The Pharma Innovation Journal 2021; 10(8): 250-254

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(8): 250-254

www.thepharmajournal.com
Received: 18-06-2021
Accepted: 29-07-2021

Niranjan Kumar Chaurasia
1. Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India
2. Department of Genetic and Plant Breeding, M. S. Swaminathan School of Agriculture, CUTM, Paralakhemundi, Odisha, India

RBP Nirala
Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Birender Singh
Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Jai Prakash Yadav
Department of Genetics and Plant Breeding, Bhola Paswan Shastri Agricultural College, Purnea, Bihar, India

Raj Kishor Roy
Department of Genetics and Plant Breeding, Pulse Research Centre, Mokama, Patna, Bihar, India

Corresponding Author:
Niranjan Kumar Chaurasia
1. Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India
2. Department of Genetic and Plant Breeding, M. S. Swaminathan School of Agriculture, CUTM, Paralakhemundi, Odisha, India

Combining ability of grain yield and yield component traits in maize (*Zea mays* L.)

Niranjan Kumar Chaurasia, RBP Nirala, Birender Singh, Jai Prakash Yadav and Raj Kishor Roy

Abstract
Understanding the nature of gene action and trait expression are keys for effective breeding. The objective of present investigation was to estimates the general (GCA) combining ability, specific (SCA) combining ability, and heritability of yield and yield component traits in maize. An experimental trial was carried out during Kharif-2019 at Experimental Area, Bhola Paswan Shastri Agricultural College, Purnea, Bihar Agricultural University, Sabour, Bhagalpur with seven parental inbred lines and their twenty one crosses generated through half diallel matting scheme during Rabi, 2018-19. The results obtained disclose the presence of a great genetic variability between the crosses and their parents; additive and non-additive gene effects are involved in the control of all the traits under study. The estimate of variance ratio of general (GCA) combining ability and the specific (SCA) combining ability was less than unity which indicates the preponderance of the non-additive gene effects for all the traits under study except ear height, ear length and 1000-kernel weight. The best selected crosses with significant SCA effects and GCA effects for at least female parent for grain yield per plant and yield component traits was, P5 x P7 and may be exploited commercially after critical evaluation for their superior and stable performance over environments.

Keywords: General (GCA) combining ability, specific (SCA) combining ability and Maize

Introduction
Maize (*Zea mays* L., 2n=20) third major cereal crop after rice and wheat. In addition the human food, it has huge potential toward animal's feed and industrial raw material. Maize offers a range of nutritional benefits and has clinical implications in various diseases (Murdia *et al.* 2016) [15]. According to National Collateral Management service, Special report (2017), just about 13 per cent of the whole maize consumed in a straight line as food, 7 per cent as processed food, 13 per cent as animal feed, 47 per cent as poultry feed, 14 per cent as industrial raw materials, and 6 per cent as export and others. Maize is grown in Bihar under the three crop cultivating seasons such as kharif, rabi and summer among them kharif season cultivation faced a number of abiotic and biotic stresses such as uneven rainfall, water logging, pest and disease occurrence etc. which direct to severe reduction in grain yield. To enhance the grain yield heterosis breeding is one of an important tool. Selection of the parental lines exploited in hybrid breeding programmes is vital task for breeder or researcher. Phenotypic selection of parental lines not always fulfils breeder's requirements because phenotype is always linked with environments. Therefore, it is necessary to choose the parental lines on the basis of their genetic parameters. Combining ability (CA) analysis helps breeder to isolate the best combining inbred lines that may be used as parents for hybrid breeding programme to exploit heterosis/hybrid vigour or to mount up productive genes. Keeping this point in views the present study was performed with the objectives, (I) to estimate the general (GCA) combining ability and specific (SCA) combining ability effects of inbred lines and crosses, respectively.

Materials and Methods
The experimental material includes seven inbred lines and their twenty one crosses generated by half diallel matting scheme during Rabi 2018-19. Field evaluation was performed for their agronomic performance during the Kharif, 2019 at Experimental Farm, Bhola Paswan Shastri Agricultural College, Purnea, Bihar. The experiment was carried out in Randomized Block Design (RBD) with three replicas and 5m row length having row-row distance 60 cm and plant-plant distance 20 cm. The standard package of practices was adopted for raising healthy

crops. The data were taken on fourteen quantitative characters on ten randomly selected plants from each one replication *viz*., days to anthesis, days to silk, anthesis-silking interval, days to 50 per cent physiological maturity, plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), kernel row per ear, kernels per row, grains per plant, 1000-kernel weight (g), shelling (%) and grain yield per plant. The mean values on various characters were analysed by INDOSTAT 9.2 software following the method II model I suggested by Griffing, 1956 [9].

