



Combining ability of yellow maize (*Zea mays*) inbred lines for yield and agronomic traits

MOHAMMAD R ISMAIL^{1*}, HANY A A MOHAMED¹, MOHAMED A A ABD-ELAZIZ¹
and HESHAM A ABOYOUSEF¹

Field Crops Research Institute, Agricultural Research Centre, Giza 12619, Egypt

Received: 23 June 2023; Accepted: 29 November 2023

ABSTRACT

Present study was carried out during 2021 and 2022 at Field Crops Research Institute, Agricultural Research Centre, Giza, Egypt to estimate combining ability effects of newly developed 8 yellow maize (*Zea mays* L.) inbred lines using diallel cross fashion. The 28 maize hybrids were obtained by half diallel crosses at Ismailia Research Station in 2021 and evaluated at 3 locations, viz. Ismailia, Sids and Sakha Research stations in 2022 for yield and agronomic traits. Experimental results revealed that crosses mean square was significant for all the studied traits. Similarly, general and specific combining ability were significant for all the traits. Parental line P8 considered to be an excellent combiner for all traits studied except for, number of days to 50% silking and number of rows characters. The hybrid $P_5 \times P_8$ possessed desirable SCA effects for a great number of studied traits. Besides, it recorded the highest mean value for grain yield (12.55 t/ha) plus lowest ear position. As result, this cross $P_5 \times P_8$ could be recommended for releasing after extensive evaluation.

Keywords: Combining ability, Diallel cross, GCA, Gene action, Maize, SCA

Maize (*Zea mays* L.) is a versatile multipurpose crop. In the world, maize (dry grain) is mostly used for feed (56% of production), a fifth for non-food applications, and 13% for food. Although maize is largely used for animal feed worldwide, it is still a significant food crop in Latin America and sub-Saharan Africa and has number of non-food purposes as well (Erenstein *et al.* 2022). Maize is cultivated on an estimated 197 million hectares (FAOStat 2021). In Egypt, maize is used for both human and livestock. Additionally, it is employed in industries. But nearly 60% of Egypt's needs are met by imports. In view of this, Egypt should tapering the gap between production and consumption. Thereby, Egypt would be protected from changes in global prices. The expansion of corn cultivation is a challenging due to limited arable land and water resources. Therefore, genetic improvement would be the only way to increase productivity. Information on the combining abilities of parents and crosses is crucial for developing desirable hybrids (Kage *et al.* 2013). Vieira *et al.* (2009) stated that both general and specific combining abilities are important in assessing whether hybrid traits have improved or declined. Diallel cross analysis had been suggested by (Griffing 1956) to determine the combining ability of parents.

However, diallel is still being widely used by plant breeder (Chinthiya *et al.* 2019, Ismail *et al.* 2019a and b, Patel *et al.* 2019, Rana *et al.* 2020, Patel 2022, Seledes *et al.* 2022, Shaaban *et al.* 2022, Kamal *et al.* 2023 and Nadeem *et al.* 2023). Diallel cross analysis is a useful method to acquire information about genetic factors impacting several plant characteristics in one generation. Hence the present study was carried out a) to assess the effect of GCA and SCA and their interaction with locations and b) to find certain cross combinations with desired traits and highly yielding for realizing.

MATERIALS AND METHODS

An experiment was conducted during 2021 and 2022 at Field Crops Research Institute, Agricultural Research Centre, Giza, Egypt. Eight yellow maize inbred lines (developed by the Maize Research Department, Agricultural Research Centre, Egypt) were chosen based on genetic diversity and flowering synchronization for experiment. A half diallel were adopted to make all the crosses between the 8 inbred lines i.e. Mall 5031, Mall 5020, SK-3, SK-2020, Nub-645, Sd-15/2013, Sd-3/2015 and GZ-658 by hand pollination at Ismailia Research Station in 2021. The resulting 28 F_1 's along with one commercial check SC-168 were evaluated in RCBD with 3 replications at 3 locations, viz. Ismailia, Sids and Sakha Research stations in 2022. Each entry was sown in two rows of 6 m long. Plants were spaced 25 cm

