Mysore J. Agric. Sci., 56 (4) : 237-243 (2022)

Comparative Commercial Grain Yield Potential of Maize (*Zea mays*. L) Single Cross Hybrids and their Modified Single Cross Hybrid Versions

T. Kavya[1], J. Shanthala[2], S. Ramesh[3], P. Mahadevu[4], M. Navinkumar[5] and Mounachari[6]
[1,2,3,5&6]Department of Genetics & Plant Breeding, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
[4]Zonal Agricultural Research Station, V. C. Farm Mandya
e-Mail : kavyat.prasad@gmail.com

Authors Contribution
T. Kavya : Conceptualization, design and field experiment;
J. Shanthala : Manuscript drafting;
S. Ramesh : Data analysis & supervision;
P. Mahadevu : Material provided and conducted experiments;
M. Navinkumar & Mounachari : Material preparation and field experiments.

Corresponding Author :
T. Kavya
Department of Genetics & Plant Breeding,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : July 2022
Accepted : November 2022

Abstract

Development and deployment of single cross hybrids (SCH) is considered as an attractive means of enhancing productivity of crops, including maize with a viable hybrid cultivar option. Never the less, production of hybrid seed is an intricate process, as seed quality, seed purity and cost of production are all critically important factors. Grain yield of the seed parent is the key factor that influences cost of hybrid seed production due to high inbreeding depression usually associated with seed parent. Based on previous reports, we hypothesize that modified single cross hybrids (MSCH), besides offering an alternative means to reduce hybrid seed costs, are comparable to SCH in terms of their commercial grain yield potential. MSCH are developed by combining inbred line × its sister inbred line cross progeny as seed parent (female) and an inbred line from opposite heterotic group as male parent. To test our hypothesis, we compared commercial grain yield^{-1} of 20 SCH and their 10 MSCH versions evaluated in alpha lattice design in two replications at two locations. The results suggested significant differences among SCH and their MSCH versions. Further, SCH as one group and MSCH as separate group differed significantly at both the locations. Both SCH and their MSCH versions did interact significantly with locations warranting the need for identifying specifically adapted hybrids to maximize their productivity in each location. While SCH performed better than their MSCH in a few genetic backgrounds at both the locations, MSCH fared better than their SCH versions in few other genetic backgrounds at both the locations. Thus, our results provide preliminary evidence that MSCH are at least comparable to SCH, if not better than the latter ones, thus supporting our hypothesis. However, large-scale investigation involving many SCH and their MSCH versions is essential to confirm our results.

Keywords : Single cross hybrids, Modified single cross hybrids, Inbred line, Sister line, Hybrid seed cost, Grain yield potential

Development and deployment of single cross (SCH) hybrids is considered as an attractive means of enhancing productivity of crops with an economically viable hybrid cultivar option, which includes maize also. However, production of hybrid maize seed is an intricate process, as seed quality, seed purity and cost of production are all critically important factors (Sowjanya *et al.,* 2019). Grain yield of the seed parent is the key factor that influences cost of seed production. This is because, high inbreeding depression usually associated with inbred lines used as parents, especially as seed parent, result in low hybrid seed production (Beck, 2004). Based on previous reports, we hypothesize that modified single cross hybrids (MSCH) could be used as viable option to circumvent the problem of low hybrid seed production. MSCH are developed by combining inbred line × its sister inbred line cross progeny as seed parent (female) and an inbred line from opposite heterotic group as male parent. Selection of suitable sister line of inbred lines is critical to accomplish this. Seed yield is expected to be increased by using sister line crosses in hybrid seed production.We also hypothesize that the crop phenological traits and commercial grain yield potential of MSCH are comparable to SCH. The rationale of our hypotheses is that while SCH involve inbred line *per se* as seed parent, MSCH involve progeny of cross between inbred line and its sister line as seed parent. Hence, genetic constitution of inbred line *per se* and cross progeny between inbred line and its sister line are expected to be similar, although not same. Hence, it is likely that genetic constitution of SCH and MSCH are also similar but not same. Consequently, commercial grain yield potentials of SCH and MSCH are expected to be comparable for crop phenological traits and commercial grain yield potential (Lee *et al.*, 2006). Hence, MSCH are expected to offer an attractive alternative to reduce the costs of hybrid seed production besides retaining grain yield potential of SCH.