Results and Discussion

Analysis of variances

The results obtained from analysis of variance for diallel analysis (Table 1) disclose the presence of a great genetic variability between the crosses and their parents. Analysis of variance for combining ability (Table 2) disclosed the mean squares due to general (GCA) combining ability and specific (SCA) combining ability were highly significant for all the quantitative traits under study highlighted that all the traits might be governed by both additive and non-additive gene effects. The estimate of variance ratio of general (GCA) combining ability and the specific (SCA) combining ability (Table 3) was less than unity which indicates the preponderance of the non-additive gene effects for all the traits under study except ear height, ear length and 1000-kernel weight.

Table 1: Analysis of variance for diallel analysis (Method II and Model I) for fourteen quantitative characters in maize

Source of variation	DF	Mean squares						
		DA	DS	ASI	DPM	PH	EH	EL
Genotypes	27	15.84**	27.40**	3.67**	23.71**	985.35**	526.46**	3.72
Parents	6	10.22**	27.86**	8.19**	4.65	2500.28**	1458.88**	5.53
Crosses	20	15.01**	23.48**	2.29**	22.99**	427.47	267.52**	2.97
Parent Vs. Crosses	1	66.04**	102.86**	4.06**	152.44**	3053.32**	110.67	8.04
Error	54	2.33	2.32	0.02	8.46	243.40	97.45	2.70

DF: Degree of freedom, DA: Days to 50 per cent anthesis, DS: days to 50 per cent silk, ASI: anthesis-silking interval, DPM: days to 50 per cent physiological maturity, PH: plant height, EH: ear height, EL: ear length, **Significant at $p< 0.01$, and *Significant at $p< 0.05$.

Contd. Table 1: Analysis of variance for diallel analysis (Method II and Model I) for fourteen quantitative characters in maize

Source of variation	DF	Mean squares						
		ED	KRPE	KPR	GPP	1000-KW	SP	GYP
Genotypes	27	0.45**	7.65**	65.59**	13835.21**	3631.32**	194.41**	1315.91**
Parents	6	0.41**	11.34**	93.35**	16934.87**	6835.72**	431.79**	1823.50**
Crosses	20	0.13*	1.78	15.99**	4017.65**	2398.32**	6.95	357.91**
Parent Vs. Crosses	1	6.97**	102.86**	890.93**	191588.40**	9064.80**	2519.40**	17430.13**
Error	54	0.06	1.25	5.60	950.14	897.64	8.67	126.98

DF: Degree of freedom, ED: ear diameter, KRPE: kernel rows per ear, KPR: kernels per row, GPP: grains per plant, 1000-kw: 1000-kernel weight, SP: shelling per cent and GYP: grain yield per plant, **Significant at $p< 0.01$, and *Significant at $p< 0.05$.

Table 2: Analysis of variance for combining ability and heritability for fourteen quantitative characters in maize

Sources	Mean squares														
	DF	DA	DS	ASI	DPM	PH	EH	EL	ED	KRPE	KPR	GPP	1000-KW	SP	GYP
GCA	6	10.65**	24.72**	3.72**	6.47*	864.20**	570.19**	2.61*	0.08**	0.78	31.01**	5527.52**	3417.17**	65.09**	292.06**
SCA	21	3.74**	4.68**	0.51**	8.31**	175.38*	62.71*	0.85	0.17**	3.06**	19.25**	4350.08**	579.95**	64.72**	480.52**

DF: Degree of freedom, DA: Days to 50 per cent anthesis, DS: days to 50 per cent silk, ASI: anthesis-silking interval, DPM: days to 50 per cent physiological maturity, PH: plant height, EH: ear height, EL: ear length, ED: ear diameter, KRPE: kernel rows per ear, KPR: kernels per row, GPP: grains per plant, 1000-kw: 1000-kernel weight, SP: shelling per cent and GYP: grain yield per plant, **Significant at $p< 0.01$, and *Significant at $p< 0.05$.