¹Field Crops Research Institute, Agricultural Research Centre, Giza, Egypt. *Corresponding author email: Breeder82@live.com

apart and rows were 70 cm apart. After the proper thinning, one plant was kept per hill. To guarantee healthy plant standing in all entries, all required agronomic practises were adopted. The data were recorded on, days number to silk emergence (DTS), Plant height (PH), Ear height (EH), Ear length (EL), Ear diameter (ED), rows number per ear (NRE), number of kernels per row (NKR). Grain yield was estimated and adjusted at 15.5% kernel moisture, and then adjusted to t/ha. In accordance with Steel and Torrie (1980) analysis of variance (ANOVA) was performed on the recorded data. Bartlett test was employed to test error variance homogeneity among locations for all traits. The method of Griffing (1956), method 2 model I was used to analyse both general and specific combining abilities.

RESULTS AND DISCUSSION

Results showed that location mean square were significantly different at $P \leq 0.01$ for all traits except number of rows per ear (NRE) and number of kernel per row (NKR), reflecting that the locations differed in their climate and soil condition (Table 1). Crosses variance for all studied traits was highly significant which reflect the divergence among the inbred lines for all traits studied. Similar trends have been reported by Karim *et al.* (2022) and Kamal *et al.* (2023). The crosses and locations interaction were highly significant for every studied trait, revealed that those crosses vary in performance depending on the location. Both GCA and SCA mean square were highly significant for all studied traits. Thus, both additive and non-additive gene action had role in controlling these traits. Kage *et al.* (2013), Ismail *et al.* (2019a and b) and Karim *et al.* (2022) also reported similar findings for almost all the traits. Mean squares of GCA and SCA interactions with location were significant at 1% probability level reflected that both

additive and non-additive gene action were impacted by location. GCA/SCA ratios were greater than unity for all assessed traits, with the exception of NRE and NKR traits, showing that additive gene effects predominated for all traits. Same findings have been reported by Ismail *et al.* (2019a) and Karim *et al.* (2022). The GCA/SCA ratio was less than the unity for NRE and NKR traits, revealed that non-additive is more important in inheritance of these traits. Chozin *et al.* (2017), Chinthiya *et al.* (2019) and Revilla *et al.* (2021) also found the ratio of GCA and SCA less than unity for maturity traits in maize. $GCA \times L/GCA$ ratio was higher than $SCA \times L/SCA$ ratio for DTS, NRE and NKR, representing that the additive gene effects influenced with locations rather than the non-additive gene effects. On the contrary for the rest traits $SCA \times L/SCA$ ratio was higher than $GCA \times L/GCA$, showing that the non-additive gene effects changeable more by locations.

General combining ability: The estimates of general combining ability effects of parents are given in Table 2. The parental line P_1 obtained significant favourable GCA effects for 50% silking, ear height and grain yield traits. Consequently, it is considered as a good combiner for these characteristics. In terms of days to 50% silking, plant height and ear length attributes, P_2 was a good combiner. The paternal inbred line P_3 was simultaneously considered as an excellent combiner and possessed the desirable significant GCA for the traits of plant and ear heights, ear length, ear diameter and number of kernels per row. The parental lines P_4 , P_6 , and P_7 showed undesirable GCA effects for all the traits. For creating short-statured hybrids with high yields, the parental line P_5 appeared to be an effective combiner since it showed the significant favourable GCA effects for plant height, ear heights and grain yield. P_8 parental inbred line possessed significant

Table 1 Analysis of ordinary and combining ability mean squares for the tested characters across 3 locations

