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ESTIMATION OF SPECIFIC COMBINING ABILITY EFFECTS USING TWO METHODS AND THEIR RELATIONSHIPS WITH MEAN PERFORMANCE AND HETEROTIC GROUPS IN MAIZE

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ABSTRACT

The specific combining ability testing is used to identify pairs of inbred lines capable to produce the best hybrids. A line × tester analysis involving 45 hybrids obtained from crossing between 15 inbred lines and three testers was performed. The experiment was conducted at three locations for grain yield in 2023 summer season. The objectives of this study were to compare between estimation of specific combining ability effects by Kempthorne and Yang methods, classify the inbred lines into heterotic groups and identify the superior hybrids for high grain yield. A randomized complete blocks design (RCBD) with three replications was used at each location. Analysis of variance indicated significant mean squares due to lines (L), testers (T), (L×T) and their interactions with locations (Loc) for grain yield. The results showed that grain yield was mainly controlled by non-additive gene effects. The inbred lines Sk27, Sk31, Sk32 and Sk36 had desirable general combining ability effects (GCA) for grain yield. The two hybrids (Sk24×Sk1) and (Sk27×Sk1) were significantly out-yielded the check hybrid SC168. The results showed that numbers of SCA effects of hybrids which showed positive or negative significance according to Yang method were more than those estimated by Kempthorne method, which means that Yang method is better for explanation of SCA effects. Furthermore, SCA effects of Yang were more correlated with mean performance of hybrids than SCA effects obtained by Kempthorne method, hence Yang method is more practical to the breeders. Heterotic groups HSGCA method which estimated using GCA effects plus SCA effects of Yang was more efficient than HSGCA that estimated using GCA effects plus SCA effects estimated by Kempthorne for classification of inbred lines into heterotic groups. This study concluded that Yang method to estimate SCA effects is more beneficial than Kempthorne method for the maize breeders in selection of superior hybrids.

Key words: ***Zea mays, Hybrids, GCA, SCA, Additive, Non-Additive, Gene effects, Classification, HSGCA.***

INTRODUCTION

Maize (*Zea mays* L.) is considered a special crop due to its wide adaptability, food, feed use and as raw materials for industrial processing to generate products like, oil, starch, textiles, pharmaceuticals, cosmetics…etc. Information on the combining ability of inbred lines in hybrid combinations is necessary for a successful maize hybrid improvement (Oluwaseun *et al* 2022). Combining ability is the ability of an inbred line to transmit desirable performance to a hybrid (Allard 1960). It is important not only for selecting desirable parents but also generating information regarding the nature and magnitude of gene effects controlling quantitative traits (Basbag *et al* 2007). Combining ability comprises general combining ability (GCA) and specific combining ability (SCA). Information on GCA plays a significant role in evaluation of inbred lines and selecting the best lines and resulted from the additive gene effects. In contrast, the SCA plays a role in determining the best crosses for maize hybrid development and resulted from non-additive gene effects (Sprague and Tatum 1942, Sharief *et al* 2009, Karim *et al* 2018 and Yadesa *et al* 2021). Line × tester mating design has widely been used for evaluation of inbred lines by crossing them with testers to estimate GCA and SCA effects. The GCA of line is determined by evaluating its performance when crossed with various testers and the average performance across these crosses reflects the lines GCA. Estimate of SCA to identify line pairs that produce hybrids with either superior or inferior performance compared to what would be expected based on the GCA of individual lines. So line × tester analysis provides information on GCA of parents and SCA of hybrids which helps to identify good inbred lines and hybrids, respectively (Silva *et al* 2010 and Moterle *et al* 2011). GCA is directly related to the breeding value of a parent and is associated with additive genetic effects, while SCA is associated with non-additive gene effects such as dominance, over dominance and epistasis (Falconer 1989). Heterotic grouping of available germplasm in any breeding program is crucial for developing high-yielding hybrids (Fan *et al* 2008). Further evaluation of large number of parental lines and their all possible cross combinations will be impractical without knowing their heterotic grouping (Mahato *et al* 2021). Information on combining abilities can be used to classify inbred lines into distinct heterotic ability groups. Heterotic groups comprise related or unrelated genotypes that exhibit similar combining ability effects when crossed with genotypes from the other germplasem group (Warburton *et al* 2022). Crossing representatives of different heterotic pools will maximize heterozygosity, hybrid vigor and ultimately grain yield of the new cultivars (Reif *et al* 2003). Classification of inbred lines into heterotic groups is pivotal for effective hybrid breeding programs, as it enables breeders to strategically select parents using specific heterotic groups to maximize heterosis and develop hybrids with superior performance (Akinwale 2021). There are many techniques used for maize heterotic groups classification depending on results of SCA effects, SCA and GCA effects (HSGCA), pedigree information, GCA effects for multiple traits (HGCAMT) and molecular marker analysis (Menkir *et al* 2004, Barata and Carena 2006, Fan *et al* 2009 and Badu-Apraku *et al* 2015). We observed in previous researches studies that there is no high correspondence between the SCA effects estimated according to Kempthorne and mean performance, where may be some hybrids had high mean performance while, their SCA effects were small or even negative and *vice versa*. Therefore in this study, the SCA effects were estimated by another method according to Yang. The mean goals of this study were to estimate GCA effects for inbred lines, compare between estimation of SCA effects of hybrids using both Kempthorne (1957) and Yang (1983) methods, classify inbred lines into heterotic groups and identify superior hybrids for grain yield.

