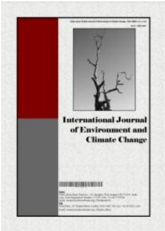

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Stability Analysis of Quality Protein Maize Hybrids Qualitative and Quantitative Traits under Heat Stress across Different Environments of Prayagraj District in Central India

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Author's contribution

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Maize, also known as corn (*Zea mays* .L), is one of the world's most important cereal crops. Maize is the only food cereal crop that can be produced throughout the year and requires a moderate environment to thrive. This study claims to determine whether such a statement is accurate and to examine stability in terms of gene action. The study was carried out in three research sites representative different places in CRF, SHUATS, Prayagraj City at an elevation of 98 meters above sea level at 25.87^{O}N latitude and 81.54 ^{O}E longitude. and all the locations has sub-tropical climate with extremes of summer and winter. During winter season especially in month of December and January, temperature drops down to as low as 1-2^{0} C, while during summer the temperature reaches up to 45^{0}C (NICMEIT 2022). This experiment was undertaken under Randomized Block Design with three replications for assessing their stability. The mean squares due to genotypes, parents, hybrids, and parent vs. hybrids were very significant for all eighteen quantitative and qualitative characters under study, according to the analysis of variance for diallel analysis (model I method II). A stability study was carried out to determine the grain yield of 45 maize hybrids under three environments (E_1, E_2 and E_3), using Eberhart and Russel model. The analysis of variance for combining ability revealed the mean squares due to general combing ability (GCA) and specific

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combing ability (SCA) were highly significant for all characters studied. Inbred lines P_4, P_5 and P_2 showed significant to highly significant positive GCA effects on grain yield per plant and its attributes, indicating that both parents were good general combiners for this trait. Four hybrids ($P_5 \times P_7$, $P_5 \times P_6$, $P_4 \times P_8$ and $P_4 \times P_5$) exhibited significant to highly significant SCA effects for grain yield per plant. The estimates of standard heterosis over the best check (HQPM-5) for grain yield per plant revealed five top cross combinations ($P_5 \times P_7$, $P_5 \times P_6$, $P_4 \times P_8$, $P_5 \times P_9$ and $P_4 \times P_5$), exhibiting highly significant positive standard heterosis regarding their high and stable performance across environments. The single cross hybrids over all the environments $P_5 \times P_6$, $P_5 \times P_7$ and $P_4 \times P_5$ were found promising for the majority of characters studied, with high mean performance across environments. Based on a regression coefficient close to unity ($\beta_i \approx 1$) and a non-significant deviation from regression (s^2di), indicating their adaptability across all environments investigated, best performing hybrids were identified according to three different environments in E_1, E_2 and E_3 were $P_1 \times P_6$, $P_2 \times P_4$, $P_2 \times P_6$, $P_2 \times P_8$, $P_3 \times P_5$, $P_4 \times P_5$, $P_4 \times P_7$, $P_4 \times P_{10}$, $P_5 \times P_6$, $P_5 \times P_7$, $P_6 \times P_8$, $P_7 \times P_8$, $P_7 \times P_9$, regression coefficient near to unity ($\beta_i \approx 1$) and non-significant deviation from regression (s^2di) there by indicating its adaptability over all environments, thus indicating stable performance in different environments for most of the characters.

Keywords: Heat tolerance; combining ability; G x E interaction; heterosis effect; diallel crossing; cereal crop; dominance effect.

1. INTRODUCTION

Maize is a multipurpose crop that is grown all over the world for food, feed, and industrial use and maize plays an exceptionally conspicuous part to play in the Indian economy as well.

This coarse grain is currently grown on around 10.2 million hectares in India (FICCI, 2022). Furthermore, maize consumption has expanded at a compound annual growth rate of 11% over the last five years, indicating that the country's maize value chain has enormous potential for development. Maize is now a source of over 3500 items, including specialised maize such as Quality Protein Maize - QPM (FICCI, 2022), baby corn, sweet corn, and so on. Quality protein maize, single cross, and three-way cross hybrids have improved the nutritional quality of this crop as a result of recent research advances [1-3]. More than two-thirds of India's maize production is used for feed and other industrial purposes. The feed sector, which is growing at a CAGR of 6-7% globally and 9% in India, represents a major opportunity for maize growers [4,5]. With the world's largest livestock population, India's poultry industry, including eggs and chicken meat, is rising at a CAGR of roughly 6% and 9%, respectively [6,7]. Considering these aspects, maize will continue to be an important crop for food, feed, and fodder. Maize is the main food cereal crop that can be grown in various seasons and requires moderate environment for development. In the country, more than three-fourths of the area to maize production is contributed by eight states, *viz*., Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh and Tamil Nadu [8-11]. The crop has grown in popularity in these states over the last two decades. Indian maize production relies vigorously upon the South west monsoon as more than three-fourth of the maize is produced in the Kharif season. Unfortunate monsoon and rainfall in 2015 has impacted the yield of Kharif maize for the most part in Maharashtra, Rajasthan, Gujarat, Karnataka, Andhra Pradesh and Telangana. Dry soils and lacking water system water accessibility also impacted planting of Rabi maize [12-14]. The trend in area and production from 2012 to 2016 is depicted here. Rabi maize has been sown in around 19.31 lakh hectares (47.72 lakh acres) in India as of February 4, 2022, which is greater than the 17.51 lakh hectares (43.27 lakh acres) covered during the same period previous year. Major maize growing states are Bihar 5.96 lakh ha (14.73 lakh acres), Maharashtra 3.37 lakh ha (8.33 lakh acres), Telangana 1.92 lakh ha (4.74 lakh acres) and Tamil Nadu 1.91 lakh ha (4.72 lakh acres). Irrigation is used on only 15% of the maize cropped area (Department of Agriculture & farmers welfare 2022). In terms of maize hybridization, India ranks fifth. Maize hybridization has nearly reached 100% in Bihar and Tamil Nadu.

One of the most significant goals of breeders is to find hybrid combinations with high grain yield that are adaptable to different environments. For the successful selection of feasible parents for hybridization programmes, combining ability studies of parental generations should be led under adequately pressured selection conditions [15]. The estimation of combining abilities comprises several processes, including parental selection for crossing, crossing using a specific mating design, evaluation, and data interpretation [16-18]. The effects of combining ability, both general and specific combining ability, are essential markers of potential value for appraising inbred lines in hybrid combinations as a step toward developing hybrid varieties in maize [19]. If the SCA/GCA ratio is greater than one, it is a good sign of the preponderance of non-additive effects in the expression of quantitative characters [20]. Heterosis and combining ability are required for developing a hybrid breeding programme, and diallel analysis offers information on genotypes' type of gene action, general combining ability (GCA), and specific combining ability (SCA) [21,22].

Yield is a complicated quantitative character that is governed by multiple genes interacting with the environment and is the result of numerous factors known as yield components [23]. Overall the Association studies could guide plant breeders in the selection of features that contribute to the characteristics of interest, ultimately leading to their advancement [24]. Therefore, the use of secondary traits that have strong association with yield under stress conditions has been proposed for yield improvement. Moreover, the genotype x environment interaction provides information to plant breeders in order to generate stable genotypes that can be farmed in a variety of environmental situations, as stability and adaptability of genotypes tested in different conditions is critical for maize breeding programmes [25]. When varieties are tested in a wide range of conditions, their relative ranking varies slightly. Wide genotype by environment (GxE) interactions delay selection progress and have significant implications for testing and cultivar release procedures for plant breeders [26-28]. G x E interactions are found statistically as a significantly varied pattern of response among genotypes across environments, and this will occur biologically when the contributions (or level of expression) of genes governing traits evaluated varies across environments [29]. As a result, in plant breeding, an ideal approach is to generate cultivars with reasonably uniform performance (low G x E) across a variety of environments as well as the ability to utilise resources in high yielding environments. The goal of this study was to find promising early to extra early QPM hybrids under high stress circumstances while not relinquishing yield potential.

2. MATERIALS AND METHODS

The study was carried out in three research sites representative different places in Central Research Farm, SHUATS, Prayagraj City at an elevation of 98 meters above sea level at 25.87^{O}N latitude and 81.54 ^{O}E longitude. and all the locations has sub-tropical climate with extremes of summer and winter. During winter season especially in month of December and January, temperature drops down to as low as 1-2^{0}C, while during summer the temperature reaches up to 45^{0}C (NICMEIT 2022). The experimental field has sandy loam soil, rich in organic carbon, nitrogen, medium in phosphorus and potash. Soil is neutral in pH and contained 60% S and 27% silt and 13% clay Selection of these 10 parental lines are based up on some special characters as *i.e.*, profuse tassel, nearest anthesis silking interval, leaf angle, ear height

Table 1. Name, origin and heat stress status of QPM inbred lines

QPM Inbred line	Name	Origin	Heat tolerance status
P_1	BHU-QPM-8	B	HT
P_2	BHU-QPM-2	B	HT
P_3	NBPGR-33000	N	HS
P_4	NBPGR-36548	N	HT
P_5	VL-153237	C	HT
P_6	IC-53826	N	HT
P_7	IC-381506	N	HT
P_8	IC-1306641	N	HT
P_9	BHU-N3	B	HT
P_{10}	BHU-B73-BC2	B	HS

B = BHU, Varanasi; N = NBPGR, New Delhi; C = CIMMYT, R/o Hyderabad;
HT = Heat Tolerance; HS = Heat susceptible

and plant height ratio, prodigious cob and shoot and root lodging. These lines are very homozygous and they are a great ideotype for selecting them for diallel analysis programme and these genotypes are procured from CIMMYT, ICRISAT, LUDHIANA, CSA KANPUR, BHU, IIMR and the experiment was conducted in Genetics and Plant Breeding departmental field, SHUATS.

2.1 Experimental Design

The experiment was conducted following a randomized complete block design (RCBD) with 56 lines (45 F_1s, 10 parents and 1 check HQPM-5) with three replications. The experiment was laid out across three different environments *viz.,* E_1, E_2 and E_3 during kharif season of 2020. Experiment was designed following a row length of 4 m, with inter and intra row spacing of 60 cm and 20 cm respectively. Five plants from each replication were randomly selected and tagged for recording observations in each genotype except for days to 50% tasselling, days to 50% silking, anthesis-silking interval and days to maturity. Data were recorded across all three environments following different morphological and yield parameters recorded. QPM inbred lines obtained from different research centres in India, were used to generate single cross hybrids (Table 1).

A total of 45 F_1s were obtained using diallel fashion with non-reciprocals. Among them, 10 selected inbred lines were crossed in all possible ways without reciprocals to produce 45 F1s. Mean values on different traits were analysed using model I method II suggested by Eberhart and Russell [30]. The stability of yield performance for each genotype was calculated by regressing the mean yield of individual genotypes on environmental index. The regression coefficient (bi) obtained was considered as an indication of genotype response to a varying environment, while genotype × environment interactions were partitioned into three components *viz.*, environment (linear), genotype x environment (linear) and deviation from regression. The stability analysis was done using the linear regression model suggested by Eberhart and Russell [30].

2.2 Statistical Analysis

The statistical analysis was done by using replication mean values based on the recorded data. The different statistical procedures followed were Analysis of variance, Estimation of Heterosis, Heterobeltiosis and Economic heterosis, Combining ability analysis and Stability Analysis. The data obtained for each character in F_1's and parents were analyzed for each statistical procedure given by Panse and Sukhatme [31], 'F' test and 'I' test were worked out by the analysis of variance to test the significance. It was carried out according to the procedure of RBD analysis for each character as per methodology of Fisher and Yates [32]. In the present experiment heterosis, expressed as percent deviation from the mid parent, was estimated for 5-6 hybrids for the 19 characters studied, suggested by Turner [33]. The combining ability analysis was computed on data obtained for parents and F_1s only by using diallel mating design (Model-I Method-II), [34].

Table 2. Analysis of variance for phenotypic stability parameters [30]

Source	D.F	S.S	M.S
Genotype (G)	g-1	$\sum_{i=1}^{g}\left(\sum_{j=1}^{s}\sum_{k=1}^{r}Y_{ijk}\right)^2 / sr - CF$	M_1
Environment (E)	s-1	$\sum_{j=1}^{s}\left(\sum_{i=1}^{g}\sum_{k=1}^{r}Y_{ijk}\right)^2 / gr - CF$	M_2
G X E	(g-1) (s-1)	$\sum_{i=1}^{s}\sum_{j=1}^{s}\left(\sum_{k=1}^{r}Y_{ijk}\right)^2 / r - \sum_{i=1}^{g}\left(\sum_{j=1}^{s}\sum_{k=1}^{r}Y_{ijk}\right)^2 / sr$ $\sum_{j=1}^{s}\left(\sum_{i=1}^{g}\sum_{k=1}^{r}Y_{ijk}\right)^2 / gr + CF$	M_3

Source	D.F	S.S	M.S
E+ (G X E)	G (s-1)	$\sum_{i=1}^{g}\sum_{j=1}^{s}\left(\sum_{k=1}^{r}Y_{ijk}\right)^2/r-\sum_{i=1}^{g}\left(\sum_{j=1}^{s}\sum_{k=1}^{r}Y_{ijk}\right)^2/sr$	M_4
Environment (Linear)	1	$\left(\sum_{j=1}^{s}Y_jI_j\right)^2/\left(\sum_{j=1}^{s}I_j^2\right)/g$	M_5
G X E (Linear)	g-1	$\sum_{j=1}^{s}\left[\sum_{i=1}^{s}\left(\sum_{k=1}^{r}Y_{ijk}\right)^2 r/\left(\sum_{j=1}^{s}I_J^2\right)\right]-Env.linear$	M_6
Pooled deviation	g (s-2)	$\sum_{i=1}^{g}\left(\delta_i^2\right)$	M_7
Pooled error	s (r-1) (g-1)	$\sum_{j=1}^{s}Se_j$	M_8

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance

The analysis of variance for eighteen quantitative and qualitative traits over different environments (Table 4) shows that mean squares due to genotypes, parents, hybrids and parent vs. hybrids were highly significant for all the characters studied, which indicated the existence of significant difference. Analysis of variance for combining ability Table 4 revealed the mean squares due to GCA and SCA were highly significant for most of the characters studied indicating that importance of both additive and non-additive gene actions in the expression of most of the quality traits in maize. The dominance variance has greater influence in the inheritance of trait as it was evident from the ratio of additive to dominance variance which was below unity (VA/VD<1). There was a significant difference among the genotypes tested at both 1 and 5 per cent level of significance for all characters studied. In the expression of most characters in maize, except for kernel row per cob, chlorophyll content and canopy temperature deficit in E_1 and anthesis-silking interval, kernel row per cob and canopy temperature deficit in E_2 and all parameters were significant in E_3.