Trait	df	Mean squares							
		DTS	PH	EH	EL	ED	NRE	NKR	GY
Loc. (L)	2	883.29**	92891.47**	64556.99**	106.90**	9.69**	4.46ns	5.03ns	158.63**
Rep/L	6	5.99	149.98	50.05	2.08	0.05	2.05	21.34	0.73
Crosses (C)	28	7.90**	883.23**	591.30**	5.81**	0.085**	1.25**	14.30**	4.08**
C×L	56	3.37**	132.52*	128.12**	3.25**	0.090**	0.77**	6.46**	1.29**
Error	168	1.75	95.42	51.64	0.73	0.03	0.33	2.95	0.44
GCA	7	1.14**	249.45**	199.73**	1.83**	0.013**	0.11**	1.36**	1.20**
SCA	20	0.80**	49.83**	21.08**	0.20**	0.009**	0.14**	1.74**	0.20**
GCA×L	14	3.26**	313.40**	297.54**	3.55**	0.05**	0.34**	4.46**	1.65**
SCA×L	40	1.61**	85.33**	45.03**	1.01**	0.035**	0.42**	3.65**	0.62**
Error	162	1.74	98.13	51.94	0.73	0.03	0.33	2.97	0.45
GCA/SCA		1.41	5.00	9.47	9.02	1.54	0.76	0.78	5.96
GCA×L/GCA		2.86	1.25	1.49	1.94	3.84	3.09	3.28	1.37
SCA×L/SCA		2.01	1.71	2.13	5.05	3.88	3.00	2.09	3.10
CV		2.05	3.98	5.60	4.21	3.82	3.87	4.04	8.65

* and ** are significant at 5% and 1%, respectively. Traits details are given under Materials and Methods.

Table 2 Estimates of GCA effects of the parental lines over the 3 locations for all the studied traits

Trait Parent	DTS (Days)	PH (cm)	EH (cm)	EL (cm)	ED (cm)	NRE	NKR	GY (t/ha)
P ₁	-0.60**	3.06*	-1.90*	-0.03	0.03	0.07	-0.30	0.45**
P ₂	-0.52**	-4.38**	-1.05	0.26*	-0.05*	-0.05	0.07	-0.48**
P ₃	0.37*	-2.68*	-3.81**	0.24*	0.05*	-0.29**	0.53*	0.01
P ₄	0.05	-0.46	2.08*	-0.48**	-0.04	0.01	-0.58**	-0.18*
P ₅	0.16	-5.16**	-6.42**	0.25*	-0.01	0.00	0.07	0.38**
P ₆	-0.32	10.34**	11.69**	-0.73**	0.02	0.08	0.19	-0.35**
P ₇	0.25	7.43**	3.67**	-0.48**	-0.07**	0.01	-0.64**	-0.49**
P ₈	0.61**	-8.14**	-4.25**	0.98**	0.05*	0.18*	0.65**	0.66**
LSD gi 5%	0.33	2.51	1.83	0.22	0.05	0.15	0.44	0.17
LSD gi 1%	0.43	3.25	2.37	0.28	0.06	0.19	0.57	0.22

* and ** are significant at 5% and 1%, respectively. Traits details are given under Materials and Methods.

desirable GCA effects for all traits, except for days to 50% silking and number of rows per ear. In addition, it ranked the first good combiner for plant height, ear length, ear diameter, number of kernel per row and grain yield traits. These parents with desirable GCA for particular trait could be utilised in future breeding programme to increase maize yield with a desired trait

Mean performance: The mean performance of the 28 studied crosses plus the hybrid check SC-168 for the studied traits is given in Table 3. Days to 50% silking ranged from 62.5 days for the hybrid P₁×P₂ to 65.8 days for the two hybrids P₃×P₅ and P₇×P₈. The 6 crosses, viz. P₁×P₂, P₁×P₆, P₁×P₅, P₂×P₆, P₆×P₇ and P₂×P₇ were significantly earlier compared to the check hybrid SC-168 at 1% probability. While the two hybrids P₄×P₈ and P₃×P₄ showed significant at 5% probability for the same trait. Regarding plant and ear heights, the two crosses P₁×P₈ and P₂×P₈ obtained significantly short stature and low ear placement as compared to check hybrid. Thus, these two hybrids would be considered as short stature hybrids to decrease lodging and to be used in increasing plant density for hectare. Contrarily, the 3 hybrids, viz. P₆×P₇ (277.4 cm), P₁×P₆ (264.2 cm) and P₄×P₆ (259.5 cm) were the tallest hybrids. Thus, they could be used for silage purpose. The cross P₅×P₈ performed better as compared to check hybrid SC-168 for ear length trait. Three crosses, viz. P₅×P₈, P₃×P₄ and P₁×P₈ significantly recorded the highest values for ear diameter trait. Out of 28 crosses, 8 crosses significantly performed better as compared to check hybrid SC-168 for number of row per ear trait. However, the highest value was recorded with cross P₁×P₇ (15.8 row). The cross P₅×P₆ (44.9) followed by P₃×P₈ (44.8) significantly outperformed the check hybrid SC-168 for number of kernel per row trait. With regarding to grain yield per hectare, cross i.e. P₅×P₈ recorded significantly higher grain yield as compared to check hybrid SC-168. Whereas, non-significant results were obtained with 8 crosses of maize, viz. P₁×P₄, P₁×P₅, P₁×P₇, P₁×P₈, P₃×P₅, P₃×P₈, P₄×P₈ and P₇×P₈. These crosses showed increase of one or more of yield components traits. The