MATERIALS AND METHODS

The present study was conducted using 15 new yellow maize inbred lines and three inbred lines as testers. These materials were derived from different genetic sources at Sakha Research Station. A total of 45 F_1 hybrids were generated during 2022 summer season by crossing 15 inbred lines with three testers (Sk1, Sk14 and Sk18) using line × tester mating design. The resulting 45 F_1 hybrids along with the cheek hybrid SC168 were evaluated in a randomized complete blocks design with three replications at the three Agricultural Research Stations; Sakha, Gemmeiza and Sids in 2023 summer season during the first half of May. The experimental unit consisted of one row, 6 m length with 0.8 m spacing between rows and 0.25 m spacing between plant to plant. All other management practices such as fertilizer application, intercultural operations and harvesting were performed as the recommended package of practices. The observation of grain yield trait was recorded on ardab per feddan [ardab (ard) = 140kg and feddan (fed) = 4200m^2] which was adjusted at 15.5% grain moisture. Homogeneity test was performed between the three locations according to Bartlett (1937). As a result of the emergence of homogeneity between trials, combined analysis across three locations was done according to Snedecor and Cochran (1989), using computer application of Statistical Analysis System (SAS 2008). Line × tester analysis across the three locations, was estimated according to Kempthorne (1957) as explained by Singh and Chaudhary (1985). AGD-R Software (Analysis of Genetic Designs in R for windows) version 5.0

Statistical Software was used to calculate variances and effects (Rodríguez *et al* 2015). Equation for SCA effects estimation according to Kempthorne (1957) was as follows: $(S_{ij}) = X_{ij}-\bar{x}_{i.}-\bar{x}_{.j}+\bar{\bar{x}}$, where S_{ij} is the SCA effects of cross, X_{ij} is the mean yield of the cross between the ith line and jth tester, $\bar{x}_{i.}$ is the mean yield of the ith line in their crosses and $\bar{x}_{.j}$ is the mean yield of the jth tester in their crosses and $\bar{\bar{x}}$ is the mean of all crosses. While, estimation for SCA effects from Tian *et al* (2015) performed according to Yang (1983) was as follows: $(S_{ij}) = X_{ij}-(\bar{x}_{i.}+\bar{x}_{.j})/2$ or $S_{ij}+(g_i+g_j)/2$, where g_i is the GCA effects of line and g_j is the GCA effects of tester. The inbred lines were classified into heterotic groups based on HSGCA method proposed by Fan *et al* (2009), where HSGCA= GCA effects of line + SCA effects of the cross between same line with tester. The relative importance of additive gene effects (GCA) and non-additive gene effects (SCA): $[2K^2GCA/(2K^2GCA+K^2SCA)]$ was calculated according to Baker (1978), modified by Hung and Holland (2012).