Table 3: Estimates of components of variance for fourteen quantitative characters in maize

Sources	Mean squares						
	DA	DS	ASI	DPM	PH	EH	EL
σ^2 gca	1.10	2.66	0.41	0.41	87.01	59.75	0.19
σ^2 sca	2.97	3.90	0.50	5.494 6	94.24	30.23	-0.05
σ^2gca/σ^2 sca	0.37	0.68	0.83	0.07	0.92	1.98	-3.89

DA: Days to 50 per cent anthesis, DS: days to 50 per cent silk, ASI: anthesis-silking interval, DPM: days to 50 per cent physiological maturity, PH: plant height, EH: ear height, EL: ear length.

Contd. Table 3: Estimates of components of variance for fourteen quantitative characters in maize

Sources	Mean squares						
	ED	KRPE	KPR	GPP	1000-KW	SP	GYP
σ^2 gca	0.01	0.04	3.24	578.98	346.44	6.91	27.75
σ^2 sca	0.15	2.64	17.39	4033.37	280.73	61.84	438.19
σ^2gca/σ^2 sca	0.05	0.02	0.19	0.14	1.23	0.11	0.06

ED: ear diameter, KRPE: kernel rows per ear, KPR: kernels per row, GPP: grains per plant, 1000-KW: 1000-kernel weight, SP: shelling per cent and GYP: grain yield per plant.

General combining ability (GCA) effects

The estimates of General (GCA) combining ability effects on various quantitative traits were either positive or negative (Table 4). Positive GCA effects are desirable for the traits grain yield per plant. The parents namely, P5 and P7 had significant to highly significant positive GCA effects and were grouped as best general combiners for grain yield per plant. The parents namely, P4 and P6 were identified as average general combiners, while, P1, P2 and P3 were identified as poor general combiners for grain yield per plant. For shelling per cent, grains per plant, and kernels per row the parent, P7 had highly significant positive GCA effects and was considered as good general combiner for these traits. For the trait ear length the parent, P5 had significant positive GCA effects, and was considered as good general combiner for this trait. For the characters like shelling per cent, and 1000-kernel weight the parent P6 exhibited highly significant positive GCA effects and was grouped as good general combiner for these traits. Hence, these parents can be used in a straight line for development of high yielding hybrids and synthetic by contributing favourable alleles. Significant positive GCA effects for inbred lines highlighted that they are enviable parents for development hybrid maize and participation in the maize breeding program as they can be valuable source of superior alleles in the process of varietal development (Rawi, 2016) [7]. Negative GCA effects are advantageous for days to 50 per cent anthesis, days to 50 per cent silk, anthesis-silking interval and days to 50 per cent maturity. The parents, P1 exhibited highly significant negative GCA effects for days to anthesis, days to silk, anthesis-silking interval and days 50 per cent physiological maturity, while, the parent, P5 exhibited significant to highly significant negative GCA effects for days to silk and anthesis-silking interval. Hence, these parents were good general combiners these traits which can be exploited for developing early maturing hybrids. Negative GCA effects are enviable for the trait plant height to overcome the problem of lodging. The result disclosed that the parent, P3 had highly significant negative GCA effects for ear height and plant height and was considered as good general combiner for these traits. These results are close consistency with the results of Chaurasia *et al.* (2020) [13], Elmyhun *et al.* (2020) [6], Singh *et al.* (2019) [5], Kumar *et al.* (2017) [10], Singh *et al.* (2017) [2], Kumar and Babu (2016) [1], Kumar *et al.* (2015) [8], Dar *et al.* (2015), Gouda *et al.* (2013) [3]

Table: 4: Estimates of general (GCA) combining ability effects of seven parental inbred lines for fourteen quantitative characters in maize

Sources	DA	DS	ASI	DPM	PH	EH	EL
P1	-2.30**	-3.36**	-1.06**	-1.61**	-0.42	2.19	0.05
P2	0.29	0.20	-0.10**	0.13*	-0.10	-3.41	-0.78*
P3	0.51	1.12**	0.61**	0.24	-20.21**	-15.35**	-0.72*
P4	1.07**	1.31**	0.24**	0.35	3.02	1.46	0.34
P5	-0.08	-0.62*	-0.54**	0.10	2.34	-0.71	0.59*
P6	-0.04	0.01	0.05	-0.39	11.85**	7.67**	0.31
P7	0.55*	1.34**	0.79**	1.17*	3.52	8.16**	0.21

DA: Days to 50 per cent anthesis, DS: days to 50 per cent silk, ASI: anthesis-silking interval, DPM: days to 50 per cent physiological maturity, PH: plant height, EH: ear height, EL: ear length, **Significant at $p< 0.01$, and *Significant at $p< 0.05$.