highest mean value for grain yield (12.5 t/ha) was recorded with cross P₅×P₈. Additionally, it provided significant values for the traits, viz. ear height, length, diameter and number of rows per ear.

Specific combining ability: The SCA of 28 crosses effects for various character are given in Table 3. Eight crosses out of 28 had substantial negative SCA effects for days taken to 50% silking. The most favourable SCA combination for this trait attained with P₄×P₈ (-1.3**) followed by P₁×P₅ (-1.0**). The crosses P₁×P₈, P₄×P₇ and P₅×P₆ recorded negative significant effect of SCA for both plant and ear heights. Therefore, these hybrids are recommended to be exploited in short-statured hybrids programme. Regarding ear length character, 3 crosses, viz. P₄×P₇, P₅×P₈ and P₆×P₇ expressed significant beneficial SCA effects. The best hybrid combination for ear diameter trait was P₅×P₈ (0.19**) followed by P₃×P₄ (0.13**) and P₂×P₆ (0.12*). Regarding number of row per ear, 3 crosses (P₁×P₇, P₅×P₈ and P₆×P₇) performed significant favourable SCA effects. Five crosses, viz. P₁×P₈, P₃×P₈, P₄×P₇, P₅×P₆ and P₆×P₇ showed significant favourable effects for number of kernel per row trait. The parental combination, viz. P₁×P₇, P₂×P₆, P₃×P₅ and P₅×P₈ showed the best significant desired SCA effects for grain yield trait. It is worthy noted that these crosses additionally exhibited the highest mean grain yield values as compared to check hybrid SC-168.

The cross P₅×P₈ possessed favourable SCA effects for most the studied characters. Besides, it had significantly outyielded the check hybrid SC-168. The cross P₅×P₈ revealed that both parents had combiner for grain yield trait. Thereby, in order to get high yield, GCA of the parental lines is crucial. Similar findings were observed by Xingming *et al.* (2002). Vasal (1998) additionally recommended using a good combiner (particularly a female parent) during crossing to increase heterosis. Its concluded that parents P₅ and P₈ considered to be a good combiner for grain yield, plant height and ear height. Therefore, they could be used as donor for combining high yielding with short stature trait. The cross P₅×P₈ possessed the favour SCA effects for the

Table 3 Combined mean performance of crosses along with the check hybrid and specific combining ability effects across 3 locations for the studied season 2022