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variances of hybrids for grain yield across the three locations is shown in Table (1). There were highly significant mean squares for grain yield among hybrids (H), locations (Loc) and their interaction (H × Loc). The highest percentage to total sum squares was shown by (H) of 35.09% followed by (Loc) of 28.49% and their interaction (H × Loc) which was 18.33%. These results confirmed that the hybrids variation had the main influence on the total variation, indicating that the differences between hybrids were very broad for grain yield due to differences in genetic background and it response to various environmental conditions. Ruswandi *et al* (2017) stated that the superior hybrids resulted from direct crosses between two parental lines with a far genetic background. Variances in environmental conditions lead to differences in yield of maize hybrids (Adnan *et al* 2020, Katsenios *et al* 2021, Wicaksana *et al* 2022 and Mosa *et al* 2024a, b).

Table 1. Mean squares of locations, hybrids and their interaction for grain yield.

SOV	df	Grain yield		
		SS	MS	Explained%
Locations (Loc)	2	4208.25	2104.12**	28.49
Rep/Loc	6	123.73	20.62	-
Hybrids (H)	45	5183.44	115.19**	35.09
H×Loc	90	2708.30	30.09**	18.33
Error	270	2549.86	9.44	-
Total	413	14773.58	-	-

**** Indicate significant at 0.01 level of probability.**

Mean performance

Mean performance of 45 hybrids and the check hybrid SC168 for grain yield (ard/fed) across three locations are presented in Table (2). The hybrid (Sk24×Sk18) had the lowest grain yield (18.59 ard/fed), while the hybrid (Sk24×Sk1) gave the highest grain yield (35.39 ard/fed). The four hybrids (Sk31×Sk1), (Sk36×Sk18), (Sk27×Sk14) and (Sk37×Sk18), 33.37, 31.36, 31.0 and 30.91 ard/fed, respectively did not significantly out-yield the check hybrid SC168 (30.59 ard/fed). While the two hybrids Sk24×Sk1 (35.39 ard/fed) and Sk27×Sk1 (33.53 ard/fed) were significantly out-yielded the commercial hybrid SC168. The above mentioned hybrids can be used in maize hybrids breeding program to develop new commercial hybrids.

Table 2. Mean performance of 45 hybrids and check hybrid SC168 for grain yield (ard/fed) across three locations.

Line	Tester		
	Sk14	Sk1	Sk18
Sk24	26.99	35.39	18.59
Sk25	26.63	26.93	24.48
Sk26	22.73	25.21	28.95
Sk27	31.00	33.53	21.28
Sk28	29.20	29.36	19.87
Sk29	27.81	28.08	20.16
Sk30	27.56	26.70	22.33
Sk31	27.33	33.37	27.90
Sk32	30.10	30.30	26.67
Sk33	26.91	30.73	25.94
Sk34	29.49	28.17	24.86
Sk35	27.55	29.40	27.09
Sk36	26.09	28.84	31.36
Sk37	29.75	23.06	30.91
Sk38	28.54	24.14	29.74
Check SC168	30.59		
LSD 0.05	2.85		
0.01	3.76		

Line × tester analysis

Line × tester analysis and their interactions with locations for grain yield are given in Table (3). Mean squares due to lines (L), testers (T) and their interaction (L×T) were highly significant for grain yield, indicating adequate variability in the tested materials for making valid experimentation and inferences. Similar results were reported by Kamara *et al* (2021), Kumar *et al* (2022) and Mosa *et al* (2024b). Mean squares due to the interactions effects of lines, testers and lines × testers with locations (Loc) were highly significant for grain yield. This means a varied response of lines, testers and lines × testers to different locations. These results are in agreement with previous researches; from them Mbuvi *et al* (2018) and Ismail *et al* (2023).