3.2 General Combining Ability (GCA)

The estimates of GCA effects for different characters were either negative or positive (Table 5). For grain yield per plant, positive GCA effects is desirable likewise for days to 50% tasseling, days to 50% silking, anthesis-silking interval, plant height and days to maturity suitable for negative GCA effects. The parents, P_2, P_4 and P_5 had highly significant positive GCA effects and were grouped as good general combiners for grain yield per plant. The lines P_3, P_7 and P_{10} were noted as poor inbred lines selected as parental material, while among all parental line P_{10} was found susceptible for Heat-stress. The parent, P_2 was good general combiner for chlorophyll content, tassel length, ear length, ear girth, number of kernels per row, oil content in all the environments and had highly significant positive GCA effects. Hence these two parents, P_4 and P_5 showed highly positive GCA for number of kernel row per cob, number of kernels per row and seed yield per plant, while parents P_3 and P_9 showed positive GCA for quality parameters like oil content and starch content. Among them, parents P_2, P_4 and P_9 can be used directly for the development of high yielding hybrids and synthetic by contributing desirable alleles. Significant positive GCA effects for inbred lines indicated that they were desirable parents for hybrid maize development and involvement in the maize breeding program as they can be source of good alleles in the process of varietal development [35]. Negative GCA effects are desirable for days to 50% tasselling, days to 50% silking, anthesis-silking interval and days to 50% maturity and plant height. The parents, P_2 had highly significant negative GCA effects for days to 50 percent tasselling, days to 50 percent silking and plant height, while parents P_5 and P_6 had significant to highly significant negative GCA effects for anthesis-silking interval. Hence these two parents, P_2 and P_6 were good general combiners for these traits and can be used as parent for development of early maturing hybrids. For plant height, negative GCA effects are desirable. Parents P_2 and P_{10} had highly significant negative GCA effects for plant height and ear height, and therefore were grouped as good general combiners for these traits. These findings are in close conformity with the results of [36,35,37] (Nyasha, E. C and Charles, S. M. 2020).

3.3 Specific Combining Ability (SCA)

Estimates of specific combining ability (SCA) effects for eighteen quantitative and qualitative traits (Table 6) showed that ten cross combinations (P_1 x P_{10}, P_3 x P_5, P_3 x P_7, P_3 x P_8, P_4 x P_8, P_4 x P_{10}, P_5 x P_7, P_5 x P_8, P_5 x P_9 and P_7 x P_9) had significant to highly significant positive SCA effects for grain yield per plant in all three environments, and were grouped as good specific combinations for these traits. All these hybrids also exhibited significant to highly significant positive SCA effects for one or more yield contributing characters. Preponderance of additive effects is observed when the GCA:SCA ratio is greater than one while preponderance of dominance effects is observed when the ratio is less than one. Dominance or epistatic genetic effects mostly influenced maize grain yield under heat stress. The results obtained in this investigation are partially in accordance with findings reported by Hallauer and Miranda [15]. High estimates of SCA effects for these cross combination revealed the preponderance of additive and non-additive gene effects and may be exploited commercially for this trait after critical evaluation over locations and years. Negative SCA effects are desirable for days to 50% tasseling, days to 50% silking, anthesis-silking interval, days to 50 per cent maturity for earliness and plant height.

Hybrids P_1 x P_4, P_1 x P_5, P_1 x P_{10}, P_5 x P_9, P_5 x P_{10} showed negative SCA in environment E_1. F_1s P_2 x P_4, P_2 x P_5, P_2 x P_7, P_2 x P_8, P_3 x P_6, P_3 x P_8, P_4 x P_5, while P_8 x P_{10} depicted great SCA effects in environments E_1 and E_2. Only P_1 x P_4, P_7 x P_8 and P_5 x P_7 gave significantly negative SCA in environment E_3. All P_1 x P_4 and P_7 x P_8 combinations exhibited highly significant negative SCA effects for days to 50% tasseling and P_1 x P_4, P_4 x P_8, P_6 x P_7 and P_7 x P_8 shows significantly negative SCA in all the environments E_1, E_2 and E_3 for days to 50% silking. Among all the cross combinations P_1 x P_3, P_1 x P_4, P_2 x P_3, P_4 x P_8, P_4 x P_9, P_4 x P_{10}, P_5 x P_6, P_5 x P_7, P_5 x P_{10}, P_6 x P_8 and P_7 x P_9 exhibited highly significant negative SCA effects for anthesis-silking interval across environments investigated. Cross combinations P_1 x P_5, P_1 x P_6, P_1 x P_7, P_2 x P_7, P_3 x P_9, P_4 x P_6, P_6 x P_7, P_6 x P_8, P_7 x P_9, and P_9 x P_{10} had highly significantly negative SCA effects for days to 50% maturity. Combinations F_1s P_4 x P_7, P_4 x P_{10}, P_6 x P_8, and P_6 x P_9 exhibited highly significant negative SCA effects for plant height, although none of the crosses exhibited significantly negative SCA effects for ear height across environments. Subsequently, 30 hybrids showed significantly positive SCA for chlorophyll content, whereas 15 F_1s depicted negative specific combining ability across environments. Among them, P_2 x P_7, P_4 x P_5, P_5 x P_8, P_7 x P_9, and P_9 x P_{10} showed highest negative SCA. Hybrids P_1 x P_7, P_2 x P_3, P_2 x P_6, P_2 x P_{10}, P_3 x P_6, P_4 x P_9, P_4 x P_{10}, P_5 x P_6, P_6 x P_{10} exhibited highest significant positive SCA in all environments. Hybrids P_1 x P_2, P_3 x P_5, P_4 x P_6, P_6 x P_9 showed significant positive specific combing ability regarding canopy temperature deficit in all environments.

For yield attributing characters like number of kernel rows per cob, number of kernels per row, ear length and ear width, hybrids P_1 x P_3, P_1 x P_8, P_2 x P_3, P_3 x P_8, P_5 x P_6, and P_7 x P_9 showed significant and positive combining ability for ear length and ear girth across environments. Moreover, hybrids P_2 x P_3 and P_5 x P_6 were great in all yield attributing characters except for the number of kernel row per cob. Hybrids P_1 x P_8 and P_7 x P_9 F_1s were also revealed as good combiners in all yield attributing traits across environments. Ten hybrids, namely P_1 x P_4, P_1 x P_6, P_3 x P_6, P_3 x P_{10}, P_4 x P_9, P_5 x P_9, P_6 x P_{10}, P_7 x P_8, P_7 x P_{10}, P_8 x P_9 , exhibited positive SCA across environments for quality parameters like oil content and starch content. These outcomes are in close congruity with findings reported by, [1,36,35,37] (Charles 2020 and Mohammed and Yousif 2020; Nyasha, E. C and Charles, S. M. 2020).

The best cross combinations for seed index were P_3 x P_8 (6.22***), P_3 x P_6 (4.03**), P_1 x P_4 (3.41***). Single cross hybrids like P_4 x P_9 (6.05), (6.13*), (5.67); P_6 x P_9 (5.61), (5.92*), (4.90), P_6 x P_8 (4.73), (4.51), (0.98) combined well for chlorophyll content across environments. On the other hand, hybrids P_2 x P_6 (-4.13), P_3 x P_7 (-3.51), and P_6 x P_8 (-4.61) were the worst three combinations for seed index. Among them, the third environment effects were more worse than the other two, whereas P_5 x P_9 (-5.58), (-8.41), (-6.68); P_1 x P_6 (-5.91), (-7.35), (-6.93), P_4 x P_5 (-3.33), (-2.42), (-3.19), were the worst three combiners for chlorophyll content.

Table 3. Best and worst cross combinations for maize grain yield

High yielding hybrids				L ow-yielding hybrids			
Hybrid	**Grain yield (q/ha)**			**Hybrid**	**Grain yield (q/ha)**		
Env	E_1	E_2	E_3		E_1	E_2	E_3
P_3 x P_6	153.57	101.13	83.67	P_8 x P_9	74.81	107.03	91.25
P_4 x P_9	165.73	109.87	84.33	P_1 x P_5	75.17	113.57	83.30
P_5 x P_6	184.77	126.30	79.27	P_2 x P_5	96.70	92.17	75.41
P_5 x P_7	184.23	127.73	95.02	P_3 x P_4	99.93	95.23	88.50
P_5 x P_{10}	161.05	109.23	101.83	P_8 x P_{10}	106.27	85.47	84.33

3.4 Eterosis Effect

The estimates of standard heterosis over the check (HQPM-5) for eighteen quantitative and qualitative traits revealed the percent of standard heterosis for grain yield, ranging from 0.7% (P_2 x P_6) to 45.1% (P_5 x P_6) under E_1, from 0.4% (P_1 x P_7) to 5.7% (P_1 x P_8) under E_2 and 18.9% (P_4 x P_8) under E_3. Data for this character further revealed that hybrid P_5 x P_6 (45.1%) exhibited highest significantly positive standard heterosis for seed yield, followed by hybrids P_5 x P_7 (44.69%), P_4 x P_5 (34.9%), P_4 x P_8 (33.9%), P_4 x P_9 (30.2%) in environment E_1. Similarly under environment E_2, 5.7%. (P_1 x P_8) depicted the highest significantly positive value followed by hybrids P_1 x P_{10} (4.2%), P_2 x P_3 (2.3%), P_5 x P_7 (0.5%), P_1 x P_7 (0.4%). However, under environment E_3, 18.9% (P_4 x P_8) exhibited the highest significantly positive standard heterosis value for seed yield**.** These hybrids also exhibited significant to highly significant positive standard heterosis for one or more grain yield contributing traits. Hence, these hybrids can be exploited commercially after critical evaluation for their superiority and stability over all locations investigated. Days to 50% tasseling and days to 50% silking regulate the early flowering. The range of standard heterosis for days to 50% tasseling varied from -0.6% (P_1 x P_8) to -14.1% (P_3 x P_6) in E_1, from -2.5% (P_1 x P_8) to -12.7% (P_3 x P_6) in E_2 and from -1.9% (P_7 x P_8) to - 7.5% (P_2 x P_4) in E_3. Data for this character further revealed that hybrid P_3 x P_6 (-14.10%) exhibited the highest negative significant standard heterosis for days to 50% tasseling and for days to 50% silking varied from -3.09 (P_4 x P_8) to -14.20% (P_3 x P_6) in E_1, from -2.44 (P_1 x P_8) to -12.20% (P_3 x P_6) in E_2 and from -4.24 (P_7 x P_8) to -9.09% (P_3 x P_8) in E_3, Data for this character further revealed that hybrid P_3 x P_6 (-14.20%) exhibited highest negative significant standard heterosis for days to 50% silking. While for chlorophyll content, there were least number of hybrids which recorded significant heterosis over the check. Similarly, over the check, a total of 12 hybrids recorded significant standard heterosis in desirable positive direction regarding leaf area index. These results were in line with findings reported by Mohammed and Yousif (2020) and Karim et al., [38]. For yield attributing traits like the number of kernel rows per cob, number of kernels per row, ear length and ear girth, hybrids P_3 x P_5 and P_5 x P_6 showed positive standard heterosis. Furthermore for the quality parameters like oil content and starch content, hybrids F_1s P_2 x P_3, P_1 x P_5, P_4 x P_9, P_5 x P_9, P_5 x P_{10} and P_8 x P_9 showed significantly positive heterosis under all environments studied. Hence, these hybrids can be exploited earliness after critical testing over environments. Similar results were reported by Ambikabathy et al., [39], Kumar and Babu (2016), Kumar et al., [40], Ofori et al., (2015), Lahane et al., [41]. These hybrids may be exploited commercially after critical evaluation for their performance and stability across different environments.

3.5 Stability Analysis

The mean value of days to tasselling across environmental conditions was 52 days. A total of 32 hybrids out of 45 regarding days to 50% tasseling, showed non-significant deviation from regression (s^2di). Their behavior was predictable, while 13 hybrids showed significant deviation from regression (s^2di) and therefore behaved unstable. The hybrid (P_1 × P_8) exhibited a negative phenotypic index (P_i<1), a regression coefficient close to unity ($\beta_i \approx 1$) and a non-significant deviation from regression (s^2di), indicating its stability across environments and suitability for early tasseling. Hybrids P_1 x P_8, P_1 x P_2, and P_6 x P_9 showed non-significant deviation from regression (s^2di), with negative phenotypic index (P_i‹1), and a regression coefficient greater than unity (β_i>1), indicating their adaptability under un-favorable environments and their suitability for early tasseling. For days to silking, 32 hybrids out of 45 showed non-significant deviation from regression (s^2di), with therefore a predictable behavior. In contrast, 13 hybrids remaining showed significant deviation from regression (s^2di), with an unpredictable behavior. The hybrid $P_1 \times P_8$ presented a negative phenotypic index (P_i<1), a regression coefficient close to unity ($\beta_i \approx 1$) and a non-significant deviation from regression (s^2di), indicating its adaptability across environments and suitability for early silking. Hybrids P_1 x P_8 and P_4 x P_8 showed non-significant deviation from regression (s^2di) with a negative phenotypic index (P_i<1), and a regression coefficient greater than unity (β_i >1), indicating their adaptability and suitability for early silking across different environments.

The highest mean plant height (184.1 cm) was recorded for hybrid P_1 x P_8 whereas the lowest mean (131.5 cm) was observed on hybrid P_6 x P_9, and the average plant height across different environments was 163.5 cm. All hybrids tested were significantly deviating from the regression value across environments. Over the three environments tested, 26 hybrids showed a non-significant deviation from regression (s^2di), with therefore a predictable behavior. In contrast, 19 hybrids showed a significant deviation from regression (s^2di), with an unpredictable behavior. The hybrid P_2 x P_6 had negative phenotypic index (P_i<1), a regression coefficient near to unity (β_i ≈1) and a non-significant deviation from regression (s^2di), indicating its adaptability across environments and suitability for lower plant height.

Cob length for P_3 x P_5 had a high mean value (20.33 cm) and P_9 x P_{10} had a low mean value (15.72 cm), with an overall average value of 17.63 cm. Across the three environments, P_1 x P_6, P_3 x P_9, P_7 x P_{10}, and P_9 x P_{10} hybrids had higher mean, regression value close to one, and non-significant deviation from regression (Lata *et al.,* 2010). As a result, for cob length, these genotypes were stable across environments. P_2 x P_9 hybrid had the highest mean value for cob girth (14.85 cm), whereas P_7 x P_8 had the lowest (12.67 cm). Seven hybrids were selected from the 45 hybrids: P_1 x P_2, P_1 x P_8, P_2 x P_6, P_5 x P_7, and P_7 x P_9, P_8 x P_{10}, and P_9 x P_{10} demonstrated non-significant (s^2di) and regression coefficients less than unity (βi <1), with mean values greater than the population mean, demonstrating its adaptability to unfavourable circumstances for increased ear girth.