Trait	Mean performance						Trait	Specific combining ability effects											
	Cross	DTS	PH	EH	EL	ED		NRE	NKR	GY	Cross	DTS	PH	EH	EL	ED	NRE	NKR	GY
		(Days)	(cm)	(cm)	(cm)	(cm)				(t/ha)		(Days)	(cm)	(cm)	(cm)	(cm)	(cm)		
P ₁ ×P ₂		62.5	239.6	123.8	20.3	4.5	14.7	42.0	10.5	P ₁ ×P ₂	-0.7*	-7.5**	-1.7	-0.25	-0.08	-0.30	-0.36	-0.28	
P ₁ ×P ₃		64.1	256.1	128.6	20.3	4.8	14.8	42.1	11.0	P ₁ ×P ₃	-0.1	7.2**	5.7**	-0.24	0.06	0.03	-0.68	-0.22	
P ₁ ×P ₄		64.6	256.8	131.3	19.9	4.6	15.2	42.6	11.4	P ₁ ×P ₄	0.7*	5.8*	2.5	0.11	-0.09	0.18	0.89	0.28	
P ₁ ×P ₅		63.0	255.3	124.2	20.7	4.6	15.2	42.4	11.5	P ₁ ×P ₅	-1.0**	8.9**	3.9	0.18	-0.03	0.14	0.09	-0.09	
P ₁ ×P ₆		62.7	264.2	135.6	19.6	4.7	14.5	40.8	10.9	P ₁ ×P ₆	-0.7*	2.3	-2.7	0.07	0.00	-0.6**	-1.6**	0.01	
P ₁ ×P ₇		65.1	257.8	129.8	19.6	4.7	15.8	42.3	11.5	P ₁ ×P ₇	1.0**	-1.09	-0.4	-0.21	0.08	0.7**	0.66	0.72**	
P ₁ ×P ₈		65.3	227.6	115.1	21.6	4.8	15.1	44.0	11.5	P ₁ ×P ₈	0.8*	-15.7**	-7.3**	0.34	0.07	-0.17	1.03*	-0.42*	
P ₂ ×P ₃		64.5	246.2	126.0	20.7	4.7	14.8	43.4	10.5	P ₂ ×P ₃	0.2	4.8	2.26	-0.05	0.04	0.11	0.22	0.15	
P ₂ ×P ₄		65.2	248.0	130.0	20.0	4.5	15.2	41.2	9.9	P ₂ ×P ₄	1.2**	4.3	0.37	-0.03	-0.09	0.30	-0.85	-0.21	
P ₂ ×P ₅		64.1	240.6	125.6	20.9	4.6	14.9	42.9	10.9	P ₂ ×P ₅	0.02	1.7	4.5*	0.05	0.03	0.00	0.14	0.24	
P ₂ ×P ₆		63.0	251.5	138.2	19.9	4.7	15.1	43.1	10.7	P ₂ ×P ₆	-0.6	-2.8	-1.02	0.06	0.12*	0.05	0.23	0.79**	
P ₂ ×P ₇		63.5	252.1	126.0	20.5	4.6	14.8	42.2	9.64	P ₂ ×P ₇	-0.6	0.58	-5.2*	0.42	0.07	-0.14	0.20	-0.22	
P ₂ ×P ₈		65.0	234.8	124.1	21.3	4.6	15.1	43.7	10.5	P ₂ ×P ₈	0.47	-1.07	0.82	-0.19	-0.08	-0.03	0.42	-0.47*	
P ₃ ×P ₄		63.8	245.5	123.2	20.2	4.8	14.6	43.4	10.7	P ₃ ×P ₄	-0.9**	0.21	-3.6	0.19	0.1**	-0.10	0.90	0.07	
P ₃ ×P ₅		65.8	238.6	116.6	20.7	4.5	14.4	43.3	11.5	P ₃ ×P ₅	0.9*	-1.9	-1.7	-0.07	-0.1**	-0.25	0.14	0.37*	