However, published reports on comparative assessment of grain yielding ability of SCH and their modified counterparts (MSCH) in maize are scanty. With this background, the objective of the present investigation is to compare the performances of SCH and their MSCH versions for grain yield^{-1} in maize.

MATERIAL AND METHODS

Basic Genetic Material

The material for the study consisted of 10 pairs of inbred lines and their sister lines selected from F_4 populations derived from the two crosses *i.e.,* MAI 137×97B and MAI 137×MAI 345 (Table 1). The 10 pairs of inbred lines & their sister lines were selected based on their uniformity for plant type and flowering time. Hereafter, the inbred lines and their sister lines will be designated as A and A^1, respectively. The material also consisted of two other genotypes namely CML564 and CML578 which are hereafter referred as testers (T).

TABLE 1

Details of females (A) & their counter parts sister females (A^1) and male lines (T) along with their pedigree used in the study

Pedigree of female line (A)	Pedigree of sister female line (A^1)	The cross from which A and A^1 are derived
F_4-47-4	F_4-47-5	MAI 137 × 97B
F_4-101-5	F_4-101-7	MAI 137 × MAI 345
F_4-113-3	F_4-113-4	
F_4-133-2	F_4-133-4	
F_4-144-4	F_4-144-5	
F_4-160-3	F_4-160-4	MAI 137 × 97B
F_4-161-2	F_4-161-4	
F_4-170-2	F_4-170-3	
F_4-185-2	F_4-185-3	
F_4-186-3	F_4-186-4	

Male lines	Pedigree
CML564	HY18R-Y75-3
CML578	HY18R-Y75-5

Development of Experimental Material

The 10A and their A^1 lines were crossed to two testers to obtain 20 each of (A× T) and (A^1×T) hybrids. The 10A lines were also crossed to A^1 line to obtain 10 (A×A^1) hybrids. The 10 (A×A^1) hybrids were crossed to two testers to obtain 20 (A×A^1) × T hybrids (Fig. 1) which are designated as modified single cross hybrids (MSCH). The 5(A×T_1), 5(A×T_2), 5(A^1×T_1) and 5(A^1×T_2) and their corresponding MSCH versions, namely 5(A×A^1)×T_1 and 5(A×A^1)×T_2 along with non-corresponding MSCH, 5(A×A^1)×T_1 and 5(A×A^1)×T_2 hybrids of two testers were synthesized during 2021 *summer* and *kharif* seasons.

Evaluation of Experimental Material

A total 20 SCH hybrids which included 10 A×T, 10 A^1×T and their 10 [(A×A^1) × T] MSCH versions plus other 10 MSCH (Table 2 and Table 3) were evaluated for commercial grain yield in two replications in alpha lattice design at two locations *i.e.,* College of Agriculture (CoA), University of Agricultural Sciences (UAS), GKVK, Bengaluru and F-Block,

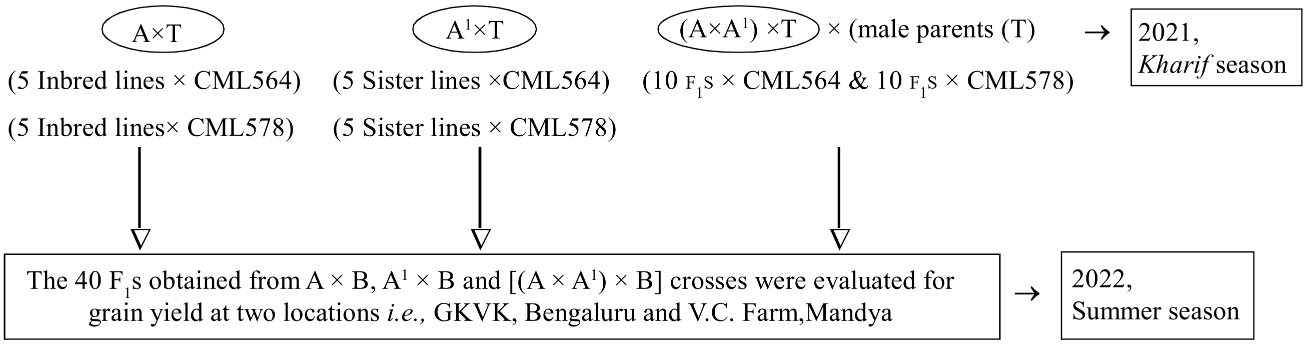

Fig.1: Schematic representation of synthesis of single cross hybrids (SCH) and their modified SCH versions and evaluation at two locations