P_1 x P_2, P_1 x P_8, P_2 x P_6, P_5 x P_7, P_6 x P_9, P_8 x P_{10}, P_9 x P_{10} hybrids show adaptation in favourable conditions and are ideal for larger ear girth. Data for kernel rows per cob revealed that 18 hybrids showed non-significant deviation from regression, indicating stable behaviour, while 27 hybrids showed substantial deviation from regression, indicating unstable behavior. P_1 x P_7, P_4 x P_5, and P_5 x P_{10} hybrids show stable performance under varied settings for a greater number of kernel rows per cob. The hybrid P_2 x P_6 had a high number of kernels per row (36.66), whereas P_8 x P_9 had a low number of kernels per row (22.33). While, across the three environments, hybrids P_1 x P_5, P_1 x P_6, P_1 x P_9, P_4 x P_5, P_5 x P_6, P_6 x P_8, P_7 x P_{10}, and P_8 x P_{10} shown their adaptability in favourable circumstances and suitability for a greater number of kernels per row.

The mean value for seed index (100 seed weight) across three environments ranged from 22.72 to 28.43 g, with a mean value of 25.61 g. The hybrid P_7 x P_8 had the lowest value (22.72 g), while the hybrid P_3 x P_8 had the highest kernels per row (28.43 g). Among the check HQPM-5 (26.88 g) hybrids, P_1 x P_7, P_2 x P_6, P_3 x P_5, P_4 x P_6, P_4 x P_8, P_4 x P_9, P_4 x P_{10}, P_5 x P_6, P_5 x P_8, P_5 x P_7, P_7 x P_8, P_7 x P_9 exhibited non-significant deviation from regression (s^2di), Having a positive phenotypic index (Pi >1) and a regression coefficient greater than unity (βi >1), showing adaptability in favourable environments and high yield potential.

The hybrids in three environments had the highest F_1 P_5 x P_6 with mean value (256.62 qt/ha) and the lowest F_1 P_8 x P_9 mean value (103.90 qt/ha), as shown by their higher mean yield, statistically unit regression, and non-significant S^2di value (Eyherabide *et al.,* 2016) P_5 x P_7, P_5 x P_6, and P_4 x P_9 were not significantly influenced by the environment and were promising for the majority of the characters studied, with high mean performance across the environments. These single cross hybrids, which are stable and prevalent for grain yield, could be tried in a wide range of conditions due to their wide variation in diverse ecological regions. From this, we can stabilise agricultural production and concentrate on national production and efficiency, as production and productivity levels in India are lower by more than 50% when compared to global efficiency.

Table 4. Analysis of variance for diallel analysis (Model I and Method II) for eighteen quantitative and qualitative characters in maize

Source of variation	Df	Env	Days to 50% tasseling	Days to 50% silking	ASI	Plant height	Cob height	Tassel length	Ear length	Ear girth	Kernel row per cob	Kernels per row	LAI	Chlorophyll Content	CTD	Seed Index	Grain yield/ plant	Days to maturity	Oil content	Starch content
Replicate	2	E_1	42.62***	44.92***	0.65*	2442.61***	736.86**	14.49	0.10	1.55	14.04 *	50.35*	2.69***	148.54*	12.91***	5.65	20665.98***	0.55	0.05	1.32
		E_2	0.01	0.46	0.44	687.12	310.13	19.74	1.06***	4.52**	29.19**	194.96***	3.01***	125.94**	94.81***	1.06	1733.81	0.99	0.01	003
		E_3	0.92	5.31	0.12	104.33	79.23	12.48	7.91*	0.99	0.30	10.22	2.16***	112.18*	33.85***	5.70	40.28	0.84	0.00	0.02
Treatments	54	E_1	9.12***	9.36***	0.28*	853.37***	414.37***	89.16***	7.37***	2.50***	3.89	36.63***	0.60***	42.62	1.64	15.29***	2165.46*	26.28***	1.25***	59.65***
		E_2	8.42***	7.19***	0.24	1955.13***	765.89***	92.33***	8.38*	2.60***	5.35	27.23***	0.47***	43.11**	1.17	8.38***	877.93*	14.30***	1.07***	65.51***
		E_3	26.73***	25.89***	0.36*	657.38***	306.53***	57.33***	12.06***	2.09***	2.21*	33.46***	0.41***	36.52*	1.13*	13.22***	356.23***	21.17***	1.08***	65.34***
Parents	9	E_1	4.67	5.86	0.83***	410.88*	231.51*	68.66***	11.64***	7.05***	4.76	45.57 **	0.61*	90.52*	1.31	17.23***	588.75	31.50***	0.53***	15.39***
		E_2	24.40***	25.72***	0.09	411.88	230.52	47.89*	13.01*	7.45***	3.91	29.35**	0.67**	90.36***	2.13*	13.01***	687.24	23.44***	0.45***	19.09***
		E_3	19.43***	12.09**	0.03	409.88***	230.90***	106.73***	11.32***	7.44***	3.90**	29.30**	0.65***	89.30***	2.10**	15.68***	688.20***	23.40***	0.44***	17.51***
Hybrids	44	E_1	9.32***	9.30***	0.18	397.97**	235.87***	39.46***	5.04*	1.22*	3.79	31.93***	0.26	30.66	1.74	9.04***	2120.54	25.60***	1.30***	69.40***
		E_2	3.37 **	2.73**	0.26	1363.18***	587.96***	45.56**	7.61	1.48*	5.11	24.21***	0.19	31.17	6.76	7.61***	935.37*	12.37***	1.12***	75.84***
		E_3	4.99***	5.75*	0.40*	608.69***	243.87***	43.75***	11.86***	1.00***	1.76	24.72***	0.18	25.37	0.37	13.00***	168.73	10.04***	1.14***	76.18***
Parent vs hybrids	1	E_1	40.07***	43.39***	0.01	24873.18***	9913.87***	2460.57***	71.61***	17.51***	0.11	162.63***	15.69***	139.50	0.01	273.22***	18332.02***	9.50**	5.60***	28.89***
		E_2	86.55***	75.33***	0.49	41899.23***	12404.10***	2550.00***	0.42***	7.83**	28.71*	141.38***	11.16***	142.92*	1.74**	0.42	67.07	17.05**	4.39***	28.87***
		E_3	1048.90***	1035.86***	1.42*	5018.52***	3739.18***	210.13	27.42***	1.73	6.60*	454.63***	7.76***	42.70	25.69***	0.63	5627.40***	490.52***	4.28***	18.96***
Error	108	E_1	2.97	2.99	0.19	189.72	736.86	15.48	2.99	0.70	3.10	13.76	0.27	37.36	1.49	2.73	1466.44	0.93	0.02	0.82
		E_2	1.91	1.52	0.27	238.77	141.24	21.74	1.90	0.87	4.45	10.67	0.20	25.03	1.00	1.90	598.49	1.64	6.00	0.09
		E_3	2.22	3.82	0.24	96.51	63.13	10.22	1.91	0.48	1.50	9.42	0.17	24.66	0.68	2.43	146.66	2.22	0.01	0.02

*Significant levels: * = <.05, ** = <.01 & *** = <.001*

ASI: Anthesis-silking interval; LAI: Leaf area index; CTD: Canopy temperature deficit

Table 5. Estimates of general combining ability (GCA) effects of ten parental inbred lines for eighteen quantitative and qualitative characters in maize

S.NO	Parents	Env.	Days to 50% tasseling	Days to 50% silking	ASI	Plant height	Cob height	Tassel length	LAI	Chlorophyll content	CTD
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1		E_1	1.161 ***	1.128 ***	0.01	6.294 **	6.528 ***	-0.224	0.012	-1.648	0.008
2	P_1	E_2	0.850 ***	0.661 ***	-0.117	10.671 ***	9.353 ***	-0.689	0.015	-1.803 *	-0.415 **
3		E_3	0.083	-0.139	-0.128	9.521 ***	7.691 ***	-1.144 *	0.06	-1.939 *	-0.174
4		E_1	-0.978 ***	-0.872 **	0.083	-6.187 **	-5.494 **	0.343	0.01	0.376	-0.228
5	P_2	E_2	-0.261	-0.089	0.133	-3.407	-6.421 ***	-0.419	0.016	0.487	0.152
6		E_3	-0.194	-0.222	0.067	-7.002 ***	-3.999 **	-1.144 *	-0.015	0.581	0.081
7		E_1	-0.728 **	-0.817 **	-0.083	-4.412 *	-4.832 **	0.028	-0.199 *	0.98	-0.228
8	P_3	E_2	-0.067	0.05	0.106	5.732 *	-1.477	-0.028	-0.170 *	1.076	0.249
9		E_3	0.944 ***	1.194 ***	0.067	-8.085 ***	-3.388 **	-1.506 **	-0.188 **	1.08	0.379 **
10		E_1	0.717 **	0.656 *	-0.056	-2.46	-3.086	0.841	-0.126	-0.735	-0.009
11	P_4	E_2	0.600 **	0.578 **	-0.033	3.743	-0.095	1.464 *	-0.089	-0.629	0.027
12		E_3	0.306	0.111	-0.1	-3.602 *	-0.7	1.078 *	-0.074	-0.689	0.062
13		E_1	-0.144	-0.122	-0.028	3.697	0.656	1.01	0.141	0.76	-0.106
14	P_5	E_2	0.294	0.272	-0.033	8.898 ***	5.516 **	0.714	0.148 *	0.513	-0.001
15		E_3	1.028 ***	0.833 **	-0.1	3.776 *	2.049	2.661 ***	0.168 *	0.784	-0.172
16		E_1	-0.45	-0.511	-0.028	-4.397 *	-0.516	-2.176 ***	0.035	-0.125	-0.014
17	P_6	E_2	0.156	0.05	-0.117	-11.907 ***	-5.882 **	-2.925 ***	-0.089	0.028	-0.104
18		E_3	0.194	0.278	-0.017	1.943	-1.293	0.328	-0.066	-0.457	-0.154
19		E_1	-0.644 *	-0.761 **	-0.083	1.742	2.889	0.688	0.025	1.577	0.205
20	P_7	E_2	-0.344	-0.311	0.05	-1.613	1.904	0.186	0.025	1.259	-0.009
21		E_3	-0.222	-0.361	0.039	5.571 ***	2.188	3.022 ***	0.015	1.141	0.163
22		E_1	1.050 ***	1.017 ***	-0.056	6.852 **	5.648 **	-0.076	0.026	0.308	0.283
23	P_8	E_2	0.544 *	0.661 ***	0.106	3.654	5.714 **	1.381	0.038	0.16	-0.024
24		E_3	0.167	0.25	0.178 *	2.976	1.192	-0.533	-0.012	0.389	-0.143
25		E_1	0.578 *	0.878 **	0.306 ***	1.682	1.675	-0.833	0.053	-1.137	0.099
26	P_9	E_2	-0.844 ***	-0.922 ***	-0.061	-5.168 *	-2.786	0.297	0.082	-0.932	0.057
27		E_3	-1.194 ***	-0.667 *	0.067	-4.541 **	-3.559 **	-0.367	0.071	-0.483	-0.013
28		E_1	-0.561 *	-0.594 *	-0.056	-2.812	-3.467 *	0.398	0.023	-0.357	-0.009
29	- P_{10}	E_2	-0.928 ***	-0.950 ***	-0.033	-10.602 ***	-5.826 **	0.019	0.023	-0.158	0.068
30		E_3	-1.111 ***	-1.278 ***	-0.072	-0.557	-0.181	-2.394 ***	0.041	-0.407	-0.029
	Gi <> 0 at 95%	E_1	0.617 ***	0.618 ***	0.154 ***	4.927 ***	3.778 ***	1.407 ***	0.184 ***	2.186 ***	0.437 ***
	Gi--Gj at 95%		0.920 ***	0.922 ***	0.230 ***	7.344 ***	5.632 ***	2.098 ***	0.275 ***	3.259 ***	0.651 ***
	Gi <> 0 at 95%	E_2	0.495 ***	0.441 ***	0.186 ***	5.527 ***	4.251 ***	1.668 ***	0.159 ***	1.790 ***	0.357 ***
	Gi--Gj at 95%		0.738 ***	0.658 ***	0.277 ***	8.239 ***	6.337 ***	2.486 ***	0.237 ***	2.668 ***	0.533 ***
	Gi <> 0 at 95%	E_3	0.533 ***	0.699 ***	0.175 ***	3.514 ***	2.842 ***	1.143 ***	0.149 ***	1.776 ***	0.295 ***
	Gi--Gj at 95%		0.795 ***	1.041 ***	0.260 ***	5.238 ***	4.236 ***	1.704 ***	0.223 ***	2.648 ***	0.440 ***

*Significant levels: * = <.05, ** = <.01 & *** = <.001*

ASI: Anthesis-silking interval; LAI: Leaf area index; CTD: Canopy temperature deficit

Table 5 (continue). Estimates of general combining ability (GCA) effects of ten parental inbred lines for eighteen quantitative and qualitative characters in maize