Types of gene effects

The relative contribution of lines, testers and lines × testers to the total sum of squares of crosses (Table 3), were 13.70%, 17.55% and 68.75%, respectively, indicating that the contribution of lines × testers interaction was greater than both lines and testers for grain yield, meaning that higher estimate of variance of specific combining ability or non-additive gene effects than general combining ability or additive gene effects. Also, according to Baker (1978), the ratio between twice the GCA component to total genetic effects among F_1 hybrids (twice the GCA component plus the SCA component) was 0.31, indicating that grain yield was mainly controlled by the non-additive gene effects. A similar result was obtained by Fan *et al* (2008), Ifie (2013), Ngoune *et al* (2015), Akula *et al* (2016), Mbuvi *et al* (2018) and Mosa *et al* (2024b). Meanwhile the result obtained in the present study was different to that of Badu-Apraku *et al* (2016) and Mosa *et al* (2024a); they found that grain yield was predominantly controlled by additive gene effects.

Table 3. Mean squares of lines, testers, lines × testers and their interactions with locations for grain yield.

SOV	df	Grain yield		
		SS	MS	Explained%
Line (L)	14	697.63	49.83**	13.70
Tester (T)	2	893.31	446.65**	17.55
L×T	28	3500.53	125.02**	68.75
L×Loc	28	783.77	27.99**	-
T×Loc	4	1051.86	262.96**	-
L×T×Loc	56	845.28	15.09**	-
Error	264	2522.26	9.55	-
$2K^2$ GCA/$2K^2$ GCA+K^2 SCA		0.31		

**** Indicate significant at 0.01 level of probability.**

General combining ability effects

General combining ability effects of 15 inbred lines and three testers for grain yield are given in Table (4). Four new inbred lines (Sk27, Sk31, Sk32 and Sk36) and the inbred line Sk1 as tester had significant and positive values for GCA effects.

Table 4. General combining ability effects (GCA) of 15 inbred lines and three testers and specific combining ability effects (SCA) of 45 crosses using Kempthorne and Yang methods for grain yield.

Line	GCA	SCA effects - Kempthorne			SCA effects - Yang		
		Tester			Tester		
		Sk14	Sk1	Sk18	Sk14	Sk1	Sk18
Sk24	-0.36	-0.49	6.88**	-6.38**	-0.43	7.46**	-7.57**
Sk25	-1.34*	0.13	-0.61	0.48	-0.30	-0.52	-1.20
Sk26	-1.73**	-3.39**	-1.95	5.34**	-4.01**	-2.06*	3.47**
Sk27	1.25*	1.91	3.40**	-5.31**	2.77**	4.79**	-5.69**
Sk28	-1.21*	2.57*	1.69	-4.26**	2.21*	1.85	-5.87**
Sk29	-2.00**	1.97	1.20	-3.18**	1.22	0.96	-5.18**
Sk30	-1.83**	1.54	-0.35	-1.19	0.87	-0.51	-3.11**
Sk31	2.18**	-2.69**	2.31*	0.38	-1.36	4.17**	0.47
Sk32	1.67**	0.59	-0.25	-0.34	1.67	1.35	-0.52
Sk33	0.50	-1.44	1.35	0.09	-0.94	2.36*	-0.66
Sk34	0.15	1.49	-0.86	-0.64	1.81	-0.02	-1.57
Sk35	0.65	-0.95	-0.14	1.09	-0.38	0.95	0.41
Sk36	1.41*	-3.16**	-1.45	4.61**	-2.21*	-0.02	4.31**
Sk37	0.55	1.35	-6.38**	5.02**	1.87	-5.34**	4.29**
Sk38	0.12	0.58	-4.86**	4.28**	0.88	-4.03**	3.33**