TABLE 2

List of the single cross hybrids (SCH) and their modified SCH (MSCH) versions evaluated for grain yield plant^{-1} at two locations GKVK, Bengaluru and V. C. Farm, Mandya

SCH (A) using CML564	SCH (A^1) using CML564	MSCH (A×A^1) using CML564
F_4-185-2×CML564	F_4-185-3×CML564	(F_4-185-2 ×F_4-185-3)×CML564
F_4-144-4×CML564	F_4-144-5×CML564	(F_4-144-5×F_4-144-5)×CML564
F_4-47-4×CML564	F_4-47-5×CML564	(F_4-47-4×F_4-47-5)×CML564
F_4-186-3×CML564	F_4-186-4×CML564	(F_4-186-3×F_4-186-4)×CML564
F_4-133-2×CML564	F_4-133-4×CML564	(F_4-133-2×F_4-133-4)×CML564
SCH (A) using CML578	**SCH (A^1) using CML578**	**MSCH (A×A^1) using CML578**
F_4-101-5×CML578	F_4-101-7×CML578	(F_4-101-5×F_4-101-7)×CML578
F_4-161-2×CML578	F_4-161-4×CML578	(F_4-161-2×F_4-161-4)×CML578
F_4-113-3×CML578	F_4-113-4×CML578	(F_4-113-3×F_4-113-4)×CML578
F_4-170-2×CML578	F_4-170-3×CML578	(F_4-170-2×F_4-170-3)×CML578
F_4-160-3×CML578	F_4-160-4×CML578	(F_4-160-3×F_4-160-4)×CML578

TABLE 3

MSCH (A×A^1) using CML 564	MSCH (A×A^1) using CML 578
($F_4$88-2×F_4-88-3)×CML564	(F_4-88-2×F_4-88-3)×CML578
(F_4-66-5×F_4-66-6)×CML564	(F_4-156-8 ×F_4-156-9)×CML578
(F_4-86-2×F_4-86-5)×CML564	(F_4-39-4 ×F_4-39-5)×CML578
(F_4-141-2×F_4-141-3)×CML564	(F_4-9-2×F_4-9-3)×CML578
(F_4-59-6×F_4-59-7)×CML564	(F_4-59-6×F_4-59-7)×CML578

List of (MSCH) which are not SCH versions

V.C. Farm, Mandya during 2022 *summer* season (Fig. 1). Each hybrid was grown in two rows of 3m length with a spacing of 0.3m between plants within a row and 0.6m between rows. During the crop growth period, the recommended management practices were followed to raise a healthy crop.

Sampling and Data Collection

Cobs were harvested from five randomly selected plants (avoiding border one's) from each of 5(A×T_1), 5(A×T_2), 5(A^1×T_1), 5(A^1×T_2), 5(A×A^1)×T_1, 5(A×A^1) ×T_2 plus other 5(A×A^1)×T_1 and 5(A×A^1)×T_2 hybrids. The cobs were sun-dried and hand threshed and grains were weighed. The average grain weight from each hybrid in each replication was recorded as grain yield plant^{-1} (g).

Statistical Analysis

ANOVA

Data on average grain yield plant^{-1} of each hybrid and replication were used for statistical analysis. Locationwise and pooled analysis of variance was performed as per Alpha-lattice design (Patterson and Williams, 1976) to detect significance or otherwise of differences among the hybrids. The analysis was performed using 'R Studio' and 'Metan : An R package' (Olivoto *et al.,* 2020). Each of 5 SCH with T_1 and T_2 testers and their MSCH versions were compared to detect the significance of differences between them for grain yield using critical difference computed from error mean squares of pooled ANOVA.