S.NO	Parents	Env.	Ear length	Ear girth	Kernels rows per cob	Kernels per row	Seed Index	Seed yield per plant	Days to maturity	Oil content	Starch content
1		E_1	-0.488	-0.254	0.244	-0.972	0.925 ***	-16.433 **	-0.206	-0.248 ***	0.710 ***
2	P_1	E_2	0.26	-0.051	-0.15	1.517 **	-0.018	5.414	0.544 **	-0.275 ***	0.888 ***
3		E_3	-0.651 **	-0.422 ***	0.078	0.017	-0.697 **	-2.004	1.039 ***	-0.296 ***	0.682 ***
4		E_1	0.814 **	0.845 ***	-0.2	1.167 *	0.644 *	-3.651	0.572 ***	0.182 ***	-2.776 ***
5	P_2	E_2	-0.079	0.909 ***	0.767 *	-0.9	0.647 **	2.317	-0.233	0.165 ***	-2.887 ***
6		E_3	-1.131 ***	0.708 ***	0.522 **	1.350 **	-0.232	2.837	-1.128 ***	0.176 ***	-2.837 ***
7		E_1	-0.766 **	-0.422 **	-0.533	-0.75	1.013 ***	0.824	-1.428 ***	-0.021	1.241 ***
8	P_3	E_2	-0.429	-0.287	-0.372	-1.206 *	0.179	-1.635	-0.761 ***	-0.002	1.550 ***
9		E_3	0.259	0.004	-0.172	0.794	0.272	-2.241	-0.35	0.011 *	1.262 ***
10		E_1	0.437	-0.013	-0.033	0.25	-0.638 *	7.883	-0.567 ***	0.042	-0.388 **
11	P_4	E_2	0.184	0.087	0.378	0.517	-0.883 ***	5.923	-0.344	0.012	-0.277 ***
12		E_3	0.723 **	0.329 **	0.244	1.211 *	0.036	6.586 ***	-0.322	0.004	-0.07
13		E_1	0.462	0.525 ***	-0.144	0.444	-0.284	14.405 *	-0.900 ***	0.308 ***	-0.112
14	P_5	E_2	1.012 **	0.256	-0.261	0.1	0.336	0.519	0.072	0.304 ***	-0.120 *
15		E_3	1.458 ***	0.402 ***	0.022	0.683	0.066	-1.211	-0.1	0.300 ***	-0.215 **
16		E_1	0.253	-0.163	0.244	3.194 ***	-1.005 ***	8.394	0.739 ***	-0.252 ***	1.099 ***
17	P_6	E_2	-0.37	-0.558 ***	-0.178	1.794 ***	-0.369	1.68	0.35	-0.239 ***	0.756 ***
18		E_3	-0.372	-0.312 **	-0.394 *	-0.094	-0.227	-1.861	0.511 *	-0.250 ***	0.855 ***
19		E_1	0.513	-0.159	-0.311	0.167	-0.067	1.919	-0.011	0.015	-2.040 ***
20	P_7	E_2	0.274	-0.104	-0.344	0.378	0.372	0.571	-0.289	0.019	-2.310 ***
21		E_3	0.224	-0.092	-0.033	-0.317	-0.15	-0.016	-0.433	0.028 ***	-2.199 ***
22		E_1	-0.801 **	-0.216	-0.644 *	0.528	-0.011	-3.537	1.683 ***	0.026	0.736 ***
23	P_8	E_2	-0.11	-0.229	-0.539	1.100 *	0.266	-1.869	1.128 ***	-0.006	0.345 ***
24		E_3	-0.332	-0.330 **	-0.228	0.1	0.650 **	-1.365	1.206 ***	0.002	0.802 ***
25		E_1	-0.154	-0.088	0.522	-1.639 **	-0.611 *	-2.906	-0.178	0.182 ***	0.890 ***
26	P_9	E_2	-0.186	-0.071	0.433	-1.622 **	-0.228	-6.327	0.156	0.208 ***	1.329 ***
27		E_3	-0.22	-0.17	0.022	-2.067 ***	0.093	-0.308	0.011	0.198 ***	0.863 ***
28		E_1	-0.27	-0.056	0.856 **	-2.389 ***	0.034	-6.898	0.294	-0.233 ***	0.639 ***
29	- P_{10}	E_2	-0.557	0.049	0.267	-1.678 **	-0.302	-6.592	-0.622 **	-0.186 ***	0.726 ***
30		E_3	0.043	-0.118	-0.061	-1.678 ***	0.188	-0.416	-0.433	-0.174 ***	0.856 ***
	Gi <> 0 at 95%	E_1	0.618 ***	0.299 ***	0.630 ***	1.327 ***	0.591 ***	13.697 ***	0.345 ***	0.049 ***	0.324 ***
	Gi--Gj at 95%		0.921 ***	0.446 ***	0.938 ***	1.978 ***	0.881 ***	20.418 ***	0.514 ***	0.073 ***	0.482 ***
	Gi <> 0 at 95%	E_2	0.832 ***	0.333 ***	0.754 ***	1.168 ***	0.492 ***	8.750 ***	0.458 ***	0.022 ***	0.108 ***
	Gi--Gj at 95%		1.241 ***	0.497 ***	1.124 ***	1.741 ***	0.734 ***	13.044 ***	0.683 ***	0.033 ***	0.161 ***
	Gi <> 0 at 95%	E_3	0.495 ***	0.244 ***	0.438 ***	1.098 ***	0.558 ***	4.332 ***	0.533 ***	0.012 ***	0.167 ***
	Gi--Gj at 95%		0.737 ***	0.363 ***	0.653 ***	1.636 ***	0.831 ***	6.457 ***	0.794 ***	0.018 ***	0.249 ***

*Significant levels: * = <.05, ** = <.01 & *** = <.001*

ASI: Anthesis-silking interval; LAI: Leaf area index; CTD: Canopy temperature deficit

Table 6. Specific combining ability (SCA) effects for different characters in maize over three environments

S.No	Hybrids	Env.	Days to 50% tasselling	Days to 50% Silking	ASI	Plant height	Ear height	Tassel length	LAI	Chlorophyll content	CTD
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	P_1 X P_2	E_1	0.629	0.399	-0.265	1.558	-2.404	1.52	-0.007	1.4	1.753 **
		E_2	-0.753	-0.639	0.068	-7.344	3.688	2.136	0.736 **	1.923	0.368
		E_3	-0.404	-0.487	-0.169	-7.763	-10.855*	5.495 **	0.727 **	0.813	0.46
2	P_1 X P_3	E_1	0.712	0.677	-0.098	10.149	2.933	-5.049 *	-0.041	-2.184	-1.213
		E_2	-0.28	-0.444	-0.237	10.184	-7.257	-1.223	0.408	-2.615	0.004
		E_3	-0.543	-0.904	-0.169	2.32	-7.466	0.856	0.443	-3.472	-0.171
3	P_1 X P_4	E_1	-0.732	-0.795	-0.126	12.061	5.655	0.705	0.262	1.331	1.267
		E_2	-0.947	-0.972	-0.098	16.173	9.695	7.519 **	0.451	-0.654	-0.641
		E_3	-0.947	-0.972	-0.098	16.173	9.695	7.519 **	0.451	-0.654	-0.641
4	P_1X P_5	E_1	-0.205	0.649	0.513 *	-3.846	-4.487	1.987	-0.108	-1.274	-0.702
		E_2	-0.641	-0.333	0.235	0.684	-3.916	-2.731	-0.03	-1.339	0.654
		E_3	0.707	0.79	-0.003	1.459	4.43	-4.977 **	-0.015	-1.866	0.06
5	P_1 X P_6	E_1	0.101	0.371	0.179	11.681	8.594	4.725 *	-0.252	-0.643	-0.027
		E_2	-0.169	-0.111	-0.015	14.823	12.149	5.241 *	-0.172	0.469	0.19
		E_3	1.874 *	1.679	-0.086	4.292	8.773 *	2.023	-0.048	0.475	-0.038
6	P_1 X P_7	E_1	0.629	-0.045	-0.098	4.353	13.700 *	3.242	0.068	4.175	0.12
		E_2	-0.336	-1.083	-0.182	0.862	-3.638	7.463 **	-0.056	3.052	-0.505
		E_3	2.290 **	2.652 *	0.192	6.665	7.292	-3.338	-0.186	3.23	-0.155
7	P_1 X P_8	E_1	0.934	1.177	0.207	12.799	7.897	4.782 *	0.616 *	1.298	-0.558
		E_2	1.109	1.278	0.096	46.928***	27.219***	5.602 *	0.001	0.367	-0.656
		E_3	1.235	1.374	0.053	14.592 **	6.621	2.217	0.065	0.189	-0.082
8	P_1 X P_9	E_1	1.407	0.982	-0.154	12.169	14.327 *	3.516	0.503	-0.487	-0.908
		E_2	1.164	1.194	0.263	2.417	4.72	3.352	0.11	0.396	-0.137
		E_3	2.596 **	1.957	-0.169	10.442	3.038	1.051	0.084	0.481	-0.079
9	P_1 X P_{10}	E_1	-0.455	-0.212	0.207	27.296***	20.218***	13.131 ***	0.576 *	-0.864	0.234
		E_2	0.581	0.556	-0.098	36.517***	40.426***	-3.37	0.005	0.582	0.318
		E_3	1.179	1.235	-0.03	-18.874***	-4.006	1.412	-0.032	0.892	-0.196
10	P_2 X P_3	E_1	1.184	1.01	-0.182	16.987 *	11.575 *	2.155	0.987 ***	4.858	-0.711
		E_2	1.497 *	0.972	-0.487	12.928	12.851 *	7.074 **	0.511 *	3.181	-0.562
		E_3	0.735	0.513	-0.03	-7.158	-6.442	5.856 **	0.508 *	2.518	-0.094
11	P_2 X P_4	E_1	-1.927 *	-1.795	0.124	-5.232	6.096	-0.111	0.554 *	-0.417	-0.13
		E_2	-1.169	-0.889	0.318	19.250 *	-5.532	3.916	-0.023	0.196	-0.241
		E_3	1.04	0.929	-0.197	23.026 ***	16.203***	2.273	-0.016	0.337	-0.743
12	P_2X P_5	E_1	-0.732	-0.351	0.429	-4.012	-8.979	0.943	0.083	1.122	-0.533
		E_2	-1.197	-1.25	-0.015	-10.572	-9.809	-4.667	0.036	1.981	0.221
		E_3	0.985	0.874	-0.197	1.981	2.454	3.356	-0.244	1.764	-0.176
13	P_2 X P_6	E_1	0.573	0.371	-0.237	5.615	7.106	4.359 *	0.05	3.697	-0.358
		E_2	-0.725	-0.361	0.402	5.901	14.590 *	0.638	0.041	3.756	-0.876
		E_3	0.152	0.096	0.053	3.815	0.13	4.356 *	-0.027	4.018	-0.293
14	P_2 X P_7	E_1	-1.899 *	-2.045 *	-0.182	9.676	7.188	4.095	0.12	-5.915	0.256
		E_2	-1.891 *	-1.333 *	0.235	22.606 **	9.803	2.194	0.273	-7.352 **	-0.005
		E_3	1.235	1.068	-0.336	-9.146	0.316	5.995 ***	0.225	-6.936 *	-0.241
15	P_2 X P_8	E_1	-0.927	-0.823	0.124	21.646 **	8.386	4.642 *	0.308	0.134	-1.088
		E_2	-1.114	-0.972	0.179	17.673 *	3.993	7.333 **	0.106	1.137	-0.123
		E_3	1.179	1.79	0.525 *	6.781	-5.689	-3.783 *	0.143	1.135	-0.488
16	P_2 X P_9	E_1	0.879	1.316	0.429	10.449	5.625	-0.258	0.065	-3.754	1.295
		E_2	-0.391	-0.056	0.346	14.162	6.827	6.749 **	0.386	-3.294	0.029
		E_3	2.207 **	2.04	0.303	-7.035	-0.605	0.051	0.403	-2.979	-0.011
17	P_2 X P_{10}	E_1	0.684	0.455	-0.21	5.876	4.04	4.281 *	0.045	2.709	0.803
		E_2	0.359	0.306	-0.015	14.595	3.866	3.694	-0.016	2.799	0.318
		E_3	1.790 *	2.652 *	0.775 **	-20.685 ***	-3.982	-7.255 ***	0.023	2.245	-0.155
18	P_3 X P_4	E_1	2.157 *	2.149 *	-0.043	14.483	9.1	2.17	-0.116	1.026	-0.23
		E_2	-1.364	-1.028	0.346	-13.555	-6.143	1.858	-0.067	0.484	-0.571