P ₃ ×P ₆		65.3	250.2	134.1	19.8	4.7	15.0	43.3	10.7	P ₃ ×P ₆	0.8*	-5.9*	-2.3	0.01	-0.04	0.18	0.02	0.21	
P ₃ ×P ₇		64.1	245.2	126.8	19.9	4.6	14.6	40.8	9.7	P ₃ ×P ₇	-0.9**	-8.0**	-1.5	-0.21	0.00	-0.12	-1.6**	-0.5**	
P ₃ ×P ₈		65.4	241.3	121.7	21.9	4.7	15.0	44.8	11.5	P ₃ ×P ₈	0.02	3.6	1.2	0.38	-0.01	0.15	1.05*	0.00	
P ₄ ×P ₅		64.3	240.1	124.1	19.6	4.6	14.8	41.0	10.9	P ₄ ×P ₅	-0.3	-2.7	-0.15	-0.4*	0.04	-0.23	-1.07*	-0.10	
P ₄ ×P ₆		64.6	259.5	146.7	19.1	4.7	14.6	41.0	10.3	P ₄ ×P ₆	0.49	1.19	4.4*	0.00	0.04	-0.4**	-1.19*	0.06	
P ₄ ×P ₇		64.8	247.6	128.5	19.9	4.6	15.1	43.5	9.9	P ₄ ×P ₇	0.13	-7.7**	-5.7**	0.52*	0.02	0.07	2.16**	-0.20	
P ₄ ×P ₈		63.7	238.8	128.6	20.5	4.6	15.4	41.8	11.4	P ₄ ×P ₈	-1.3**	-1.0	2.24	-0.31	-0.04	0.21	-0.84	0.09	
P ₅ ×P ₆		64.8	246.2	125.2	19.7	4.6	15.1	44.9	9.8	P ₅ ×P ₆	0.6	-7.4**	-8.6**	-0.12	-0.04	0.00	2.07**	-0.9**	
P ₅ ×P ₇		65.6	247.7	128.3	19.5	4.6	14.9	39.9	10.6	P ₅ ×P ₇	0.8*	-2.9	2.48	-0.6*	-0.02	-0.10	-2.1**	-0.11	
P ₅ ×P ₈		64.2	239.6	117.4	22.6	4.9	15.6	44.1	12.5	P ₅ ×P ₈	-0.9**	4.4	-0.48	1.04**	0.19**	0.44**	0.75	0.68**	
P ₆ ×P ₇		63.4	277.4	152.6	19.8	4.6	15.6	44.0	10.0	P ₆ ×P ₇	-0.9*	11.1**	8.7**	0.6**	-0.04	0.48**	1.83**	0.09	
P ₆ ×P ₈		65.1	252.2	137.6	19.9	4.7	15.6	42.1	10.9	P ₆ ×P ₈	0.38	1.54	1.63	-0.6**	-0.03	0.31	-1.3**	-0.17	
P ₇ ×P ₈		65.8	255.8	129.8	20.2	4.5	14.3	41.5	11.2	P ₇ ×P ₈	0.58	8.1**	1.87	-0.58*	-0.10*	-0.9**	-1.08*	0.29	
SC-168		65.2	246.1	133.1	21.4	4.6	14.5	42.7	11.2										
LSD,		1.2	9.29	6.76	0.80	0.17	0.55	1.62	0.63	LSD Sij	0.74	5.55	4.04	0.48	0.10	0.33	0.97	0.37	
0.05									5%										
LSD,		1.6	12.04	8.77	1.04	0.22	0.71	2.10	0.81	LSD	0.96	7.20	5.24	0.62	0.13	0.42	1.25	0.49	
0.01									Sij1%										