Critical Difference (CD)

CD = SEd × table value at P = 0.05

where, SEd = standard error of difference

Results and Discussion

Analysis of Variance

The development of new cultivars depends mainly on the magnitude of genetic variability in the base material for the desired trait. Most traits of breeder's interest as well as manifestation of a number of component traits are complex. Grain yield is one such trait which is influenced by many independent characters. ANOVA is a diagnostic tool for detection of variability for target traits like grain yield. In the present study, both types of hybrids, namely SCH & MSCH differed significantly at both the locations (GKVK and Mandya) for grain yield plant^{-1} as indicated from significance of mean squares (Table 4). The significant differences among the hybrids could be attributed to genetic differences between their parents. Significant differences among hybrids not only justifies the selection of inbred lines but also the use of their hybrid combinations for the study. Significant mean squares due to SCH *vs.* MSCH contrast suggest substantial differences between SCH and MSCH as separate groups at both the locations (Table 5). Several previous researchers such as Saleem *et al*. (2011); Kashiani *et al*. (2014); Azam *et al.* (2014); Kumar *et al*. (2014), Lee *et al*. (2006); Sowjanya *et al.* (2019) and Mushtaq *et al*. (2016) have also reported significant differences among test hybrids in maize.

Table 4

ANOVA of single cross hybrids and their modified single cross hybrid versions for grain yield plant^{-1} in GKVK, Bengaluru and V.C. Farm, Mandya

Source of variation	Degrees of Freedom	Mean sum of squares	
		GKVK	Mandya
Replication	01	195.09 *	0.24
Blocks	14	30.51	89.69 *
Hybrids	39	1005.23 ***	337.82 ***
SCH	19	1055.35 ***	269.57 ***
MSCH	19	1007.53 ***	335.70 ***
SCH *vs.*MSCH	01	39203.99 ***	9411.44 ***
Error	32	39.50	27.72

** Significant @ P=0.01; *** Significant @ P=0.001

Table 5

Pooled ANOVA of single cross hybrids and their modified single cross hybrid versions for grain yield plant^{-1} in two locations (GKVK, Bengaluru and V.C. Farm, Mandya)

Source of variation	Degrees of freedom	Mean sum of squares
Locations	01	60432.91 ***
Replication(Location)	2	97.67 *
Blocks(Location)	28	43.99 *
Hybrids	39	722.62 **
SCH	19	809.00 ***
MSCH	19	636.40 ***
SCH × Location	19	516.00 ***
MSCH × Location	19	706.80 ***
Hybrids × Location	39	620.42 **
Error	50.00	35.20

** Significant @ P=0.01; *** Significant @ P=0.001

The genotypes very often display differential responses to production environments represented by spatial (location-to-location) variation as is true in present study. Crop cultivars that retain consistent performance across locations are desirable from the commercial crop production point of view (Liu *et al.,* 2004; Anley *et al.,* 2013 and Chandel *et al.,* 2019). In the present study, significant interaction of SCH & MSCH hybrids with locations suggest differential

TABLE 6

Grain yield plant^{-1}of SCH (A×T) and their MSCH (A×A^1)×T versions with CML564 in GKVK, Bengaluru and V.C. Farm, Mandya

SCH with Tester 1	Mean (g)	MSCH with Tester 1	Mean (g)	Difference between SCH & MSCH	Mean (g)
		GKVK			
F_4-185-2 × CML564	148.13	(F_4-185-2 × F_4-185-3) × CML564	179.26	31.13	26.90
F_4-144-4 × CML564	147.18	(F_4-144-5 × F_4-144-5) × CML564	137.08	10.10	08.73
F_4-47-4 × CML564	155.17	(F_4-47-4 × F_4-47-5) × CML564	142.16	13.01	11.23
F_4-186-3 × CML564	154.49	(F_4-186-3 × F_4-186-4) × CML564	141.51	12.98	11.22
F_4-133-2 × CML564	166.10	(F_4-133-2 × F_4-133-4) × CML564	172.45	06.35	05.48
		Mandya			
F4-185-2 × CML564	86.20	(F4-185-2 × F4-185-3) × CML564	101.80	15.60	13.48
F4-144-4 × CML564	106.00	(F4-144-5 × F4-144-5) × CML564	102.40	03.60	03.11
F4-47-4 × CML564	82.10	(F4-47-4 × F4-47-5) × CML564	108.70	26.60	22.99
F4-186-3 × CML564	90.90	(F4-186-3 × F4-186-4) × CML564	113.30	22.40	67.36
F4-133-2 × CML564	124.20	(F4-133-2 × F4-133-4) × CML564	122.30	01.90	01.64

performance of both SCH & MSCH in both locations. These results warrant identification of specifically adaptable hybrids to maximize their productivity in each location. Researchers such as Koroma *et al.* (2017), Lalisaararsa *et al.* (2016), Lee *et al.* (2006) have also reported significant hybrid × location interaction in maize. Considering significant hybrid×location interaction, the grain yield potential of between SCH and their MSCH were compared separately for each location.