S.No	Hybrids	Env.	Days to 50% tasselling	Days to 50% Silking	ASI	Plant height	Ear height	Tassel length	LAI	Chlorophyll content	CTD
		E_3	2.568 **	2.179 *	-0.197	8.442	-6.074	-0.366	0.027	0.355	-0.541
19	P_3X P_5	E_1	0.684	0.593	-0.071	-7.54	-1.442	4.288 *	0.51	0.674	0.334
		E_2	-1.058	-1.056	0.013	25.956 **	4.58	4.608	0.492 *	1.436	0.324
		E_3	3.513 ***	3.457 **	0.136	4.731	4.176	-1.949	0.479 *	1.022	0.36
20	P_3 X P_6	E_1	-2.677 **	-3.018 **	-0.071	-4.58	-4.557	4.967 *	0.21	2.449	0.776
		E_2	-2.919 ***	-2.833 ***	0.096	11.428	2.978	1.247	-0.097	2.577	-0.073
		E_3	0.013	3.346 **	0.386	3.231	3.852	-0.616	-0.08	3.189	-0.435
21	P_3 X P_7	E_1	0.184	0.566	0.318	3.791	-2.828	4.876 *	0.33	-1.81	0.289
		E_2	-0.419	-0.806	-0.404	34.801 ***	19.858 **	1.802	-0.164	-0.987	-0.702
		E_3	3.429 ***	2.985 **	-0.336	-10.063	-6.629	0.023	-0.145	-0.735	-0.642
22	P_3 X P_8	E_1	-2.177 *	-1.879 *	0.29	14.511	3.857	1.533	-0.149	-2.084	0.145
		E_2	-1.641 *	-1.111	0.54	27.867 **	24.382 ***	2.274	0.262	-1.354	-0.787
		E_3	0.707	0.374	-0.141	1.531	-1.967	-1.088	-0.014	-1.043	-0.836
23	P_3 X P_9	E_1	-2.705 **	-2.740 **	-0.071	14.294	5.829	3.817	0.295	-0.885	-0.272
		E_2	0.747	0.806	0.04	17.356 *	2.549	2.691	0.335	-0.543	-0.535
		E_3	1.402	1.29	0.636 *	-24.285 ***	-6.216	-0.588	0.175	-0.301	-0.499
24	P_3 X P_{10}	E_1	-1.899 *	-1.934 *	-0.043	0.901	4.147	6.212 **	-0.219	1.134	0.703
		E_2	0.164	0.5	0.346	-7.877	-6.412	-1.698	0.067	1.43	0.154
		E_3	1.652 *	1.235	-0.225	-5.935	8.073	0.773	0.099	0.303	0.04
25	P_4X P_5	E_1	-0.427	-0.545	-0.098	17.508 *	-2.097	4.275 *	0.163	-3.337	0.948
		E_2	-1.725 *	-1.583 *	0.152	19.945 *	6.865	2.449	0.201	-2.42	0.112
		E_3	0.485	0.54	-0.03	-20.085 ***	-8.845 *	-5.199 **	0.158	-3.192	-0.003
26	P_4 X P_6	E_1	0.545	0.843	0.568 *	-5.866	-3.992	3.261	0.126	0.541	0.023
		E_2	-0.586	-0.694	-0.098	3.417	7.263	3.088	0.276	-0.195	0.548
		E_3	-0.682	-0.904	-0.114	-12.585 *	-6.836	-0.199	0.229	-0.498	0.226
27	P_4 X P_7	E_1	1.073	1.093	-0.043	-1.704	5.003	2.417	0.313	1.292	1.337 *
		E_2	0.247	0.667	0.402	12.789	1.476	-2.356	0.338	2.794	-0.273
		E_3	0.402	1.402	0.831 **	-17.880 **	-8.983 *	-4.561 *	0.274	3.001	-0.071
28	P_4 X P_8	E_1	0.045	-0.018	-0.071	6.952	1.511	1.04	0.294	3.075	0.126
		E_2	0.025	-0.306	-0.321	8.523	2.666	4.116	0.085	2.893	0.068
		E_3	0.013	-0.21	-0.308	-10.619 *	-5.654	-1.338	0.112	2.842	-0.289
29	P_4 X P_9	E_1	-0.482	-0.545	-0.098	14.656	6.35	-3.379	0.325	6.056	-1.258
		E_2	0.081	-0.056	-0.154	19.345 *	6.167	3.199	0.401	6.138 *	-0.713
		E_3	1.707 *	1.04	-0.197	-5.102	1.096	0.162	0.388	5.678 *	-0.766
30	P_4 X P_{10}	E_1	0.99	0.927	-0.071	-16.851 *	-8.618	-9.253 ***	-0.442	2.806	-1.316 *
		E_2	0.164	-0.028	-0.182	-9.555	13.873 *	-3.189	-0.214	3.608	0.209
		E_3	2.290 **	2.318 *	-0.058	-21.752 ***	-15.615***	-2.477	-0.255	3.185	0.067
31	P_5 X P_6	E_1	0.073	-0.045	-0.126	1.445	9.399	-2.811	-0.004	3.279	-0.347
		E_2	-1.28	-1.389 *	-0.098	13.595	4.986	2.505	-0.092	3.54	-0.557
		E_3	2.596 **	2.374 *	-0.114	-19.963 ***	-16.585 ***	-5.116 **	0.204	3.822	-0.236
32	P_5 X P_7	E_1	0.268	0.205	-0.071	8.173	-2.628	-3.985	0.283	-0.886	-0.033
		E_2	0.553	0.306	-0.265	3.634	9.199	-0.273	0.168	-0.044	0.048
		E_3	-0.321	-0.321	-0.169	-16.591 **	-12.400 **	3.523 *	0.15	0.318	-0.49
33	P_5 X P_8	E_1	-1.427	-1.24	0.235	6.329	4.236	0.938	0.031	-3.543	0.189
		E_2	-1.669 *	-2.000 **	-0.321	11.034	14.056 *	-2.134	0.184	-3.505	-0.27
		E_3	0.957	1.402	0.359	-6.33	-17.737 ***	4.078 *	0.187	-3.11	-0.251
34	P_5 X P_9	E_1	-1.288	-1.768	-0.46	11.232	9.408	1.889	0.291	-5.585	-0.127
		E_2	0.386	0.583	0.179	16.856 *	7.89	2.283	0.124	-8.410 **	0.582
		E_3	1.318	0.985	0.136	4.52	-4.32	0.912	0.107	-6.685 *	0.379
35	P_5 X P_{10}	E_1	-0.482	-0.629	-0.098	4.143	-1.427	2.881	-0.206	3.788	-0.686
		E_2	0.803	0.611	-0.182	-11.377	-7.071	4.894	-0.191	2.059	0.138
		E_3	1.568	1.596	-0.058	8.537	3.303	3.606 *	-0.24	0.516	0.335
36	P_6 X P_7	E_1	-1.427	-1.073	0.263	3.05	5.39	2.867	0.523	4.738	-0.624
		E_2	-0.641	-0.806	-0.182	-11.894	1.264	-1.967	0.292	4.541	-0.116
		E_3	0.846	-0.432	-0.253	-0.091	-6.057	-4.144 *	0.263	0.989	0.392
37	P_6 X P_8	E_1	2.212 *	2.149 *	-0.098	-1.411	3.931	1.464	0.384	-2.689	0.998
		E_2	0.47	0.222	-0.237	-25.827 **	-18.546 **	-2.828	0.092	-2.047	-0.334

S.No	Hybrids	Env.	Days to 50% tasselling	Days to 50% Silking	ASI	Plant height	Ear height	Tassel length	LAI	Chlorophyll content	CTD
		E_3	1.457	1.29	-0.058	-8.163	-2.061	8.412 ***	-0.222	-2.513	-0.316
38	P_6 X P_9	E_1	0.684	0.288	-0.46	-0.031	3.337	0.961	0.008	5.613	0.814
		E_2	0.859	0.806	-0.071	-13.005	-2.379	-4.078	0.228	5.921 *	0.785
		E_3	0.818	0.54	0.386	-7.98	-1.644	0.912	0.207	4.909	0.134
39	P_6 X P_{10}	E_1	-1.51	-1.24	0.235	3.153	4.205	-3.307	0.117	5.339	-0.044
		E_2	-0.725	-0.5	0.235	0.095	-5.006	0.533	-0.08	4.421	0.74
		E_3	2.068 *	2.152 *	0.192	0.37	-2.354	1.939	-0.129	4.863	0.081
40	P_7 X P_8	E_1	-0.927	-0.934	-0.043	8.251	7.226	1.223	-0.223	-0.671	-0.488
		E_2	-1.697 *	-1.083	0.596 *	-26.455 **	-8.333	-1.939	0.014	-0.911	0.838
		E_3	-1.793 *	-0.737	0.886 **	1.876	2.124	1.717	0.066	-1.41	-0.353
41	P_7 X P_9	E_1	0.212	-0.129	-0.404	-3.593	0.399	0.344	0.121	-4.449	-0.772
		E_2	-0.641	-0.833	-0.237	0.034	3.835	2.811	0.294	-4.813	-0.743
		E_3	1.568	0.846	-0.336	10.726 *	-3.792	1.884	0.306	-5.135	-0.373
42	P_7 X P_{10}	E_1	-2.316 *	-1.990 *	0.29	1.081	-1.526	0.126	-0.186	-0.306	-0.263
		E_2	-0.225	-0.139	0.068	-1.199	-0.126	3.088	0.012	-1.34	-0.655
		E_3	1.152	1.457	0.136	7.409	4.164	4.578 **	-0.004	-0.644	-0.083
43	P_8 X P_9	E_1	0.184	-0.24	-0.432	12.72	-0.473	4.861 *	0.129	0.857	-0.616
		E_2	0.136	-0.139	-0.293	19.434 *	11.025	3.949	0.194	0.1	-0.362
		E_3	1.513	1.235	0.192	-14.346 **	-9.129 *	1.773	0.19	-0.083	-0.487
44	P_8 X P_{10}	E_1	-0.677	-0.768	-0.071	-0.143	0.335	-1.664	-0.268	2.853	0.826
		E_2	-1.114	-1.111	0.013	5.201	-13.936 *	5.227 *	0.052	2.003	-0.873
		E_3	1.096	0.846	-0.336	5.337	-0.507	-1.199	0.08	1.804	-0.464
45	P_9 X P_{10}	E_1	-0.205	-0.295	-0.098	6.274	2.887	1.24	-0.061	-4.955	0.242
		E_2	2.609 ***	2.806 ***	0.179	-10.311	-5.435	0.311	-0.458	-2.216	-0.754
		E_3	2.457 **	1.763	-0.225	10.854 *	-4.756	1.967	-0.473 *	-2.604	-1.017 *
	Sij <> 0 at 95%	E_1	1.849	1.853	0.462	14.763	11.322	4.217	0.552	6.551	1.308
	Sij--Sik at 95%		2.718	2.724	0.678	21.701	16.642	6.199	0.811	9.63	1.923
	Sij--Skl at 95%		2.591	2.597	0.647	20.691	15.868	5.91	0.774	9.182	1.834
	Sij <> 0 at 95%	E_2	1.483	1.322	0.557	16.562	12.738	4.998	0.477	5.363	1.071
	Sij--Sik at 95%		2.179	1.944	0.818	24.345	18.724	7.346	0.701	7.883	1.574
	Sij--Skl at 95%		2.078	1.853	0.78	23.212	17.852	7.004	0.668	7.516	1.501
	Sij <> 0 at 95%	E_3	1.598	2.094	0.524	10.529	8.516	3.426	0.448	5.322	0.884
	Sij--Sik at 95%		2.349	3.077	0.77	15.477	12.518	5.035	0.658	7.824	1.299
	Sij--Skl at 95%		2.24	2.934	0.734	14.757	11.936	4.801	0.628	7.46	1.239

*Significant levels: * = <.05, ** = <.01 & *** = <.001*

ASI: Anthesis-silking interval; LAI: Leaf area index; CTD: Canopy temperature deficit

Table 6 (continue). Specific combining ability (SCA) effects for different characters in maize over three environments

S.No	Hybrids	Env.	Ear length	Ear girth	Number of grain rows per cob	Number of grains per row	Seed index	Seed yield per plant	Days to maturity	oil content (%)	Starch content (%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(12)	
1	P_1 X P_2	E_1	-0.372	0.717	-0.566	-2.801	0.801	3.642	-1.409 **	-0.674 ***	2.488 ***
		E_2	0.965	0.112	-1.902	2.22	0.219	-1.167	-0.293	-0.602 ***	3.037 ***
		E_3	2.518 **	-0.291	-1.242	-4.045 *	0.072	-2.748	1.798 *	-0.566 ***	1.690 ***
2	P_1 X P_3	E_1	1.341	0.77	1.101	2.449	-0.667	-2.067	-0.742	0.122	-0.072
		E_2	2.816 *	0.718	-0.096	4.525 *	1.387	12.985	0.568	0.148 ***	0.497 **
		E_3	3.254 ***	0.373	0.119	-1.823	0.568	-2.123	1.687 *	0.187 ***	0.41
3	P_1 X P_4	E_1	0.204	-0.269	-1.399	-3.551	3.416 ***	-11.792	1.730 **	0.856 ***	2.071 ***
		E_2	-0.131	-0.979	-1.513	2.47	0.949	8.428	0.152	0.383 ***	1.997 ***
		E_3	-0.092	-0.961 *	-0.965	-2.24	-0.528	-6.143	0.659	0.367 ***	1.553 ***
4	P_1X P_5	E_1	-0.887	-1.021 *	0.712	-1.078	0.996	-44.082 *	-3.270 ***	-0.740 ***	-0.426
		E_2	-0.792	-0.348	0.46	-2.114	0.917	3.798	-1.265	-0.732 ***	1.010 ***
		E_3	-2.981 ***	-0.035	-0.076	-3.045	1.795 *	-3.579	-1.23	-0.773 ***	0.851 **
5	P_1 X P_6	E_1	0.322	0.641	0.99	0.838	1.964 *	-2.27	-4.576 ***	0.11	5.376 ***
		E_2	-0.744	-0.011	1.71	-1.475	-0.998	-18.98	-4.210 ***	0.118 ***	5.693 ***
		E_3	-0.898	-0.278	0.341	1.399	-0.272	-7.279	-2.174 **	0.044 *	5.718 ***
6	P_1 X P_7	E_1	-1.138	-0.827	-1.121	-2.134	-0.654	-13.696	-4.826 ***	0.157 *	-4.377 ***
		E_2	0.113	0.245	-0.124	-1.058	-0.639	17.747	-4.571 ***	0.191 ***	-5.107 ***
		E_3	0.957	0.089	0.646	0.621	-0.253	-4.438	-2.230 **	0.202 ***	-5.215 ***
7	P_1 X P_8	E_1	1.376	1.131 *	1.879	1.838	-1.486	18.694	0.813	-0.258 ***	7.506 ***
		E_2	3.663 **	1.259 *	2.071	3.553 *	-1.600 *	26.887 *	2.679 ***	-0.158 ***	8.751 ***
		E_3	2.016 **	0.544	0.841	-0.462	-1.423	-2.725	3.465 ***	-0.202 ***	9.054 ***
8	P_1 X P_9	E_1	1.062	0.149	-0.621	1.672	-3.023 **	3.07	2.008 ***	-0.117	-3.961 ***
		E_2	-0.594	0.536	1.765	-1.725	-1.406	-54.056 ***	1.985 **	0.008	-5.649 ***
		E_3	-1.106	0.017	1.258	0.038	-1.686 *	-15.783 *	1.659 *	0.023	-5.230 ***
9	P_1 X P_{10}	E_1	3.145 **	0.484	-0.288	4.088 *	1.945 *	21.322	3.535 ***	-0.242 **	-6.441 ***
		E_2	2.777 *	0.692	0.932	1.997	0.802	29.686 *	1.763 *	-0.298 ***	-7.512 ***
		E_3	-0.337	-0.078	0.674	0.982	-0.614	12.992 *	1.104	-0.315 ***	-7.110***
10	P_2 X P_3	E_1	1.505	0.581	-0.455	0.311	-1.12	3.069	-1.854 ***	0.862 ***	7.891 ***
		E_2	1.855	1.648 **	-0.346	0.275	-1.012	25.415	0.346	0.745 ***	8.395 ***
		E_3	0.065	0.427	-0.326	1.51	0.903	-2.025	3.187 ***	0.765 ***	9.065 ***
11	P_2 X P_4	E_1	0.702	-0.448	-0.955	-0.023	0.89	-15.674	2.619 ***	-0.707 ***	-2.437 ***
		E_2	-0.792	-0.973	0.237	-2.78	0.35	-21.942	1.596 *	-0.516 ***	-1.342 ***
		E_3	-2.229 **	-0.318	-1.409 *	-0.24	0.073	-19.361 **	1.159	-0.499 ***	-1.899 ***
12	P_2X P_5	E_1	-2.256 *	-1.133 *	-0.177	-0.217	1.11	-35.33	-0.381	0.680 ***	-2.206 ***
		E_2	-2.386	-1.398 **	-0.124	-3.03	-0.835	-14.506	0.513	0.762 ***	-2.818 ***
		E_3	-2.498 **	-1.331 ***	0.813	-0.379	-1.824 *	-16.314 *	-0.063	0.805 ***	-2.584 ***
13	P_2 X P_6	E_1	0.92	-0.278	-0.566	0.699	-2.002 *	2.215	-0.354	-0.400 ***	-2.994 ***
		E_2	0.862	-0.361	-1.207	0.275	-1.897 *	-4.7	0.902	-0.298 ***	-2.358 ***
		E_3	-1.151	-0.731 *	-0.104	2.066	-4.131 ***	-7.404	0.992	-0.234 ***	-2.720 ***
14	P_2 X P_7	E_1	0.76	0.255	1.323	3.727	0.793	15.123	-0.937	0.853 ***	-2.438 ***
		E_2	-2.381	0.141	-0.374	-4.975 **	-0.372	-22.423	-0.126	0.751 ***	-3.399 ***
		E_3	-2.736 ***	-0.66	0.202	-3.379 *	-1.875 *	-2.616	-0.396	0.737 ***	-2.677 ***
15	P_2 X P_8	E_1	2.107 *	-0.291	-0.343	2.033	1.437	12.379	1.035 *	1.189 ***	-2.417 ***
		E_2	2.502 *	0.833	1.487	-0.364	1.035	-4.65	0.79	0.829 ***	-1.997 ***
		E_3	0.516	-0.755 *	0.396	0.871	-0.741	-1.277	-0.369	0.787 ***	-1.748 ***
16	P_2 X P_9	E_1	0.293	0.627	1.823	2.199	0.404	-4.185	0.563	-0.810 ***	-1.059 *
		E_2	0.479	-0.138	2.848 *	1.692	-1.572 *	11.208	1.429 *	-0.855 ***	-2.084 ***
		E_3	0.808	0.337	0.146	-2.962	-2.051 *	6.099	0.492	-0.836 ***	-1.975 ***
17	P_2 X P_{10}	E_1	-2.290 *	-0.825	0.157	-3.384	1.925 *	-7.96	1.758 **	-0.472 ***	-4.154 ***
		E_2	-0.384	-0.768	2.348 *	1.414	1.670 *	2.373	1.207	-0.377 ***	-5.377 ***
		E_3	0.117	0.256	0.896	-0.684	1.720 *	-10.149	1.937 *	-0.450 ***	-4.995 ***
18	P_3 X P_4	E_1	0.015	-0.678	0.045	0.894	2.168 *	-30.049	3.952 ***	-0.088	-1.293 *
		E_2	0.692	-0.43	0.043	0.525	-0.389	-12.89	2.457 ***	0.007	-2.081 ***