GCA effects for testers; Sk14=0.49, Sk1=1.52 and SK18=-2.01****
LSD g_i for lines at0.05 =1.17 and at 0.01=1.54
LSD g_i-g_j for lines at 0.05 =1.67 and at 0.01=2.21
LSD g_i for testers at 0.05 =0.53 and at 0.01=0.70
LSD g_i-g_j for testers at 0.05 =0.75 and at 0.01=0.99
LSD S_{ij} for crosses at 0.05=2.05 and at 0.01=2.71
LSD S_{ij}-S_{kl} for crosses at 0.05 =2.90 and at 0.01=3.84
***, ** indicate significant at the 0.05 and 0.01 levels of probability, respectively.**

These inbred lines had desirable general combing ability effects for grain yield and can be used for development of high yielding hybrids and synthetic varieties. Al-Rawi (2016) stated that the positive and significant GCA effects for grain yield of maize inbred lines, indicate that they are desirable parents for maize hybrid development and involvement in maize breeding program as they have good alleles source in process of varietal development. Significant GCA effects for grain yield in maize was also, reported by Amin *et al* (2014), Elmyhun *et al* (2020), Raihan *et al* (2021) and Mosa *et al* (2024 a, b).

Specific combining ability effects

Estimates of specific combining ability effects of 45 hybrids according to Kempthorne and Yang for grain yield are presented in Table (4). Eight hybrids; (Sk28×Sk14), (Sk24×Sk1), (Sk27×Sk1), (Sk31×Sk1), (Sk26×Sk1), (Sk36×Sk18),(Sk37×Sk18) and (Sk38×Sk18) exhibited significant and positive SCA effects towards high grain yield according to Kempthorne method, also same eight hybrids in addition to the two other hybrids (Sk27×Sk14) and (Sk33×Sk1) showed significant and positive SCA effects according to Yang method. While nine and ten hybrids showed significant and negative SCA effects according to Kempthorne and Yang methods, respectively. These results indicate that the number of hybrids which had significant positive or negative SCA effects according to Yang method was higher than Kempthorne method, meaning that Yang (1983) method is better for showing SCA effects than Kempthorne (1957) method.

Ranks of mean performance and SCA effects of hybrids

Ranks of mean performance and SCA effects of 45 hybrids for grain yield are given in Table (5). The highest seven hybrids for mean performance were (Sk24×Sk1) followed by (Sk27×Sk1), (Sk31×Sk1), (Sk36×Sk18), (Sk27×Sk14), (Sk37×Sk18) and (Sk33×Sk1); their SCA effects ranks were 1st, 6th, 8th, 4th, 10th, 3rd and 15th, respectively according Kempthorne method. Also their SCA effects, ranks were 1st, 2nd, 5th, 3rd, 8th, 4th and 9th, respectively, according Yang method. Meanwhile, the lowest seven hybrids for mean performance were (Sk24×Sk18) followed by (Sk28×Sk18), (Sk29×Sk18), (Sk27×Sk18), (Sk30×Sk18), (Sk26×Sk14) and (Sk37×Sk1).

Table 5. Ranks of mean performance and SCA effects of 45 hybrids according to Kempthorne and Yang methods for grain yield across three locations.