TABLE 7

Grain yield plant^{-1} of SCH (A×T) and their MSCH (A×A^1)×T versions with CML578 in GKVK, Bengaluru and V.C. Farm,Mandya

SCH with Tester 2	Mean (g)	MSCH with Tester 2	Mean (g)	Difference between SCH & MSCH	CD
		GKVK			
F4-101-5 × CML578	163.12	(F4-101-5 × F4-101-7) × CML578	127.02	36.10	31.19
F4-161-2 × CML578	180.59	(F4-161-2 × F4-161-4) × CML578	157.53	23.60	19.93
F4-113-3 × CML578	116.37	(F4-113-3 × F4-113-4) × CML578	116.60	0.23	0.19
F4-170-2 × CML578	101.49	(F4-170-2 × F4-170-3) × CML578	149.26	47.77	41.28
F4-160-3 × CML578	116.54	(F4-160-3 × F4-160-4) × CML578	137.25	20.71	17.89
		Mandya			
F4-101-5×CML578	110.10	(F4-101-5×F4-101-7)×CML578	102.6	07.50	06.48
F4-161-2×CML578	114.00	(F4-161-2×F4-161-4)×CML578	83.60	30.40	26.28
F4-113-3×CML578	94.80	(F4-113-3×F4-113-4)×CML578	99.70	04.90	04.23
F4-170-2×CML578	85.65	(F4-170-2×F4-170-3)×CML578	128.20	42.55	36.77
F4-160-3×CML578	90.75	(F4-160-3×F4-160-4)×CML578	96.10	05.35	04.61

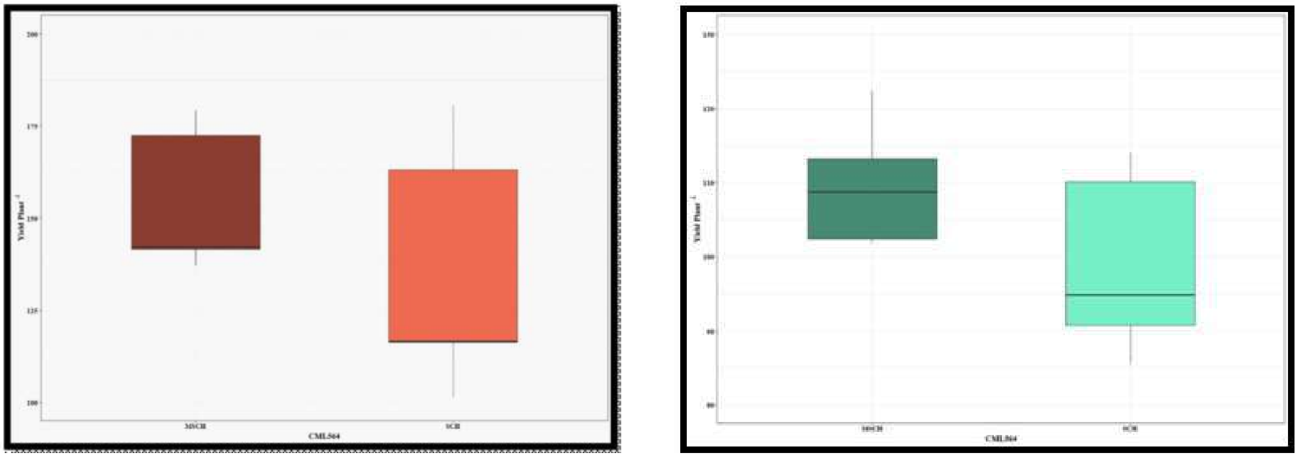

Fig. 2: Box-Whisker plots showing comparative performance of single cross hybrids and modified single cross hybrids with tester CML564 in GKVK,Bengaluruand V.C. Farm,Mandya