S.No	Hybrids	Env.	Ear length	Ear girth	Number of grain rows per cob	Number of grains per row	Seed index	Seed yield per plant	Days to maturity	oil content (%)	Starch content (%)
		E_3	-2.652 ***	-0.454	-0.715	0.649	0.396	-5.94	3.715 ***	0.027	-3.108 ***
19	P_3X P_5	E_1	1.991 *	0.327	-0.51	2.033	-1.759	15.852	4.619 ***	-0.594 ***	-2.070 ***
		E_2	2.231	-0.279	0.682	-0.725	-1.268	0.747	1.04	-0.665 ***	-3.014 ***
		E_3	2.035 **	-0.408	-0.492	-2.157	-1.791 *	5.86	0.826	-0.686 ***	-3.677 ***
20	P_3 X P_6	E_1	0	0.036	-0.899	-1.717	3.519 ***	23.077	3.980 ***	0.202 **	6.916 ***
		E_2	-0.554	0.701	1.932	-3.086	4.038 ***	-2.748	1.763 *	0.172 ***	7.079 ***
		E_3	2.202 **	1.050 **	2.591 ***	-0.712	0.962	-2.326	0.881	0.165 ***	7.023 ***
21	P_3 X P_7	E_1	-0.993	0.598	-0.343	-1.689	0.018	17.118	-0.604	-0.371 ***	-2.845 ***
		E_2	2.136	-0.073	0.098	3.997 *	-0.437	8.262	1.402 *	-0.399 ***	-2.869 ***
		E_3	3.313 ***	0.627	0.23	-1.823	-3.519 ***	7.155	2.492 **	-0.401 ***	-2.453 ***
22	P_3 X P_8	E_1	1.387	1.289 **	-0.01	-0.717	-0.265	24.897	2.035 ***	1.172 ***	-4.431 ***
		E_2	1.352	0.949	0.293	-1.391	0.202	23.102	-1.015	1.179 ***	-4.280 ***
		E_3	1.199	0.809 *	-0.242	1.093	6.221 ***	8.971	-1.48	1.109 ***	-5.727 ***
23	P_3 X P_9	E_1	1.007	0.35	1.49	3.116	-0.168	27.92	-2.104 ***	-0.244 **	-3.552 ***
		E_2	-0.704	0.071	-1.346	-0.336	-1.17	-14.507	-2.043 **	-0.199 ***	-3.547 ***
		E_3	-0.076	0.768 *	0.174	2.927	-0.555	-6.18	-1.952 *	-0.143 ***	-2.628 ***
24	P_3 X P_{10}	E_1	0.09	0.262	1.157	-0.467	0.94	-1.968	-3.576 ***	0.174 *	0.682
		E_2	-1.367	0.408	1.154	0.386	-0.596	-7.108	-2.265 **	0.163 ***	1.123 ***
		E_3	0.77	0.326	-0.742	1.538	-1.317	-0.038	0.492	0.145 ***	1.516 ***
25	P_4X P_5	E_1	-0.012	0.218	-1.01	4.366 *	1.891 *	28.263	-1.576 **	1.323 ***	-3.897 ***
		E_2	-0.382	-0.386	-1.402	2.22	0.761	-6.078	-1.376 *	1.251 ***	-4.401 ***
		E_3	0.582	-0.499	-0.909	-1.573	1.042	-1.182	0.798	1.251 ***	-4.328 ***
26	P_4 X P_6	E_1	-1.037	0.226	-0.066	-3.051	-0.797	2.744	-1.215 *	-0.271 ***	5.775 ***
		E_2	-0.768	0.671	0.515	-1.808	-0.433	-15.339	-1.654 *	-0.206 ***	7.042 ***
		E_3	1.019	0.855 *	0.174	0.871	2.335 **	-9.409	-1.146	-0.189 ***	6.653 ***
27	P_4 X P_7	E_1	2.970 **	0.045	0.49	3.644	2.255 *	13.319	0.202	-0.107	1.271 *
		E_2	0.856	-0.303	-0.652	1.275	2.658 ***	-0.462	-0.015	-0.037	1.298 ***
		E_3	1.083	-0.088	-0.187	-0.24	2.258 **	-8.548	1.465	-0.107 ***	1.796 ***
28	P_4 X P_8	E_1	0.25	0.533	0.157	1.283	2.519 **	44.898 *	-0.159	-0.618 ***	-3.855 ***
		E_2	-0.028	0.112	0.876	1.886	1.198	6.478	1.568 *	-0.546 ***	-2.497 ***
		E_3	1.206	0.417	0.008	0.343	1.458	7.685	2.826 ***	-0.528 ***	-3.265 ***
29	P_4 X P_9	E_1	0.47	0.184	0.99	3.449	-0.447	39.481	1.702 **	0.929 ***	5.938 ***
		E_2	0.349	-0.102	0.571	-0.725	-1.608 *	6.435	2.207 **	0.910 ***	4.069 ***
		E_3	1.027	-0.343	-0.242	1.51	1.215	-12.039	2.020 *	0.927 ***	4.651 ***
30	P_4 X P_{10}	E_1	-0.613	-0.638	-1.343	1.199	-1.587	14.893	0.563	-0.249 **	1.362 **
		E_2	1.687	0.664	0.071	3.997 *	1.233	12.667	2.318 **	-0.359 ***	0.813 ***
		E_3	2.596 ***	-0.728	-0.159	-0.212	0.886	7.403	1.798 *	-0.355 ***	0.678 **
31	P_5 X P_6	E_1	1.205	0.365	-0.621	5.422 **	-0.641	40.698	2.785 ***	-0.353 ***	1.825 ***
		E_2	2.172	0.219	1.154	3.275	-1.852 *	20.264	1.263	-0.381 ***	1.499 ***
		E_3	2.276 **	0.082	-0.27	-0.601	1.605	-7.755	1.965 *	-0.415 ***	1.941 ***
32	P_5 X P_7	E_1	-0.355	0.04	0.601	0.783	-0.976	46.633 *	0.535	0.667 ***	-0.688
		E_2	0.028	0.128	0.654	2.025	-0.26	22.808	1.568 *	0.698 ***	-0.235
		E_3	0.181	-0.428	-1.298	4.621 **	-1.106	6.149	-0.091	0.733 ***	-0.275
33	P_5 X P_8	E_1	-0.374	0.595	0.934	-1.912	2.132 *	18.292	1.174 *	-0.997 ***	-5.318 ***
		E_2	0.578	0.166	-2.485 *	1.97	0.312	11.848	1.485 *	-0.838 ***	-4.770 ***
		E_3	1.570 *	0.800 *	-0.437	-1.129	-2.272 **	3.882	2.270 **	-0.831 ***	-5.630 ***
34	P_5 X P_9	E_1	0.512	0.223	0.434	-0.412	-0.085	28.271	-2.631 ***	0.547 ***	5.754 ***
		E_2	0.488	-0.128	-0.79	2.359	0.706	11.205	-0.876	0.435 ***	5.166 ***
		E_3	0.791	-0.417	-0.02	2.705	-1.682 *	13.258 *	1.131	0.440 ***	5.643 ***
35	P_5 X P_{10}	E_1	-0.553	0.101	0.005	-1.564	14.923	1.230 *	-0.024	4.472 ***	-0.553
		E_2	-0.958	-0.358	0.71	0.747	-2.486 **	-24.93	0.568	0.780 ***	4.766 ***
		E_3	-0.289	-0.919 *	0.063	-0.351	-0.111	-9.567	2.576 **	0.779 ***	4.873 ***
36	P_6 X P_7	E_1	-0.412	0.405	0.212	-2.967	-0.397	-8.589	-3.770 ***	0.223 **	-0.513
		E_2	-0.424	0.185	-0.096	0.331	-1.088	11.347	-2.043 **	0.215 ***	-0.062
		E_3	-0.989	-0.047	-0.881	-4.268 *	1.854 *	-8.164	-1.035	0.177 ***	-0.122
37	P_6 X P_8	E_1	0.935	-0.07	1.212	0.338	1.017	-16	-7.465 ***	0.249 **	-6.326 ***
		E_2	-0.374	-1.077 *	-0.568	-0.725	-4.315 ***	-15.48	-5.793 ***	0.206 ***	-5.907 ***

S.No	Hybrids	Env.	Ear length	Ear girth	Number of grain rows per cob	Number of grains per row	Seed index	Seed yield per plant	Days to maturity	oil content (%)	Starch content (%)
		E_3	-2.433 **	-0.619	-0.354	-7.018 ***	-4.613 ***	-9.135	-3.674 ***	0.193 ***	-6.356 ***
38	P_6 X P_9	E_1	0.688	-0.209	-1.288	0.838	2.694 **	-5.81	4.396 ***	0.313 ***	-2.564 ***
		E_2	1.203	0.032	1.126	4.664 *	1.945 *	6.344	2.513 ***	0.139 ***	-3.967 ***
		E_3	-0.212	-0.27	-0.937	-5.184 **	-0.023	-5.012	3.520 ***	0.168 ***	-3.217 ***
39	P_6 X P_{10}	E_1	0.371	1.592***	1.712	2.922	-1.039	1.062	1.924 ***	0.354 ***	4.324 ***
		E_2	-0.593	0.402	-1.374	-0.614	3.320 ***	-1.447	2.624 ***	0.370 ***	3.753 ***
		E_3	-0.142	0.345	-0.854	-4.240 *	2.316 **	-5.904	2.631 **	0.413 ***	3.860 ***
40	P_7 X P_8	E_1	0.408	-0.541	-0.899	1.033	0.325	-4.825	4.619 ***	0.273 ***	9.194 ***
		E_2	-1.184	-0.891	0.265	0.692	2.176 **	-23.237	0.846	0.328 ***	9.242 ***
		E_3	-2.029 **	-0.595	0.285	-0.462	2.410 **	-5.28	1.27	0.308 ***	8.481 ***
41	P_7 X P_9	E_1	1.328	1.217 **	0.066	4.866 *	2.559 **	10.044	-1.187 *	-0.543 ***	-2.874 ***
		E_2	1.56	1.312 *	0.626	3.747 *	1.237	15.521	-1.515 *	-0.672 ***	-3.265 ***
		E_3	0.193	0.544	0.035	2.295	0.967	7.325	-0.202	-0.654 ***	-3.163 ***
42	P_7 X P_{10}	E_1	-0.289	0.065	-0.399	0.616	1.043	-4.231	3.341 ***	0.281 ***	3.017 ***
		E_2	0.164	0.368	-0.54	-0.864	0.245	-9.947	1.929 **	0.285 ***	2.915 ***
		E_3	-0.404	0.359	-0.548	-1.351	1.438	-1.796	1.576	0.321 ***	2.750 ***
43	P_8 X P_9	E_1	-2.358 *	-0.316	-2.399 *	-8.162 ***	2.000 *	-40.023	1.452 **	0.272 ***	5.540 ***
		E_2	0.276	0.936	0.154	-2.308	-0.524	11.394	-0.265	0.285 ***	5.417 ***
		E_3	1.415	0.116	0.23	-3.712 *	0.3	2.828	0.826	0.248 ***	5.686 ***
44	P_8 X P_{10}	E_1	0.892	0.499	0.601	-0.412	2.481 **	-4.575	-0.687	0.387 ***	4.684 ***
		E_2	-1.186	0.126	-0.346	-1.919	-0.716	-9.907	0.179	0.096 **	-0.746 ***
		E_3	0.151	-0.069	-0.354	-3.101	-1.295	-3.98	1.604 *	0.320 ***	4.713 ***
45	P_9 X P_{10}	E_1	-1.322	0.584	-1.232	-0.912	2.734 **	-15.172	-4.159 ***	-0.266 ***	-4.000 ***
		E_2	-0.943	-0.011	-0.652	-0.864	-0.955	-6.916	-3.515 ***	0.146 ***	4.600 ***
		E_3	-1.961 *	0.004	-0.604	0.732	2.195 *	-7.271	-2.202 **	-0.038 *	-1.308 ***
	Sij <> 0 at 95%	E_1	1.852	0.897	1.887	3.977	1.771	41.044	1.033	0.146	0.969
	Sij--Sik at 95%		2.723	1.319	2.773	5.845	2.604	60.332	1.518	0.215	1.425
	Sij--Skl at 95%		2.596	1.258	2.644	5.573	2.483	57.525	1.447	0.205	1.359
	Sij <> 0 at 95%	E_2	2.494	0.999	2.26	3.501	1.476	26.221	1.374	0.067	0.324
	Sij--Sik at 95%		3.666	1.468	3.322	5.146	2.169	38.543	2.019	0.099	0.476
	Sij--Skl at 95%		3.496	1.4	3.168	4.906	2.068	36.749	1.925	0.094	0.454
	Sij <> 0 at 95%	E_3	1.482	0.73	1.313	3.289	1.671	12.98	1.597	0.036	0.5
	Sij--Sik at 95%		2.178	1.073	1.93	4.834	2.456	19.08	2.347	0.052	0.735
	Sij--Skl at 95%		2.077	1.023	1.84	4.609	2.342	18.192	2.238	0.05	0.7