Line	Tester (Sk14)			Tester (Sk1)			Tester (Sk18)		
	Mean rank	SCA effects rank		mean rank	SCA effects rank		Mean rank	SCA effects rank	
		Kempthorne	Yang		Kempthorne	Yang		Kempthorne	Yang
Sk24	27	28	27	1	1	1	45	45	45
Sk25	32	22	25	28	29	30	37	20	33
Sk26	40	40	39	35	36	36	16	2	6
Sk27	5	10	8	2	6	2	42	43	43
Sk28	15	7	10	14	11	12	44	41	44
Sk29	22	9	16	20	16	17	43	39	41
Sk30	23	12	20	30	27	28	41	33	38
Sk31	25	37	34	3	8	5	21	21	21
Sk32	9	18	14	8	25	15	31	26	29
Sk33	29	34	32	7	15	9	34	23	31
Sk34	12	13	13	19	31	24	36	30	35
Sk35	24	32	26	13	24	18	26	17	22
Sk36	33	38	37	17	35	23	4	4	3
Sk37	10	14	11	39	44	42	6	3	4
Sk38	18	19	19	38	42	40	11	5	7

Ranks of these hybrids in SCA effects according Kempthorne method were 45th, 41st, 39th, 43rd, 33rd, 40th and 44th, while according to Yang were 45th, 44th, 41st, 43rd, 38th, 39th and 42nd. These results showed that the SCA effects were closer with mean performance of hybrids for grain yield according to Yang method than Kempthorne method. Therefore, Yang equation is more beneficial to the breeders for selection of superior hybrids depend on SCA effects.

Simple correlation coefficient

Simple correlation coefficients between, means of crosses, SCA effects according to both Kempthorne and Yang methods for grain yield are presented in Table (6). The results showed that the correlation coefficient between mean performance and SCA effects of crosses according to Yang (0.964**) was higher than the correlation coefficient between mean performance and SCA effects according to Kempthorne (0.829**), indicating that the SCA effects of Yang was more correlated or consistent with mean performance of hybrids, hence it is more applicable to maize breeders. Rong (1983), Wu *et al* (2006) and Mosa *et al* (2024a) stated that the specific combining ability effects according to Yang's method were effective in maize breeding programs. Also, the results in Table (6), showed that the correlation coefficient between SCA effects which estimated by both Kempthorne and Yang was positive and highly significant, which means that the two methods were going in same direction. From the above results, it is concluded that both methods for estimation of SCA effects were inter correlated, however the Yang method was higher consistence with mean performance of hybrids. So selection of superior hybrids by mean performance or by SCA effects were corresponding, hence estimate SCA effects by Yang method is more practical for maize breeders compared with Kempthorne method.

Table 6. Simple correlations coefficient between mean performance, SCA effects according to Kempthorne and SCA effects according to Yang of hybrids for grain yield.

Correlation	Mean performance	SCA effects of Kempthorne
SCA effects of Kempthorne	**0.829****	**-**
SCA effects of Yang	**0.964****	**0.948****

**** Indicate significant at 0.01 level of probability.**

Heterotic groups

The purpose of estimating maize heterotic groups is to improve maize breeding efficiency by reducing crosses among intra group lines and increasing intergroup crosses to increase developing of potential superior hybrids, hence the 15 inbred lines in this study were divided into groups depending on its GCA effects plus its SCA effects with every tester (HSGCA) for grain yield according to Fan *et al* (2009) as presented in Table (7).

Table 7. Estimates of heterotic groups using specific combining ability effects of both Kempthorne and Yang plus general combining ability effects (HSGCA) method for grain yield.