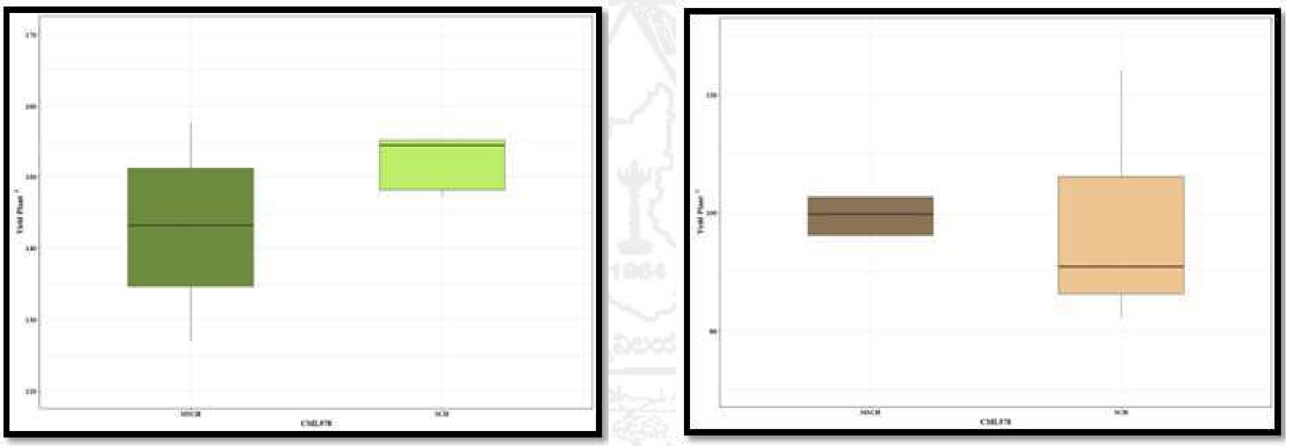

Fig.3: Box-Whisker plots showing comparative performance of single cross hybrids and modified single cross hybrids with tester CML578 GKVK, Bengaluru and V.C. Farm, Mandya.

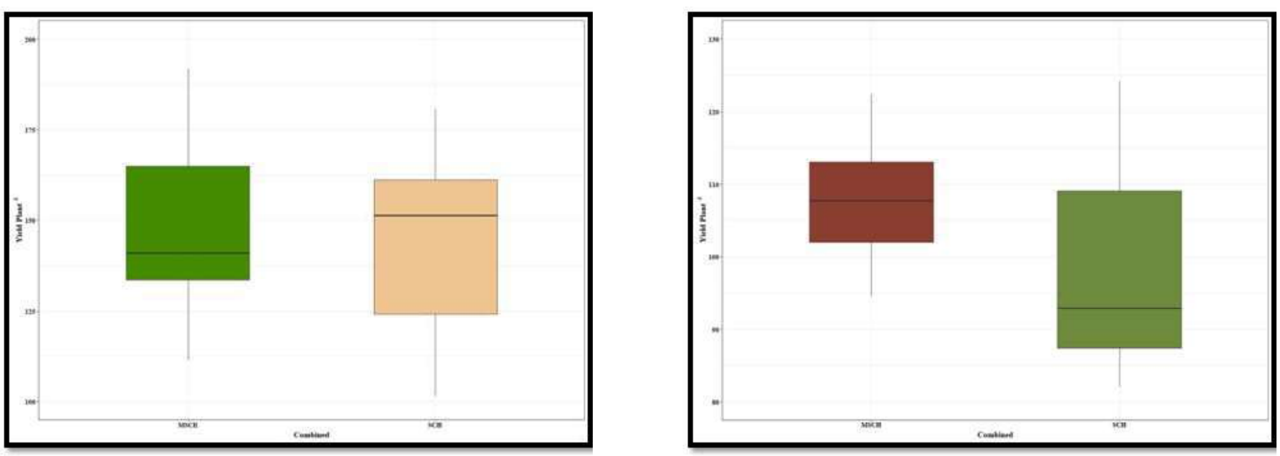

Fig. 4: Box-Whisker plots showing comparative performance of single cross hybrids and modified single cross hybrids with both the testers CML564 & CML578 in GKVK, Bengaluru and V.C. Farm, Mandya

Comparative Performance of SCH and their MSCH Versions

The SCH and their MSCH versions with both the testers,CML564 & CML578 differed significantly at both the locations.However, while SCH fared better than their MSCH in a few genetic backgrounds at both the locations, MSCH fared better than their SCH versions in few other genetic backgrounds at both the locations (Table 6 and Table 7; Fig. 2, 3 & 4). These results suggest there is no definite trend in favour of any of the two types of hybrids for grain yield plant^{-1}. However, reports of Tollenaar, *et al.* (2004), Lee and Kannenberg (2004) are contradictory to our results. They documented higher grain potential of SCH compared to their MSCH versions. The results of the present study provide preliminary evidence that MSCH are atleast comparable to SCH, if not better than the latter ones, thus supporting our hypothesis. However, large-scale investigation involving a large number of hybrids is necessary to explore comparative grain yield potential of SCH and their MSCH versions.