*Significant levels: * = <.05, ** = <.01 & *** = <.001*

ASI: Anthesis-silking interval; LAI: Leaf area index; CTD: Canopy temperature deficit

Table 7. Stability parameters for yield and related traits in maize across three environments

Sl. no	crosses	Days to 50% tasseling			Days to 50% silking			Plant height			Days to maturity			Ear length			Ear girth			Number of grain rows per cob			Number of grains per row		
		mean	bi	S^2di	mean	Bi	S^2Di	mean	Bi	S^2Di	mean	Bi	S^2Di	mean	Bi	S^2Di	mean	Bi	S^2Di	mean	Bi	S^2Di	mean	Bi	S^2Di
1	**P1 X P2**	51.00	0.88	-0.414	53.11	0.85	-0.74	144.80	1.15	-59.60	82.11	1.76	1.06	18.19	0.36	-0.67	14.62	2.70	-0.24	12.67	0.77	0.77	28.00	1.29	14.53
2	**P1 X P3**	51.66	0.95	-0.676	53.67	0.94	-0.77	160.10	1.43	7.44	82.00	2.04	6.49	19.44	-2.50	0.62	14.01	1.41	-0.20	13.56	1.00	-0.00	30.33	1.48	8.62
3	**P1 X P4**	51.77	1.00	-0.678	53.89	1.03	-0.77	167.60	1.17	33.82	82.78	1.35	-0.50	17.73	1.59	-1.22	13.02	1.59	-0.18	12.44	0.54	-1.06	28.56	0.93	36.01
4	**P1 X P5**	52.00	1.15	-0.827	54.44	1.05	-0.77	159.70	1.02	41.76	80.11	1.52	8.96	16.71	3.92	0.79	13.55	0.43	-0.13	13.78	1.31	-0.72	27.33	1.18	-3.02
5	**P1 X P6**	52.22	1.18*	-0.86	54.33	1.14	-0.48	160.30	0.96	-62.65	79.22	2.09	0.94	16.68	4.28	-1.19	13.40	2.36	0.00	14.44	2.15	-1.03	30.89	1.22	-3.83
6	**P1 X P7**	52.11	1.20	-0.432	53.78	1.32	-0.94	160.70	0.75	-62.81	78.22	2.09	0.94	17.60	-0.88	-0.24	13.34	0.61	0.54	13.11	-0.23	-0.82	28.22	0.69	1.84
7	**P1 X P8**	53.33	0.89	-0.671	55.67	0.80	-0.48	184.10	1.52	455.28	86.00	1.73	3.39	19.22	1.07	6.30	14.34	2.41	-0.13	14.67	1.62	-1.04	31.22	1.51	12.60
8	**P1 X P9**	52.89	0.91	1.031	54.89	0.89	-0.77	160.50	0.94	4.23	84.22	1.14	0.28	16.89	4.95	-1.23	13.75	1.89	0.00	14.67	0.92	0.73	27.22	1.13	-3.98
9	**P1 X P10**	51.22	0.97	-0.786	53.33	0.94	1.03	165.10	2.06	-61.27	84.22	0.85	1.60	18.89	6.93	-0.45	13.95	2.40	-0.01	14.33	1.23	-1.04	29.44	1.28	-2.76
10	**P2 X P3**	51.67	1.15	0.644	53.78	1.18	0.35	145.80	1.82	-58.00	81.33	2.10	4.28	18.28	5.17	-1.08	15.34	1.50	0.62	13.11	0.61	-0.26	29.67	0.43	1.69
11	**P2 X P4**	50.33	1.36	0.138	52.67	1.27	0.35	152.00	0.89	550.25	83.00	0.39	1.67	17.12	8.02	-0.32	14.24	0.46	-0.13	13.33	1.77	1.97	29.00	0.64	8.99
12	**P2 X P5**	50.56	1.45	-0.579	52.89	1.36	-0.95	141.70	0.91	-59.82	81.33	0.53	-0.24	16.04	3.07	-1.25	13.79	1.48	-0.15	13.89	-0.07	-0.55	28.56	0.72	12.08
13	**P2 X P6**	50.44	1.13*	-0.86	52.78	1.12	-0.79	140.80	0.86	-58.10	82.67	0.80	-0.54	17.49	8.52	-1.24	13.88	1.89	-0.19	13.11	0.54	-1.06	32.00	1.09	2.84
14	**P2 X P7**	49.22	1.52	-0.268	51.56	1.43	0.95	150.10	1.57	-26.41	80.89	0.52	-0.35	16.33	9.33	2.72	14.48	2.42	-0.23	14.00	0.77	-0.77	27.89	1.65	42.74
15	**P2 X P8**	50.78	1.23*	-0.86	53.44	1.32	-0.95	160.30	1.41	-37.04	83.44	0.14	2.11	18.74	6.52	-0.42	14.36	2.61	0.72	13.89	0.85	3.16 *	30.78	1.04	3.15
16	**P2 X P9**	50.89	1.18	0.999	53.67	1.14	1.77	143.60	1.59	-52.98	82.44	0.34	-0.54	17.79	3.49	-1.21	14.85	1.45	-0.02	15.78	3.08	0.27	27.89	1.73	-3.21
17	**P2 X P10**	50.56	1.18*	-0.86	53.00	1.27	-0.95	135.70	1.66	-62.45	83.00	0.82	2.44	16.33	0.19	-1.10	14.20	-0.01	-0.25	15.33	1.77	1.97	26.56	0.62	0.39
18	**P3 X P4**	52.67	1.43	3.385	54.89	1.36	1.78	146.10	1.09	11.52	84.00	1.59	-0.54	17.07	3.84	-0.36	13.24	-0.03	-0.20	13.11	1.38	-0.93	29.78	0.63	-3.60
19	**P3 X P5**	52.44	1.81	-0.706	54.67	1.81	-0.93	156.90	1.54	981.35	82.89	0.85	1.60	20.33	-1.85	-1.10	13.90	1.32	0.03	12.89	1.15	0.34	28.56	1.21	1.00
20	**P3 X P6**	49.11	1.61	-0.262	52.44	2.12	0.33	142.30	1.04	115.23	83.78	0.72	1.81	17.65	-3.52	0.43	13.88	-0.48	-0.23	14.22	-0.38	2.64	28.22	0.97	1.13
21	**P3 X P7**	51.67	1.70*	-0.768	53.78	1.65	-1.00	155.10	1.90	442.27	81.89	1.76	4.50	19.09	-6.10	0.56	13.90	0.15	-0.03	12.89	0.30	0.86	28.67	1.13	13.06
22	**P3 X P8**	50.56	1.45	-0.579	53.11	1.38	-0.14	162.90	1.80	47.25	82.22	0.75	4.53	18.17	-0.61	-1.02	14.39	1.21	-0.22	12.67	0.84	-0.90	28.67	0.53	-3.42
23	**P3 X P9**	50.33	1.36	2.913	52.89	1.43	2.49	143.50	2.25	-59.27	79.00	1.26	0.42	17.16	0.90	-0.09	13.92	-0.01	-0.20	13.56	0.92	2.81	28.56	0.68	5.50
24	**P3 X P10**	50.11	1.47	2.069	52.33	1.41	3.42	134.80	1.11	-38.36	79.00	2.37	2.09	16.84	-2.75	1.33	13.92	0.69	-0.20	14.00	2.81	-0.83	27.00	0.40	-4.12
25	**P4X P5**	51.33	1.29	-0.437	53.44	1.25	-0.76	156.50	2.13	-46.02	80.44	1.91	2.01	19.07	-1.99	-1.00	14.17	1.39	0.05	12.44	0.54	-1.06	31.56	1.64	-3.47
26	**P4 X P6**	51.22	0.91	-0.675	53.33	0.87	-0.49	135.40	1.17	-37.32	80.67	1.22	-0.47	17.60	-1.92	-0.46	14.24	0.04	-0.25	13.78	1.38	-0.93	29.78	0.77	-4.15
27	**P4 X P7**	51.67	0.95	-0.676	54.22	1.03	-1.00	144.90	1.59	27.37	81.78	1.50	-0.52	20.00	3.44	1.32	13.77	0.62	-0.20	13.33	0.77	-0.77	31.11	1.45	-3.52
28	**P4 X P8**	52.11	0.86	-0.673	54.11	0.85	-0.77	151.30	1.61	-62.80	84.22	1.67	1.58	18.09	-1.61	-1.18	14.09	0.77	-0.16	13.56	1.18	-0.34	31.22	1.14	-2.55
29	**P4 X P9**	51.44	1.06	-0.424	53.56	1.03	-0.09	152.20	1.71	-62.40	83.44	1.02	0.16	18.46	-0.25	-1.00	13.80	1.37	-0.23	14.44	2.15	-1.03	29.11	1.04	3.15
30	**P4 X P10**	51.78	1.13	-0.061	53.78	1.12	-0.09	124.50	1.19	-51.79	82.78	1.02	0.16	18.99	-4.57	-1.03	13.72	1.54	0.98	13.56	1.15	-0.34	29.22	1.15	4.66
31	**P5 X P6**	51.78	1.61*	-0.834	53.78	1.59	-0.94	145.00	1.51	-42.22	84.11	1.19	-0.26	20.28	-0.88	-1.12	14.14	1.45	0.07	13.33	1.69	-0.41	33.56	2.24	-2.27
32	**P5 X P7**	51.11	1.06	-0.297	53.11	1.05	-0.52	151.80	1.46	-45.52	82.00	0.47	0.47	18.84	-0.61	-1.19	14.05	1.74	-0.25	13.11	2.15	-1.03	31.78	0.50	-4.06
33	**P5 X P8**	51.22	1.38*	-0.831	53.56	1.43	-0.76	159.60	1.50	-57.26	84.56	1.35	0.08	18.73	-3.72	-0.41	14.52	0.79	0.07	12.22	0.07	4.56 *	29.44	1.12	5.90
34	**P5 X P9**	51.00	1.22	-0.589	53.22	1.23	-0.52	159.60	1.38	-61.68	80.78	1.95	7.54	18.97	-0.63	-1.25	14.04	1.94	-0.11	13.56	1.00	-0.00	29.00	0.67	-2.00
35	**P5 X P10**	51.11	1.27	0.13	53.11	1.25	-0.14	147.20	0.58	47.13	82.78	1.72	-0.54	18.02	-0.21	-0.19	13.61	1.85	-0.24	14.00	1.62	-1.08	27.44	0.97	-3.46
36	**P6 X P7**	50.11	1.33	0.663	51.89	1.16	-0.14	140.10	0.46	172.58	79.89	1.51	0.72	17.14	3.43	-1.15	13.58	1.54	-0.11	12.89	1.85	-0.66	28.22	1.90	2.59
37	**P6 X P8**	52.89	0.97	0.431	55.00	1.00	0.42	133.90	0.58	452.06	78.11	1.97	0.77	16.38	6.75	-1.24	12.67	1.51	0.73	13.00	1.50	1.32	28.56	2.64	-3.88
38	**P6 X P9**	51.22	0.91	-0.675	53.44	0.98	-0.77	131.50	0.79	267.90	85.89	1.22	1.02	17.79	3.88	-1.17	13.26	1.41	-0.24	13.33	2.54	0.38	28.78	2.65	9.27
39	**P6 X P10**	50.00	1.43	-0.274	52.33	1.41	-0.53	137.80	0.60	52.96	84.56	1.10	-0.43	17.03	1.91	0.39	14.26	2.36	0.66	13.56	2.46	8.28 **	27.89	2.32	-1.85
40	**P7 X P8**	49.67	0.88	-0.414	52.44	0.98	-1.00	146.90	0.54	658.55	85.22	0.71	11.68	16.57	4.63	-1.14	12.81	1.08	-0.19	12.67	0.07	-0.18	29.89	1.41	-3.46
41	**P7 X P9**	50.44	1.13	1.005	52.44	1.12	1.04	147.60	0.63	-56.59	80.67	1.38	-0.53	18.76	3.75	-1.14	14.66	2.10	-0.21	13.78	1.38	-0.93	29.22	2.23	-3.54
42	**P7 X P10**	49.22	1.31	1.297	51.56	1.30	0.95	145.70	0.52	-16.69	83.67	0.66	3.71	17.48	1.36	-1.26	13.97	0.90	-0.16	13.11	1.31	-0.72	26.44	1.25	-4.16
43	**P8 X P9**	51.67	0.95	1.025	53.89	1.03	1.04	153.70	1.84	-18.93	83.89	1.22	1.02	16.76	-4.60	1.34	13.74	1.36	0.58	12.67	0.15	2.46	22.89	0.76	15.78
44	**P8 X P10**	50.44	1.13	-0.061	52.56	1.09	-0.48	149.30	0.83	-54.29	83.33	1.59	-0.54	16.86	0.51	0.53	13.75	1.96	-0.23	13.33	1.54	0.09	25.67	1.37	-4.06
45	**P9 X P10**	47.22	0.976	-0.303	53.44	0.92	-0.52	140.90	0.53	321.12	78.33	1.54	-0.38	15.72	1.92	-1.23	13.91	1.84	-0.17	13.33	1.62	-1.04	24.78	0.75	-4.04
46	**HQPM**	50.66	0.956	1.03	52.67	0.936	1.033	153.2	0.414	30.33	79.33	-0.55	11.66	20.69	-11.74	-1.00	16.11	-3.59	0.91	14.22	-0.46	-0.09	28.44	0.46	14.49

Table 7 (continue). Stability parameters for yield and related traits in maize across three environments

