}
5	P1 × P6	86.73	0.84^{ns}	3.45^{ns}	15.36	1.08^{ns}	-0.20^{ns}	4.27	0.95^{ns}	0.01^{ns}	13.44	0.71^{ns}	-0.08^{ns}	26.53	0.90^{ns}	-1.13^{ns}
6	P1 × P7	88.78	1.00^{ns}	5.64^{ns}	15.03	0.76^{ns}	-0.20^{ns}	4.19	1.04^{ns}	0.01^{ns}	12.87	0.74^{ns}	-0.01^{ns}	31.45	0.80^{ns}	-0.23^{ns}
7	P2 × P3	75.06	0.96^{ns}	16.58^{ns}	15.14	1.29^{ns}	0.49^{ns}	4.62	0.75^{ns}	0.02*	14.33	-0.46*	0.07^{ns}	27.00	1.23^{ns}	0.16^{ns}
8	P2 × P4	82.49	1.34^{ns}	19.02^{ns}	14.83	1.21^{ns}	-0.25^{ns}	4.45	0.82^{ns}	0.00^{ns}	13.72	0.56^{ns}	0.05^{ns}	27.64	1.11^{ns}	0.60^{ns}
9	P2 × P5	83.73	0.96^{ns}	31.52^{ns}	15.80	1.47^{ns}	0.73*	4.45	1.02^{ns}	0.01^{ns}	13.77	0.19^{ns}	0.20^{ns}	29.66	1.09^{ns}	4.22*
10	P2 × P6	80.72	1.11^{ns}	-16.80^{ns}	14.54	1.12^{ns}	0.10^{ns}	4.46	0.81^{ns}	0.00^{ns}	13.18	0.81^{ns}	-0.07^{ns}	26.94	0.99^{ns}	2.29^{ns}
11	P2 × P7	85.22	0.53^{ns}	77.85**	14.06	1.19^{ns}	0.08^{ns}	4.43	1.25^{ns}	0.00^{ns}	13.13	0.90^{ns}	0.00^{ns}	30.01	1.17^{ns}	2.41^{ns}
12	P3 × P4	70.41	1.20^{ns}	-1.22^{ns}	16.26	1.15^{ns}	0.74*	4.21	0.63^{ns}	0.00^{ns}	13.06	0.34^{ns}	0.24^{ns}	27.63	0.95^{ns}	1.40^{ns}
13	P3 × P5	69.87	0.88^{ns}	8.47^{ns}	16.03	1.36^{ns}	-0.17^{ns}	4.24	0.54*	0.00^{ns}	13.74	-0.10*	-0.12^{ns}	29.11	1.20^{ns}	-0.61^{ns}
14	P3 × P6	73.24	1.15^{ns}	33.59^{ns}	16.14	0.94^{ns}	0.57^{ns}	4.32	0.64*	0.00^{ns}	13.04	0.72^{ns}	-0.10^{ns}	26.92	0.83^{ns}	6.27**
15	P3 × P7	73.70	0.77^{ns}	-10.05^{ns}	15.33	1.35^{ns}	0.54^{ns}	4.25	1.19^{ns}	0.00^{ns}	13.66	0.85^{ns}	-0.11^{ns}	30.82	1.44^{ns}	2.68*
16	P4 × P5	80.96	1.09^{ns}	36.45*	16.56	1.13^{ns}	0.49^{ns}	4.21	0.89^{ns}	0.01^{ns}	13.30	0.96^{ns}	-0.07^{ns}	28.06	1.06^{ns}	1.17^{ns}
17	P4 × P6	71.17	1.43*	-3.83^{ns}	13.10	0.79^{ns}	0.02^{ns}	3.63	0.59^{ns}	0.02*	11.27	0.03^{ns}	0.15^{ns}	21.36	0.83^{ns}	5.93**
18	P4 × P7	85.15	1.26^{ns}	1.07^{ns}	15.56	1.14^{ns}	-0.22^{ns}	4.06	0.82^{ns}	0.00^{ns}	12.40	0.97^{ns}	-0.12^{ns}	30.02	0.91^{ns}	-0.21^{ns}
19	P5 × P6	77.47	1.3*	-18.28^{ns}	15.92	1.27^{ns}	0.41^{ns}	4.19	0.39**	-0.01^{ns}	13.11	0.22^{ns}	0.11^{ns}	26.86	1.09^{ns}	2.88*
20	P5 × P7	87.97	1.25^{ns}	23.38^{ns}	16.03	1.16^{ns}	0.38^{ns}	4.08	0.75*	-0.01^{ns}	12.92	0.79^{ns}	-0.11^{ns}	30.81	1.12^{ns}	5.16**
21	P6 × P7	90.85	1.54*	6.93^{ns}	15.62	0.91^{ns}	-0.18^{ns}	4.11	0.58*	0.00^{ns}	12.94	0.89^{ns}	0.13^{ns}	30.18	0.86^{ns}	1.84^{ns}
22	P1	74.15	0.67^{ns}	13.03^{ns}	12.64	0.41^{ns}	1.11**	3.61	1.21^{ns}	0.04**	12.73	2.03^{ns}	0.90**	18.95	0.80^{ns}	8.52**
23	P2	60.62	0.65^{ns}	32.11^{ns}	10.49	0.49^{ns}	2.42**	3.69	1.29^{ns}	0.07**	11.48	1.65^{ns}	0.30*	13.96	0.94^{ns}	13.30**
24	P3	28.75	0.25**	-22.80^{ns}	10.22	0.72^{ns}	3.11**	2.91	2.81^{ns}	0.25**	7.94	7.97^{ns}	16.03**	9.51	1.47^{ns}	37.01**
25	P4	62.59	1.40^{ns}	241.44**	13.05	0.45^{ns}	0.30^{ns}	3.49	0.13**	0.00^{ns}	10.70	-0.09^{ns}	0.68**	17.96	0.80^{ns}	13.24**
26	P5	56.68	0.71^{ns}	28.80^{ns}	12.42	0.55^{ns}	2.15**	3.44	1.41^{ns}	0.02*	10.82	3.52^{ns}	2.25**	14.21	0.83^{ns}	17.46**
27	P6	69.56	1.41 ns	225.64**	13.04	0.86 ns	1.42**	3.63	0.65 ns	0.01 ns	11.47	0.05 ns	0.56**	19.56	0.89 ns	5.24**
28	P7	76.48	0.75 ns	128.65**	13.27	0.62 ns	0.71*	3.80	1.12 ns	0.11**	11.55	1.84 ns	0.26*	23.39	0.75 ns	36.20**
29	DMRH-1308(C1)	75.22	1.15 ns	11.30 ns	15.72	1.38 ns	0.11 ns	4.50	0.98 ns	0.00 ns	14.62	1.11 ns	-0.03 ns	30.88	1.38 ns	3.73*
30	Deep Jowala(C2)	87.13	0.44 ns	73.93**	14.90	1.39 ns	1.02*	4.40	1.31 ns	0.00 ns	14.16	0.93 ns	0.05 ns	32.31	1.37 ns	6.12**
31	SHM-1(C3)	66.15	0.77 ns	33.48 ns	14.55	1.11 ns	0.13 ns	4.29	1.45*	0.00 ns	15.61	1.06 ns	0.13 ns	29.86	0.92 ns	1.40 ns
	Mean	**75.67**			**14.59**			**4.10**			**12.91**			**25.84**		
	SE m(±)	2.45			0.32			0.06			0.30			0.75		
	CD at 5%	6.81			0.89			0.16			0.84			2.09		