Contd. Table 4: Estimates of general (GCA) combining ability effects of seven parental inbred lines for fourteen quantitative characters in maize

Sources	ED	KRPE	KPR	GPP	1000-KW	SP	GYP
P1	-0.12**	0.19	-0.04	5.33	23.89**	0.35	-3.05
P2	0.18**	0.39	-1.12	-15.33**	-6.66	-0.29	-5.64**
P3	-0.07	-0.51*	-2.79**	-27.14**	4.25	-5.15**	-7.20**
P4	-0.05	-0.18	0.24	-7.11	11.23*	1.62**	0.05
P5	0.01	0.16	0.28	6.01	2.34	-1.43**	4.69*
P6	0.04	-0.01	0.04	-11.44*	33.13**	2.54**	2.61
P7	0.01	-0.04	3.39**	49.67**	-20.38**	2.36**	8.54**

ED: ear diameter, KRPE: kernel rows per ear, KPR: kernels per row, GPP: grains per plant, 1000-kw: 1000-kernel weight, SP: shelling per cent and GYP: grain yield per plant, **Significant at $p< 0.01$, and *Significant at $p< 0.05$.

Specific combining ability (SCA) effects

The estimates of specific (SCA) combining ability effects for all the fourteen quantitative traits under study (Table 5) exposed that the cross combinations, namely P1 x P2, P1 x P3, P1 x P6, P2 x P3, P3 x P5, P3 x P6, P4 x P5, and P5 x P7 exhibited significant to highly significant positive SCA effects for grain yield per plant and were classified as good specific cross combinations for this traits. All these cross combinations also showed significant to highly significant positive SCA effects for one or more yield component characters. The estimates of SCA effects for these cross combinations highlighted the preponderance of non-additive gene effects and may be exploited commercially for this trait later than critical testing across locations/ years. Negative SCA effects are desirable for days to 50 per cent anthesis, days to 50 per cent silk, anthesis-silking interval and days to 50 per cent maturity for earliness. The cross combinations P1 x P4, and P3 x P6 exhibited significant to highly significant negative SCA effects for the characters days to 50 per cent anthesis, days to 50 per cent silk, anthesis-silking interval, and days to 50 per cent physiological maturity. The cross P1 x P2 had highly significant negative SCA effects for to 50 per cent anthesis, days to 50 per cent silk, and days to 50 per cent physiological maturity; P3 x P4 for days to 50 per cent anthesis, days to 50 per cent silk, and anthesis-silking interval; and P6 x P7 for days to 50 per cent silk, anthesis-silking interval, and days to 50 per cent physiological maturity. Among all these crosses, only one cross P2 x P7 had highly significant negative SCA effects for both plant height and ear height. Hence, all these hybrids were grouped as good specific combinations for their respective traits in desirable direction. The promising cross combinations having significant to highly significant SCA effects in desirable direction could be exploited commercially later than testing their performance over environments. These results are in close agreement with the results of Chaurasia *et al.* (2020) [13], Ambikabathy *et al.* (2019) [11], Singh *et al.* (2019) [5], Dar *et al.* (2018) [4], Singh *et al.* (2017) [2], Kumar and Babu (2016) [1], Kumar *et al.* (2015) [8] and Gouda *et al.* (2013) [3].