Line	HSGCA					
	Kempthorne			Yang		
	Tester Sk14 (A)	Tester Sk1 (B)	Tester Sk18 (C)	Tester Sk14 (A)	Tester Sk1 (B)	Tester Sk18 (C)
Sk24	-0.85	6.52	-6.74≠	-0.79	7.10	-7.93≠
Sk25	-1.21	-1.95≠	-0.86	-1.64	-1.86	-2.54≠
Sk26	-5.12≠	-3.68	3.61	-5.74≠	-3.78	1.74
Sk27	3.16	4.65	-4.06≠	4.02	6.04	-4.44≠
Sk28	1.36	0.48	-5.47≠	1.00	0.64	-7.08≠
Sk29	-0.03	-0.80	-5.18≠	-0.78	-1.04	-7.18≠
Sk30	-0.29	-2.18	-3.02≠	-0.96	-2.34	-4.94≠
Sk31	-0.51≠	4.49	2.56	0.82	6.35	2.65
Sk32	2.26	1.42	1.33	3.34	3.02	1.15
Sk33	-0.94≠	1.85	0.59	-0.44≠	2.86	-0.16
Sk34	1.64	-0.71≠	-0.49	1.96	0.13	-1.42≠
Sk35	-0.30≠	0.51	1.74	0.27	1.60	1.06
Sk36	-1.75≠	-0.04	6.02	-0.80≠	1.39	5.72
Sk37	1.90	-5.83≠	5.57	2.42	-4.79≠	4.84
Sk38	0.70	-4.74≠	4.40	1.00	-3.91≠	3.45

≠ means that this inbred line belongs to tester group.

The 15 inbred lines were placed into each tester heterotic group, then keeping the inbred line with the tester heterotic groups when its HSGCA had the smallest value or largest negative value, while if the inbred lines had positive HSGCA effects with all representative testers, it will be cautions to assign that inbred line to any heterotic group to get final groups. So, dividing inbred lines depending on GCA effects plus SCA effects of Kempthorne showed that group (A) of the tester inbred line Sk14 included the inbred lines Sk26, Sk31, Sk33, Sk35 and Sk36, group (B) of the tester inbred line Sk1 included the inbred lines Sk25, Sk34, Sk37and Sk38 and group (C) of the tester inbred line Sk18 included the inbred lines Sk24, Sk27, Sk28, Sk29 and Sk30, while this method was not able to classify the inbred line Sk32. The groups according to GCA effects plus SCA effects of Yang were divided as follows, group-A (Sk14): Sk26, Sk33 and Sk36, group-B (Sk1): Sk37 and Sk38 and group-C (Sk18): Sk24, Sk25, Sk27, Sk28, Sk29, Sk30 and Sk34, however this method was not able to classify the inbred lines Sk31, Sk32 and Sk35. These results showed that the groups; (A), (B) and (C) were different in the number of inbred lines in each group due to SCA effects of Kempthorne and SCA effects of Yang. Gurung *et al* (2009) stated that the inbred lines within the same group are similar genetically, while between the two groups are dissimilar genetically. Ceccarelli (2015) stated that if the heterotic grouping improves the identification of viable commercial hybrids, the per-hybrid cost will actually be reduced. Mahato *et al* (2021) stated that evaluating of large number of parental lines and their all possible cross combinations will be impractical without knowing heterotic grouping.

Efficiency of heterotic group (HSGCA)

Comparison of the efficiency of HSGCA estimated using SCA effects-Kempthorne plus GCA effects and HSGCA assessed using SCA effects-Yang plus GCA effects is shown in Table (8). The best heterotic grouping methods is the one that allowed inter-heterotic group crosses to produce more superior hybrids than the within group crosses (Fan *et al* 2009, Tian *et al* 2015 and Mosa *et al* 2024a, b). Hence, the HSGCA method identified 22 and 25 high-yielding hybrids obtained from parents selected from different groups of Kempthorne and Yang, respectively for yield group-1 (included hybrids ≥ grand mean, this group is of interest to maize breeders). Meanwhile, HSGCA method identified 3 and 0 high-yielding hybrids obtained from parents within the same heterotic groups of Kempthorne and Yang, respectively for yield group-1. Meanwhile, in yield group-2 (included hybrids < grand mean), HSGCA identified 9 and 8 inter-heterotic hybrids and 11 and 12 within-heterotic hybrids of Kempthorne and Yang, respectively. The breeding efficiency was defined as the percentage of superior high yielding hybrids obtained across the total number of inter-heterotic crosses (Fan *et al* 2009). Based on this, the HSGCA which estimated using SCA effects of Yang was more efficient (75.76%) in classification of inbred lines into heterotic group compared to HSGCA estimated by SCA effects of Kempthorne (70.97%). Fan *et al* (2016) reported that based on inbred lines ability to produce superior hybrids, maize parental lines have been grouped into heterotic groups. Akinwale(2021) stated that, classification of inbred lines is pivotal for effective hybrid breeding programs, as it enables breeders to strategically select parental lines from specificheterotic group to maximize heterosis and develop hybrids with superior performance.