* and ** are significant at 5% and 1%, respectively. Traits details are given under Materials and Methods.

majority of the studied characteristics. Moreover, it also significantly outyielded the check hybrid SC-168. Therefore, the findings suggest that maize research programme could release this hybrid after additional evaluation.

REFERENCES

- Chinthiya A, Ganesan K N, Ravikesavan R and Senthil N. 2019. Combining ability and association studies on different yield contributing traits for enhanced green cob yield in sweet corn (*Zea mays* con var. saccharata). *Electronic Journal of Plant Breeding* **10**(2): 500–11.
- Chozin M, Sudjattmiko S, Setyowati H, Fahrurrozi F and Mukhtar Z. 2017. Analysis of traits association in sweet corn inbred lines as grown under organic crop management. *SABRAO Journal of Breeding and Genetics* **49**(4): 361–67.
- Erenstein O, Jaleta M, Sonder K, Mottaleb K and Prasanna B. 2022. Global maize production, consumption and trade: Trends and R and D implications. *Food Security* **14**(5): 1295–1319.
- FAOStat. 2021. FAO Stat. FAO, Rome, <http://www.fao.org/faostat>
- Griffing B. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. *Australian Journal of Biological Sciences* **9**(4): 463–93.
- Ismail M R, El-Hosary A A, El-Badawy M El M and Abdallah T A. 2019a. Diallel analysis for yield and component traits in maize (*Zea mays*) under infestation and non-infestation with pink stem borer (*Sesamia cretica*). *The Indian Journal of Agricultural Sciences* **89**(11):1953–58.
- Ismail M R, El-Hosary A A, El-Badawy M El M and Abdallah T A. 2019b. Combining ability studies on resistance to pink stem borer (*Sesamia cretica*) in new yellow maize (*Zea mays*) hybrids. *Electronic Journal of Plant Breeding* **10**(4): 1376–82.
- Kage U, Lohithaswa H, Shekara B and Shobha D. 2013. Combining ability studies in maize (*Zea mays* L.). *Molecular Plant Breeding* **4**(14): 116–27.
- Kamal N, Khanum S, Siddique M, Saeed M, Ahmed M F, Kalyar M T A, Rehman S U and Mahmood B. 2023. Heterosis and combining ability studies in a 5×5 diallel crosses of maize inbred lines. *Journal of Applied Research in Plant Sciences* **4**(1): 419–24.
- Karim A, Ahmed S, Talukder Z A, Alam M K and Billah M M. 2022. Combining ability and heterosis study for grain yield and yield contributing traits of maize (*Zea mays* L.). *Bangladesh Journal of Agricultural Research* **47**(1): 81–90.
- Nadeem T, Khalil I H and Jadoon S A. 2023. Combining ability analysis for maturity and yield attributes in sweet corn across environments. *SABRAO Journal of Breeding and Genetics* **55**(2): 319–28.
- Patel R M. 2022. Gene action and combining ability analysis for kernel yield and its attributing traits in maize [*Zea mays* (L.)]. *Electronic Journal of Plant Breeding* **13**(1): 273–78.
- Patel K, Gami R A, Kugashiya K G, Chauhan R M, Patel R N and Patel R M. 2019. A Study on per se performance and heterosis for kernel yield and its attributing traits in maize [*Zea mays* (L.)]. *Electronic Journal of Plant Breeding* **10**(3): 980–87.
- Rana G, Sharma P, Kamboj M C and Singh N. 2020. Combining ability effects and nature of gene action for grain yield and quality parameters in popcorn (*Zea mays* var. everta). *Electronic Journal of Plant Breeding* **11**(4): 1215–21.
- Revilla P, Calli M A and William F T. 2021. Sweet corn research around the world 2015–2020. *Agronomy* **11**: 534.
- Seledes R M, Oglari J B and de Souza R. 2022. Diallel analysis of local sweet corn varieties for grain chemical quality. *Research, Society and Development* **11**(6): e59411629417.
- Shaaban A S, EL-Badawy M EL M, El Hosary A A A, Hammam G Y and Ayaad B N. 2022. Estimate of combining ability in 9×9 diallel crosses of maize at two locations. *Annals of Agricultural Science, Moshtohor* **60**(2): 373–84.
- Steel R G and Torrie J. 1980. *Principles and Procedures of Statistics*. Mc Graw-Hill Book Company, New York, USA.
- Vasal S K. 1998. Hybrid maize technology: Challenges and expanding possibilities for research in the next century. Vasal S K, Gonzalez C F and Xingming F (Eds). (In) *Proceedings of 7th Asian Regional Maize Workshop*, Los Banos, Philippines, February 23–27, pp. 58–62.
- Vieira F G K, Borges G D S C, Copetti C, Amboni R D D M C, Denardi F and Fett R. 2009. Physico-chemical and antioxidant properties of six apple cultivars (*Malus domestica* Borkh) grown in southern Brazil. *Scientia Horticulturae* **122**(3): 421–25.
- Xingming F, Tan J, Chen Z and Yang J. 2002. Combining ability and heterotic grouping of 10 temperate, tropical and subtropical quality protein maize. Srinivasan G, Zaidi P H, Prasanna B N, Gonzalez F C and Lesnick K (Eds). (In) *Proceedings of 8th Asian Regional Maize Workshop*. Bangkok, Thailand, August 5–8, pp. 10–18.