Note * & **: level of significance at 5 % and 1 %, respectively. ns: non-significant. DA: Days to 50 per cent anthesis, DS: days to 50 per cent silk, ASI: anthesis-silking interval, DPM: days to 50 per cent physiological maturity, PH: plant height, EH: ear height, EL: ear length, ED: ear diameter, KRPE: kernel rows per ear, KPR: kernels per row, GPP: grains per plant, 1000-KW: 1000-kernel weight, SP: shelling per cent and GYP: grain yield per plant.

Contd. Table 7: Estimate of stability parameters for fourteen quantitative characters in maize.

Sl. No.	Genotypes	GPP			1000-KW			SP			GYP		
		$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d
1	P1 × P2	378.98	0.77^{ns}	-295.21^{ns}	339.62	1.42**	-115.87^{ns}	81.27	-0.41*	-0.21^{ns}	146.30	1.13^{ns}	-28.17^{ns}
2	P1 × P3	376.81	0.76^{ns}	1118.83*	333.86	1.37^{ns}	41.50^{ns}	81.91	-0.36^{ns}	2.30^{ns}	138.34	1.08^{ns}	363.89**
3	P1 × P4	357.24	0.69^{ns}	565.64^{ns}	348.93	1.49*	191.04^{ns}	82.01	-0.04^{ns}	0.29^{ns}	135.39	1.00^{ns}	36.13^{ns}
4	P1 × P5	405.20	1.14^{ns}	418.16^{ns}	335.08	1.64*	81.90^{ns}	81.40	0.01^{ns}	-0.22^{ns}	148.94	1.40^{ns}	62.48^{ns}
5	P1 × P6	362.86	0.94^{ns}	1162.08*	369.38	1.37^{ns}	178.90^{ns}	81.92	-0.05^{ns}	1.39^{ns}	147.40	1.10^{ns}	243.36**
6	P1 × P7	481.70	1.66^{ns}	2384.19**	302.46	0.91^{ns}	43.39^{ns}	83.54	0.38^{ns}	2.91*	156.41	1.43*	168.53*
7	P2 × P3	368.80	0.85^{ns}	464.70^{ns}	350.51	1.06^{ns}	440.15*	80.75	0.53^{ns}	0.55^{ns}	148.96	1.08^{ns}	187.86*
8	P2 × P4	372.04	1.01^{ns}	1106.81*	351.50	1.26^{ns}	-97.83^{ns}	80.87	0.27^{ns}	-0.34^{ns}	145.35	1.11^{ns}	51.39^{ns}
9	P2 × P5	409.21	1.04^{ns}	340.85^{ns}	331.22	1.34**	-169.33^{ns}	81.77	0.05^{ns}	-0.42^{ns}	151.75	1.31^{ns}	45.17^{ns}
10	P2 × P6	357.63	0.92^{ns}	816.74^{ns}	365.76	1.14^{ns}	-140.23^{ns}	82.76	0.39^{ns}	-1.49^{ns}	145.20	1.05^{ns}	156.34*
11	P2 × P7	417.67	1.17^{ns}	4151.60**	295.21	1.13^{ns}	-122.01^{ns}	82.01	-0.04^{ns}	4.86**	138.20	1.16^{ns}	524.60**
12	P3 × P4	344.49	0.77^{ns}	65.96^{ns}	371.71	1.11^{ns}	21.74^{ns}	82.50	0.83^{ns}	-1.83^{ns}	138.73	0.92^{ns}	58.13^{ns}
13	P3 × P5	383.48	0.90^{ns}	-482.93^{ns}	327.67	0.89^{ns}	158.35^{ns}	81.20	0.84^{ns}	2.05^{ns}	138.48	0.93^{ns}	-46.07^{ns}