MSCH are atleast comparable to their SCH versions, if not better than the later ones.

References

Anley, W., Zeleke, H. and Dessalegn, Y., 2013, Genotype × environment interaction of maize (*Zea mays* L.) across North Western Ethiopia. *J. Plant Breed. Crop Sci.,* **5** (9) : 171 - 181.

Azam, G., Sarker, K., Maniruzzamand Banik, B. R., 2014, Genetic variability of yield and its contributing characters of CIMMYT maize inbreds under drought stress. *Bangladesh J. Agric. Res*., **39** (3) : 419 - 426.

Beck, D. L., 2004, Hybrid corn seed production. Corn–Origin, history, technology, and production. *John Wiley & Sons.,* Hoboken, New Jersey.

Chandel, U., Guleria, S. K., Sudan, R. S. andKumar, D., 2019, Genotype by environment interaction and stability analysis is for maize hybrids in North Western Himalayas ecology. *Maydica,* pp. : 64 - 73.

Kashiani, P., Saleh, G., Abdulla, N. A. P. and Sin, M. A., 2014, Evaluation of genetic variation and relationships among tropical sweet corn inbred lines using agronomic traits. *Maydica*, **59** : 275 - 282.

Koroma, M. S., Swaray, M., Akromah, R. and Obeng-Antwi, K., 2017, Genotype by environment interaction and stability of extra-early maize hybrids (*Zea mays* L.) for yield evaluated under irrigation. *Int. J. Environ. Agric. Biotech.,* **2** (5) : 2573 - 2580.

Kumar, G. P., Prashanth, Y., Reddy, V. N., Kumar, S. S. and Rao, P. V., 2014, Heterosis for grain yield and its component traits in maize (*Zea mays* L.) *Int. J. Pure and Applied Bio. Sci.,* **2** (1) : 106 - 111.

Lalisaararsa, Habtamu, Z. and Mandefro, N., 2016, Genotype by environment interaction and yield stability of maize (*Zea mays* L.) hybrids in Ethiopia. *J. Natural Sci. Res.,* **6** (13) : 93 - 110.

Lee, A. E. and Kannenberg,W. L., 2004, Effect of inbreeding method and selection criteria on inbred and hybrid performance. *Maydica.,* **49** : 191 - 197.

Lee, A. E., Singh, A., Ash, J. M. and Good, B., 2006, Use of sister-lines and the performance of modified single-cross maize hybrids. *Crop Sci.*, **46** : 312 - 320.

Liu, W., Tollenaar, M., Stewart, G. and Deen, W., 2004, Response of corn grain yield to spatial and temporal variability in emergence. *Crop Sci.,***44** : 847 - 854.

Mushtaq, M., Bhat, M. A., Bhat, J. A., Mukhtar, S. and Shah, A. A., 2016, Comparative analysis of genetic diversity of maize inbred lines from Kashmir valley using agro-morphological and SSR markers. *SABRAO J. Breeding and Genet*., **48** (4) : 518 - 527.

Olivoto, T. and Lucio, A. D. C., 2020, Metan : An R package for multi-environment trail analysis. *Methods Ecol. Evol.,***11** (6) : 783 - 789.

Patterson, H. D. and Williams, E. R., 1976, A new class of resolvable incomplete block designs. *Biometrika.,* **63** : 83 - 92.

Saleem, S., Tahir, H. M. and Saleem, U., 2011, Study of genetic variability in maize inbred lines under irrigated and drought conditions. *Int. J. Agric. App. Sci*., **3** (2) : 80 - 85.

Sowjanya, P. R., Gangappa, E. and Ramesh, S., 2019, General and specific combining ability studies in single cross hybrids of maize (*Zea mays* L.). *Int. J. Curr. Microbiol. App. Sci.,* **8** (10) : 313 - 323.

Tollenaar, M., Ahmadzadeh, A. and Lee, A. E., 2004, Physiological basis of heterosis for grain yield in maize. *Crop Sci.,***44** : 2086 - 2094.