Sl. no	crosses	Seed index			Seed yield per plant			CTD			Chlorophyll content			LAI			Oil content			Starch content		
		mean	bi	S^2di	mean	Bi	S^2Di	mean	Bi	S^2Di	mean	Bi	S^2Di	mean	Bi	S^2Di	mean	Bi	S^2Di	mean	Bi	S^2Di
1	**P1 X P2**	26.38	-6.52	-0.15	101.10	0.51	-136.25	2.63	1.22	0.51	44.76	2.11	-10.22	3.05	-3.25	0.02	3.49	0.08	-0.002	65.47	-0.71	0.96
2	**P1 X P3**	26.58	-2.41	-0.68	102.60	0.58	240.05	1.44	-0.78	0.49	41.19	2.41	-10.07	2.65	-2.06	-0.05	4.08	0.24	-0.002	67.53	-5.15	-0.08
3	**P1 X P4**	26.44	-9.00	4.17	104.40	0.33	297.94	2.06	-0.98	1.80	42.15	2.54	-7.83	2.84	-0.38	-0.08	4.48	12.03	-0.003	67.52	-0.06	-0.04
4	**P1 X P5**	26.94	0.25	-0.72	90.70	-0.35	480.01	1.68	1.96	-0.14	42.10	1.71	-10.12	2.66	0.08	-0.09	3.49	2.10	-0.001	66.23	-8.86	-0.13
5	**P1 X P6**	25.36	-4.15	3.77	94.00	1.05	-281.09	1.72	1.34	-0.58	42.82	1.18	-9.74	2.36	0.14	-0.08	3.77	2.21	0.003	72.40	-0.30	-0.13
6	**P1 X P7**	25.20	-2.07	-0.74	101.40	0.21	766.44	1.71	-0.69	0.03	47.71	1.90	-8.79	2.52	2.30	-0.09	4.13	0.70	-0.003	58.81	6.10	-0.03
7	**P1 X P8**	24.46	-0.56	-0.54	112.80	1.09	497.74	1.38	-0.81	-0.40	43.81	1.74	-9.37	2.81	4.12	0.00	3.73	0.73	-0.001	74.96	-7.02	0.31
8	**P1 X P9**	23.37	1.23	-0.23	75.30	1.17	666.45	1.44	-0.10	-0.55	42.18	0.10	-9.83	2.86	3.05	-0.06	4.10	-1.38	-0.002	61.98	7.78	0.03
9	**P1 X P10**	26.34	-7.84	1.14	117.40	0.55	81.85	1.90	2.50	-0.55	42.80	0.36	-9.17	2.77	4.13	-0.02	3.45	1.93	-0.002	59.62	5.07	-0.11
10	**P2 X P3**	26.02	3.16	-0.43	113.40	1.01	190.21	1.64	-1.73	0.23	49.75	2.41	-8.94	3.02	3.86	-0.06	5.16	2.77	-0.001	72.10	-4.71	0.12
11	**P2 X P4**	25.89	-0.92	-0.56	93.40	0.97	-275.25	1.62	2.62	-0.62	44.54	0.41	-9.94	2.61	4.13	-0.03	3.82	-2.19	-0.003	60.17	-5.90	-0.13
12	**P2 X P5**	25.47	-7.42	-0.40	88.10	0.68	-246.71	1.71	2.20	0.06	47.49	0.49	-10.03	2.65	2.98	-0.08	5.43	-0.85	-0.002	59.62	4.83	-0.13
13	**P2 X P6**	22.73	-6.12	-0.14	105.00	1.45	-282.01	1.37	-0.48	-0.63	48.82	1.01	-10.25	2.52	2.22	-0.09	3.82	-1.73	-0.001	60.52	-0.25	-0.11
14	**P2 X P7**	25.51	-8.57	-0.77	103.10	1.51	156.83	2.09	1.52	-0.63	39.77	1.39	-8.78	2.76	0.67	-0.08	5.18	3.17	-0.003	57.28	7.47	0.07
15	**P2 X P8**	26.82	-5.64	-0.76	105.50	1.19	-252.02	1.44	2.07	-0.15	46.27	0.17	-9.80	2.74	2.36	-0.08	5.32	9.37	-0.003	60.88	-0.31	0.23
16	**P2 X P9**	24.62	-4.70	0.05	106.80	0.37	-248.97	2.45	2.37	-0.03	40.99	-0.36	-9.94	2.89	-0.82	-0.06	3.74	1.42	-0.002	61.62	5.50	0.01
17	**P2 X P10**	27.69	-0.86	-0.67	95.70	0.64	-208.85	2.30	3.26	-0.61	47.46	1.64	-10.24	2.58	1.21	-0.08	3.75	-1.02	-0.001	58.20	7.45	-0.08
18	**P3 X P4**	26.31	-0.14	5.71	94.60	0.37	-280.27	1.68	0.13	-0.60	45.68	1.40	-10.19	2.20	-0.15	-0.09	4.20	-1.02	-0.003	64.08	4.83	0.73
19	**P3 X P5**	24.51	-0.36	-0.73	116.10	1.99	-119.91	2.34	0.51	-0.43	47.47	0.88	-10.12	2.99	1.01	-0.09	3.85	2.19	-0.003	63.42	6.48	0.74
20	**P3 X P6**	28.38	-6.50	-0.52	112.80	2.31	-159.45	2.10	2.34	-0.45	48.30	0.68	-10.22	2.32	3.20	-0.05	4.13	0.98	-0.003	74.40	0.14	-0.10
21	**P3 X P7**	24.82	-10.56	-0.76	115.70	1.51	-268.87	1.87	0.29	-0.40	45.89	0.56	-10.11	2.37	3.74	-0.05	3.83	0.82	-0.002	61.58	0.00	-0.08
22	**P3 X P8**	28.43	19.91	-0.18	120.80	1.55	-252.75	1.64	1.73	-0.26	44.54	0.05	-10.04	2.40	0.53	0.02	5.36	1.59	-0.001	62.30	2.36	0.82
23	**P3 X P9**	25.20	1.56	0.33	103.30	2.21	284.42	1.71	0.49	-0.61	44.32	-0.10	-10.05	2.68	1.61	-0.07	4.20	-1.52	-0.001	64.27	-4.55	-0.04
24	**P3 X P10**	25.73	-4.09	2.22	96.40	0.87	-210.59	2.41	1.25	-0.64	46.39	2.31	-10.19	2.36	-0.93	-0.07	4.16	-0.24	-0.003	68.33	-5.21	0.01
25	**P4X P5**	26.37	2.52	-0.43	123.40	2.58	117.65	2.25	2.43	-0.27	41.72	1.28	-10.03	2.76	0.63	-0.08	5.80	3.19	-0.003	60.53	2.74	-0.12
26	**P4 X P6**	24.93	13.67	-0.79	107.30	1.82	-157.55	2.17	1.77	-0.55	43.78	2.24	-10.08	2.61	0.75	-0.09	3.75	0.01	-0.003	72.28	-5.91	-0.10
27	**P4 X P7**	27.54	2.24	-0.64	114.10	1.84	-275.05	2.44	1.00	1.11	47.70	0.34	-9.45	2.77	1.04	-0.08	4.16	0.80	0.01	64.16	-0.10	0.27
28	**P4 X P8**	27.12	3.40	0.23	129.30	2.24	-51.60	2.00	2.80	-0.51	47.24	1.00	-10.24	2.62	2.01	-0.08	3.67	0.52	-0.003	62.31	-6.15	-0.10
29	**P4 X P9**	24.57	11.15	0.45	120.00	2.68	-207.03	1.13	0.83	-0.47	49.12	0.91	-10.22	2.88	0.29	-0.08	5.34	1.41	-0.003	70.80	8.32	-0.13
30	**P4 X P10**	25.25	8.29	0.96	118.90	1.10	-277.21	1.66	0.34	0.95	46.91	1.31	-9.75	2.16	-0.41	-0.07	3.70	2.70	-0.003	66.58	2.39	-0.12
31	**P5 X P6**	24.80	10.94	-0.67	130.10	3.43	-282.07	1.40	0.78	-0.62	48.75	0.86	-10.27	2.68	0.20	-0.04	3.88	1.85	-0.002	67.65	4.03	-0.07
32	**P5 X P7**	24.90	-0.39	0.96	135.70	2.92	-250.28	1.83	2.89	-0.62	46.51	0.29	-10.24	2.91	1.71	-0.08	5.23	-0.14	-0.002	62.40	-0.55	-0.13
33	**P5 X P8**	25.99	-7.67	-0.68	118.70	1.93	-274.87	1.80	2.47	-0.29	42.28	0.17	-10.22	2.84	0.24	-0.08	3.63	-1.68	-0.003	60.38	0.46	-0.01
34	**P5 X P9**	25.03	-2.39	1.20	124.00	1.97	-44.72	2.20	1.90	-0.38	37.64	-0.37	-6.30	2.93	1.84	-0.08	5.18	2.82	-0.003	71.54	1.67	-0.12
35	**P5 X P10**	24.22	7.58	-0.29	98.50	2.19	524.72	1.81	0.39	-0.02	47.20	3.66	-8.20	2.50	0.99	-0.09	5.11	1.10	-0.003	70.43	-2.10	-0.08
36	**P6 X P7**	25.23	9.32	-0.79	106.80	1.35	-59.77	1.88	-1.43	-0.54	49.26	6.00	-9.96	2.87	3.15	-0.06	4.18	1.21	-0.002	63.62	1.28	-0.12
37	**P6 X P8**	22.72	-6.10	7.51	92.00	1.06	-271.67	2.03	2.93	1.34	42.38	1.53	-10.13	2.59	5.38	-0.08	4.18	2.36	-0.003	60.47	2.33	-0.13
38	**P6 X P9**	26.35	-2.71	-0.68	103.10	1.22	-260.37	2.50	3.83	-0.54	49.15	1.90	-10.13	2.71	0.39	-0.08	4.36	3.57	-0.003	63.82	8.15	-0.12
39	**P6 X P10**	26.56	8.48	8.46	101.10	1.37	-275.86	2.14	3.19	-0.46	49.08	1.64	-10.06	2.49	2.92	-0.07	4.14	-1.04	-0.002	70.76	5.18	-0.11
40	**P7 X P8**	27.58	6.08	1.90	92.50	1.07	-64.96	2.12	4.33	-0.50	45.31	1.82	-9.94	2.52	-0.32	-0.07	4.53	0.41	-0.003	72.55	4.75	-0.06
41	**P7 X P9**	26.98	-1.09	-0.71	113.70	1.08	-280.09	1.50	-0.52	-0.63	40.38	1.25	-10.13	2.86	-0.05	-0.08	3.80	2.72	-0.002	60.88	2.38	-0.08
42	**P7 X P10**	26.52	3.31	-0.45	95.90	0.81	-205.34	1.76	-0.88	-0.57	44.95	1.22	-9.53	2.52	-0.03	-0.08	4.32	-0.79	-0.001	66.59	2.19	-0.13
43	**P8 X P9**	26.24	2.28	1.11	91.00	-0.59	71.81	1.56	2.16	-0.62	44.43	0.80	-10.01	2.79	0.84	-0.08	4.67	1.21	-0.002	72.34	0.53	-0.08
44	**P8 X P10**	26.02	-3.82	3.78	92.00	0.74	-232.85	1.84	1.88	1.57	46.90	1.67	-9.87	2.53	-0.81	-0.07	4.28	3.78	0.029	69.39	26.18	12.96
45	**P9 X P10**	26.64	6.15	7.02	87.50	0.47	-269.18	1.51	3.29	0.11	40.28	-0.33	-5.16	2.30	3.19	-0.06	4.15	-6.76	0.019	66.67	-46.32	9.21
46	**HQPM**	26.88	-8.82	-0.71	124.10	0.17	-256.62	2.20	2.80	-0.58	44.92	-0.14	-5.65	2.34	-1.70	-0.04	4.02	4.45	0.001	63.83	27.32	0.84

According to the physiological characteristics, canopy temperature and leaf area index deficit play a key role in heat stress tolerance in that hybrid $P_{6\ X}\ P_8$ demonstrated their adaptability under favourable conditions and depicted low canopy temperature depression and hybrid $P_{1\ X}\ P_2$, $P_{1\ X}\ P_3$, $P_{1\ X}\ P_4$, $P_{1\ X}\ P_5$, $P_{1\ X}\ P_6$, $P_{1\ X}\ P_8$, $P_{2\ X}\ P_3$, $P_{3\ X}\ P_{10}$ demonstrated their adaptability under favourable conditions and depicted high chlorophyll content. Furthermore, hybrids $P_{1\ X}\ P_5$, $P_{1\ X}\ P_6$, $P_{2\ X}\ P_7$, $P_{4\ X}\ P_5$, $P_{4\ X}\ P_6$, $P_{5\ X}\ P_6$, $P_{5\ X}\ P_8$, $P_{6\ X}\ P_9$ demonstrated non-significant (s^2di) and regression coefficients less than unity (βi<1), with mean values higher than the population mean, indicating its adaptability under unfavourable environments for high leaf area index. In quality criteria such as oil content and starch content, three hybrids demonstrated non-significant deviation from regression (s^2di), indicating consistent behaviour. $P_{1\ X}\ P_7$, $P_{1\ X}\ P_8$, and $P_{3\ X}\ P_6$ hybrids with mean values greater than the population mean, demonstrating adaptability in unfavourable conditions for high oil content. Out of 45 hybrids, 31 showed non-significant deviation from regression (s^2di), indicating stable behaviour, whereas 14 showed substantial divergence from regression (s^2di), indicating unstable behaviour. $P_{3\ X}\ P_6$, $P_{5\ X}\ P_8$, and $P_{8\ X}\ P_9$ hybrids demonstrated adaptation under unfavourable conditions for higher starch content, although hybrid $P_{6\ X}\ P_9$ showed non-significant deviation from and regression coefficient greater than than unity (βi >1), indicating adaptation in favourable circumstances and a high starch percentage.

4. CONCLUSIONS

The study found that three hybrids, $P_{5\ X}\ P_6$, $P_{5\ X}\ P_7$, and $P_{4\ X}\ P_5$, performed best in terms of QPM grain production due to strong standard heterosis, high specific combining ability, and high general combining ability of female parents. According to three different environments in E_1, E_2, and E_3, were $P_{1\ X}\ P_6$, $P_{2\ X}\ P_4$, $P_{2\ X}\ P_6$, $P_{2\ X}\ P_8$, $P_{3\ X}\ P_5$, $P_{4\ X}\ P_5$, $P_{4\ X}\ P_7$, $P_{4\ X}\ P_{10}$, $P_{5\ X}\ P_6$, $P_{5\ X}\ P_7$, $P_{6\ X}\ P_8$, $P_{7\ X}\ P_8$, $P_{7\ X}\ P_9$, regression coefficient near to unity (βi ≈1) and non-significant deviation from regression (s^2di). This demonstrates its adaptability to all conditions. They must pass additional observation tests in a variety of environmental situations before being released.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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