14	P3 × P6	355.97	0.84^{ns}	1455.59*	390.63	1.12^{ns}	-145.63^{ns}	83.86	0.83^{ns}	-1.33^{ns}	150.68	0.97^{ns}	243.88**
15	P3 × P7	436.82	1.44^{ns}	2654.04**	310.14	1.03^{ns}	-166.04^{ns}	83.17	0.32^{ns}	0.99^{ns}	146.46	1.36^{ns}	238.00**
16	P4 × P5	368.74	0.87^{ns}	336.48^{ns}	348.81	1.35^{ns}	68.04^{ns}	81.31	0.32^{ns}	-0.69^{ns}	145.37	0.97^{ns}	166.13*
17	P4 × P6	233.14	0.60^{ns}	2576.14**	327.95	0.94^{ns}	203.93^{ns}	83.51	0.35^{ns}	0.90^{ns}	83.05	0.58*	41.19^{ns}
18	P4 × P7	408.51	1.24^{ns}	594.26^{ns}	329.73	0.91^{ns}	330.06*	83.59	-0.02^{ns}	3.59*	144.88	1.12^{ns}	108.90^{ns}
19	P5 × P6	339.13	0.83^{ns}	2184.71**	356.32	0.84^{ns}	293.14^{ns}	81.10	0.28^{ns}	-1.38^{ns}	132.42	0.77^{ns}	40.38^{ns}
20	P5 × P7	410.46	1.08^{ns}	2996.56**	301.87	0.49**	-77.01^{ns}	82.22	0.54^{ns}	1.79^{ns}	136.42	0.84^{ns}	383.06**
21	P6 × P7	426.09	1.26^{ns}	1439.52*	324.63	0.70**	-205.12^{ns}	85.04	-0.46^{ns}	0.63^{ns}	146.01	1.14^{ns}	281.35**
22	P1	266.90	1.24^{ns}	1011.60*	249.87	0.81^{ns}	658.94**	75.43	2.11^{ns}	6.78**	80.88	0.87^{ns}	345.72**
23	P2	158.35	0.90^{ns}	2227.34**	275.14	0.50^{ns}	886.10**	71.98	2.96^{ns}	48.08**	55.26	0.67^{ns}	310.61**
24	P3	104.05	0.94^{ns}	5030.37**	260.80	0.40^{ns}	1489.29**	58.55	10.32^{ns}	227.66**	38.52	0.68^{ns}	477.93**
25	P4	183.00	0.72^{ns}	3320.04**	314.27	0.31*	282.84^{ns}	78.20	4.08^{ns}	14.17**	66.62	0.51^{ns}	321.32**
26	P5	144.50	0.72^{ns}	3035.82**	280.92	0.33*	102.35^{ns}	68.26	2.61^{ns}	20.73**	54.67	0.51^{ns}	208.46*
27	P6	215.74	0.77^{ns}	792.94^{ns}	337.66	0.67^{ns}	391.57*	82.32	0.77^{ns}	0.90^{ns}	83.18	0.67^{ns}	195.96*
28	P7	333.07	1.07^{ns}	9961.50**	256.61	0.43*	96.98^{ns}	77.76	0.09^{ns}	2.52^{ns}	98.25	0.79^{ns}	975.31**
29	DMRH-1308(C1)	430.24	1.35^{ns}	1759.54**	294.07	0.99^{ns}	157.23^{ns}	83.14	1.09^{ns}	-1.80^{ns}	130.51	1.22^{ns}	188.75*
30	Deep Jowala(C2)	454.47	1.41^{ns}	375.86^{ns}	287.42	1.40^{ns}	130.09^{ns}	83.74	1.74^{ns}	1.56^{ns}	128.62	1.29^{ns}	81.51^{ns}
31	SHM-1(C3)	450.61	1.09^{ns}	137.59^{ns}	246.94	1.63^{ns}	1198.66**	84.80	0.66^{ns}	0.64^{ns}	123.13	1.33^{ns}	185.85*
Mean		**346.32**			**319.89**			**80.38**			**123.37**		
SE m(±)		14.15			7.96			1.02			5.45		
CD at 5%		39.33			22.14			2.83			15.15		