Table 5: Estimate of specific (SCA) combining ability effects for fourteen quantitative characters in maize

Crosses	DA	DS	ASI	DPM	PH	EH	EL
P1 x P2	-3.12**	-2.82**	0.30**	-5.00**	4.74	6.94	0.76
P1 x P3	-2.34**	-1.75*	0.59**	0.56	18.80*	12.51*	0.48
P1 x P4	-1.98*	-2.94**	-1.04**	-3.89*	-1.74	-4.20	0.41
P1 x P5	0.25	0.99	0.74**	-1.63	-5.27	-2.58	0.33
P1 x P6	-0.45	-0.97	-0.52**	2.19	0.03	-2.67	0.59
P1 x P7	0.62	0.03*	-0.59**	-0.37	3.30	-3.51	0.32
P2 x P3	0.73	0.36	-0.37**	1.15	10.87	6.57	0.40
P2 x P4	-1.16	-1.16	0.00	2.37	13.51	0.87	0.03
P2 x P5	0.99	0.77	-0.22*	-0.37	-0.69	-1.63	-0.40
P2 x P6	1.29	1.47	0.199*	-1.56	4.50	-2.30	-0.74
P2 x P7	1.36	0.81	-0.56**	2.22	-25.71**	-14.11*	-0.99
P3 x P4	-1.71*	-2.42**	-0.70**	0.59	5.07	2.49	0.71
P3 x P5	-0.90	-0.82	0.07	-2.48	14.68	4.55	0.18
P3 x P6	-1.94*	-3.45**	-1.52**	-4.67**	10.59	3.22	1.96*
P3 x P7	-0.19	0.55	0.74**	0.11	3.41	0.99	-0.55
P4 x P5	-1.45	-1.01	0.44**	-0.59	2.03	3.98	0.99
P4 x P6	2.84**	2.69**	-0.15	1.22	-13.71	-14.65**	-1.47
P4 x P7	0.58	0.69	0.11	-1.33	3.16	-0.48	-0.26
P5 x P6	-1.68*	-1.05	0.63**	-1.85	0.45	-0.79	0.09
P5 x P7	-1.27	-1.38	-0.11	1.59	16.29	11.61*	0.73
P6 x P7	-1.31	-2.01*	-0.70**	-4.59**	8.78	7.123	0.17

DA: Days to 50 per cent anthesis, DS: days to 50 per cent silk, ASI: anthesis-silking interval, DPM: days to 50 per cent physiological maturity, PH: plant height, EH: ear height, EL: ear length, **Significant at $p< 0.01$, and *Significant at $p< 0.05$.

Contd… Table 5: Estimate of specific (SCA) combining ability effects for fourteen quantitative characters in maize

Crosses	ED	KRPE	KPR	GPP	1000-KW	SP	GYP
P1 x P2	0.08	0.58	2.24	54.42 **	25.68	3.15	23.07**
P1 x P3	0.43**	2.16**	4.81**	74.43**	19.37	9.82**	22.02**
P1 x P4	0.11	0.09	2.52	33.00	-1.14	0.26	5.85
P1 x P5	0.11	0.81	1.04	15.54	2.08	1.34	0.74
P1 x P6	0.31*	0.45	1.84	16.46	32.75*	0.31	13.96*
P1 x P7	0.12	0.34	3.02	37.29*	5.27	3.41*	7.19
P2 x P3	0.48**	2.28**	2.52	50.49**	30.47	7.96**	21.03**
P2 x P4	0.30*	0.68	2.00.	22.46	13.49	-0.90	9.97
P2 x P5	0.04	0.40	2.97*	52.34**	-12.75	5.24**	5.41
P2 x P6	0.16	-0.16	0.81	9.92	6.32	0.78	2.05
P2 x P7	0.06	-0.27	0.00	-5.92	-9.57	1.37	-3.44
P3 x P4	0.22	0.99	3.37*	34.94*	11.45	5.68**	9.70
P3 x P5	0.44**	2.18**	4.48**	66.55**	17.14	10.59**	20.36**
P3 x P6	0.37*	0.75	4.02**	51.14**	29.41	6.53**	22.60**
P3 x P7	0.11	1.78**	0.15	5.96	-6.81	6.14**	-2.21
P4 x P5	0.16	0.45	1.63	23.52	4.42	0.99	22.04**
P4 x P6	-0.38**	-0.65	-3.66**	-44.43*	-39.30*	-1.38	-24.51**
P4 x P7	0.02	-0.35	1.17	1.60	-2.92	0.72	-1.64
P5 x P6	0.23	0.60	0.61	10.92	9.25	0.76	3.75
P5 x P7	0.07	0.57	2.79*	57.27**	1.63	2.99	16.52*
P6 x P7	0.04	-0.27	1.22	11.12	-10.29	0.63	0.18

ED: ear diameter, KRPE: kernel rows per ear, KPR: kernels per row, GPP: grains per plant, 1000-kw: 1000-kernel weight, SP: shelling per cent and GYP: grain yield per plant, **Significant at $p< 0.01$, and *Significant at $p< 0.05$.