Table 8. Number of hybrids classified by the mean grain yield for HSGCA heterotic group method and breeding efficiency of HSGCA.

Yield group	Hybrid type	HSGCA	
		Kempthorne	Yang
Group-1 (27.33-35.39)	Inter-group	22	25
	Within-group	3	-
Group-2 (18.59-27.32)	Inter-group	9	8
	Within-group	11	12
Number of inter-group		31	33
Number of within-group		14	12
Breeding efficiency%		70.97%	75.76%

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تقدير تأثيرات القدرة الخاصة على الإئتلاف بإستخدام طريقتين وإرتباطها مع متوسطات الأداء والمجاميع الهجينية فى الذرة الشامية

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تستخدم تأثيرات القدرة الخاصة على الإئتلاف فى التعرف على أفضل أزواج السلالات قدرة فى إنتاج هجن متفوقة. إشتمل تحليل السلالة × الكشاف على ٤٥ هجين (مُتحصل عليها من التهجين بين ١٥ سلالة و ٣ كشافات) تم تقييمها فى ثلاثة مواقع لصفة محصول الحبوب موسم ٢٠٢٣. تهدف هذه الدراسة إلى المقارنة بين تقدير تأثيرات القدرة الخاصة على الإئتلاف بطريقة Kempthorne وطريقة Yang، وعمل مجاميع هجينية للسلالات، وكذلك التعرف على أفضل الهجن فى محصول الحبوب. تم إستخدام تصميم القطاعات الكاملة العشوائية (RCBD) فى ثلاث مكررات لكل موقع. أظهرت النتائج أن التباين الراجع للسلالات والكشافات والسلالات×الكشافات وتفاعلها مع المواقع كان معنوياً لصفة محصول الحبوب. كانت تأثيرات الفعل الوراثى غير المضيف هى المتحكمة فى وراثة صفة محصول الحبوب. أظهرت السلالات Sk27 ، Sk31 ، Sk32 ، Sk36 قدرة عامة على الإئتلاف مرغوبة لصفة محصول الحبوب. تفوق الهجينين (Sk24×Sk1) ، (Sk27×Sk1) فى محصول الحبوب عن هجين المقارنة (SC168). كان عدد الهجن التى أظهرت معنوية موجبة أو سالبة لتأثيرات القدرة الخاصة على الإئتلاف طبقاً لطريقة Yang أعلى من المقدرة طبقاً لطريقة Kempthorne وهذا يعنى أن طريقة Yang هى الأفضل فى توضيح تأثيرات القدرة الخاصة على الإئتلاف. كذلك كان التلازم المظهرى بين متوسطات الهجن وتأثيرات القدرة الخاصة على الإئتلاف والمقدرة بطريقة Yang أعلى من المقدرة بطريقة Kempthorne وبالتالى تعتبر طريقة Yang عملية أكثر للمربين. تقدير المجاميع الهجينية بطريقة (HSGCA) المقدرة بإستخدام تأثيرات القدرة العامة على الإئتلاف بالإضافة إلى تأثيرات القدرة الخاصة على الإئتلاف المقدرة عن طريق Yang أكثر فاعلية عن (HSGCA) المقدرة عن طريق Kempthorne. خلصت هذه الدراسة إلى أن طريقة Yang لتقدير تأثيرات القدرة الخاصة على الإئتلاف أكثر إفادة لمربى الذرة الشامية فى الإنتخاب للهجن المتفوقة عن طريقة Kempthorne.

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