Note * & **: level of significance at 5 % and 1 %, respectively. ns: non-significant. DA: Days to 50 per cent anthesis, DS: days to 50 per cent silk, ASI: anthesis-silking interval, DPM: days to 50 per cent physiological maturity, PH: plant height, EH: ear height, EL: ear length, ED: ear diameter, KRPE: kernel rows per ear, KPR: kernels per row, GPP: grains per plant, 1000-KW: 1000-kernel weight, SP: shelling per cent and GYP: grain yield per plant.

Conclusion: In the present investigations, the pooled estimates of analysis of variance for the design of the experiment revealed highly significant mean squares due to genotypes, environments, and genotype by environment interaction (GEI) for fourteen quantitative characters studied across the test environments. These results indicated a significant difference existed among the genotypes and environments and environments played an important role in the expression of characters. The analysis of variance for the stability of fourteen quantitative characters across the test environments revealed significant to highly significant mean squares due to genotypes, Env. + (G × Env.), environment (linear), G × E (linear), the pooled deviation for all the under study except due to G × E (linear) for days to 50 per cent anthesis and silking, plant height, ear length, kernels per row and grains per plant. Based on environmental indices values, environment E4 (Rabi 2019-20, BAU, Sabour) was regarded as the best environment amongst the test environments for the expression of characters studied and had positive environmental indices for all these characters. Based on stability parameters for grain yield per plant, the hybrid combinations, P1 × P5 and P1 × P2 were identified as the stable and promising hybrid across test environments. Hence these two hybrids may be exploited commercially under test environments for the high grain yield.

Acknowledgments: The authors are thankful to Dean PGS, Bihar Agricultural University, Sabour, Bhagalpur for their financial support for accomplishing research works. The authors are also thankful to advisory committee members for the framing of research work and their consistent guidance, and support in accomplishing the same.

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