Conclusion
In the present study for grain yield per, the cross combination, P5 x P7 was identified as the best experimental hybrids on the basis of high SCA and high GCA for at least female parent. Hence, this cross combination may be exploited commercially after critical field testing for their performance and stability across environments for this character.

Acknowledgement
Authors thankful to Dean PGS, Bihar Agricultural University, Sabour, Bhagalpur for their financial support for accomplishing research works.

References
1. Kumar SVP, Babu DR. Combining ability and heterosis in maize (*Zea mays* L.) for grain yield and yield components, International Journal of Agriculture, Environment and Biotechnology 2016;9(5):763-772.
2. Singh M, Dubey RB, Ameta KD, Haritwal S, Bhagchand. Combining ability analysis for yield contributing and

quality traits in yellow seeded late maturing maize (*Zea mays* L.) hybrids using Line x Tester, Journal of Pharmacognosy and Phytochemistry 2017;6(5):112-118.

3. Gouda R Kambe, Kage UK, Lohithaswa HC, Shekara BG, Shobha D. Combining ability in maize (*Zea mays* L.), Molecular Plant Breeding 2013;3(4):116-127.
4. Dar ZA, Lone AA, Alie BA, Ahangar MA, Ali G, Abidi I *et al.*. Combining ability analysis for yield and yield contributing traits in Popcorn (*Zea mays everta L.*) under temperate conditions, Journal of Pharmacognosy and Phytochemistry 2018;7(1):361-366.
5. Singh B, Abhishek A, Nirala RBP, Mandal SS, Ranjan T. Study of Combining Ability and Nature of Gene Action for Yield and Yield Related Traits in Maize (*Zea mays* L.) 2019;33(2):1-8.
6. Elmyhun M, Liyew C, Shita A, Andualem M. Combining ability performance and heterotic grouping of maize (*Zea mays*) inbred lines in testcross formation in Western Amhara, North West Ethiopia, Cogent Food & Agriculture 2020;6(1):1727625.
7. Rawi. Relative performance and combining ability for yield and yield components in maize by using full diallel cross, International Journal of Current Research 2016;8(9):37721-37728.
8. Kumar R, Mandal SS, Mishra AK, Smriti, Singh R, Kumar P. Heterosis and combining ability for yield and its contributing traits of kharif maize (*Zea mays* l.), The Bioscan 2015;10(4):2049-2056.
9. Griffing B. Concept of general and specific combining ability in relation to diallel crossing system, Australian Journal of Biological Science 1956;9:463-493.
10. Kumar A, Dadheech A, Kiran N, Bisen P, Kumar S. Diallel Analysis of Combining Ability for Yield and Yield Contributing Traits over the Environments in Maize (*Zea mays* L.), International Journal of Current Microbiology and Applied Sciences 2017;6(10):196-208.
11. Ambikabathy A, Jegadeesh SN, Thirusendura SD, Dhasarathan M, Vairam N, Renganathan GV *et al.*. Determination of Combining Ability and Heterosis for Yield and Yield Related Traits in Maize Hybrids Based on Line × Tester Analysis, Research Journal of Agricultural Sciences 2019;10(1):215-220.
12. National Collateral Management service, Special report 2017.
13. Chaurasia NK, Nirala RBP, Singh B. Combining Ability and Heterosis Studies in Maize (*Zea mays* L.) under Kharif Season, International Journal of Current Microbiology and Applied Sciences 2020;9(11):2576-2586.
14. Abhishek A. Combining Ability and heterosis in maize (*Zea mays* L.) for yield and its associate traits, M.Sc. (Ag.) thesis, Bihar Agricultural University, Sabour, Bhagalpur 2018.
15. Murdia LK, Wadhwani R, Wadhawan N, Bajpai P, Shekhawat S. Maize Utilization in India: An Overview, American Journal of Food and Nutrition 2016;4(6):169-176.