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RESEARCH ARTICLE

Combining ability for grain yield and grain components of sorghum hybrid containing high lysine, threonine, iron and zinc content in mali

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Abstract

Sorghum is a staple food in Mali, yet grain yields are low and do not contain high lysine, threonine, iron and zinc content. The development of fortified hybrids could generously enhance grain yields and nutrients content for smallholders' farmers. In the present study, male parents KO-BC1-F6-1053, SB-BC_1-F6-1090, SB- B BC1-F6-1036, SB- BC1-F6-1053 and female parent 216-2AP4-5 identified as a good general combiners for the most of the characters under study. The predominance of additive gene action was observed and high heritability were identified in the inheritance of these traits. Twenty hybrids had significant better parent heterosis for grain yield. For the mineral content (iron and zinc), four hybrids obtained a better parent heterosis for ion and then zinc. Seven hybrids obtained a significant better parent heterosis more productive, stable and well adapted for studied zones. Top hybrids for high yield 12A/BE-BC1-F6-2070 (4610.5 kg/ha) and 216-2AP4-5/KO-BC1-F6-1053 4608.2 (kg/ha) identified as superior based on *per se* performance and specific combining ability in the one of the parents. The identified crosses and parents are worthy to be utilized for the future breeding.

Key words: Combining ability, sorghum hybrid, heterosis, yield, gene action

Introduction

In Africa, sorghum remains an essential crop for food security in rural areas. Africa's share is estimated at 32% of the global harvest. It is generally cultivated both for its grain, which is used for human food, and for its straw, which is used as fodder. Sorghum is nevertheless an essential option for meeting the future food needs of West Africa. Sorghum, along with millet, is an essential food source of energy, protein, vitamins and minerals for people in Asia and Africa. The guinea type sorghum is the most cultivated in West Africa and in particular in Mali. It is one of the sorghums most appreciated by farmers because of its grain quality (culinary quality) and its good level of tolerance to major insects and diseases.

However, its yield, although stable, remains low and poor in nutrients according to Tefera (2020). With the aim of improving the nutritional value of sorghum in Mali, 5 lines of high digestibility and high lysine content developed by Purdue University in the USA were introduced in Mali and crossed with 6 elite varieties of the sorghum program of the 'Institute of Rural Economy (IER). In the present study the same material is used for the combining ability study. One of the best approaches to significantly increase the production and productivity of sorghum while maintaining its adaptability and interesting characteristics is the development of F_1 hybrids with characteristics of the guinea race, the most dominant in Mali. Several studies highlighted the advantage of hybrids over parental forms. Various genes with complex gene action and consequently a complete comprehension on the nature represent the qualities like grain yield and its parts and size of gene action, learning on the combining ability of parents and hybrids through appropriate breeding techniques was fundamental to establish plant-breeding programme. Sarker *et al.,* (2002) believed that, the combining ability impacts and helps in choosing the good parents and crosses for using heterosis and include them in the development of desirable hybrids and segregants.

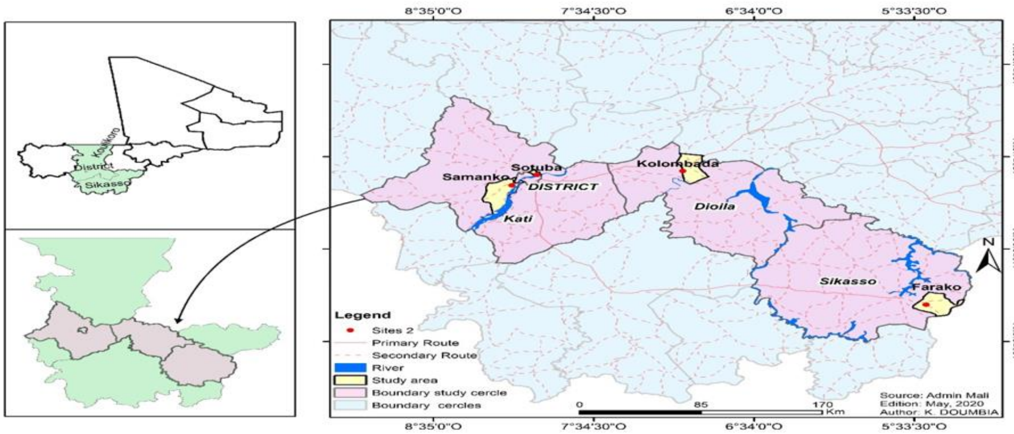
Sorghum is characterized mostly as a self-pollinated plant, however heterosis has been used to enhance its profitability. Although heterosis was exhibited as ahead of schedule as 1927 in sorghum (Conner *et al.,* 1927), its use was conceivable simply after the disclosure of a stable and heritable cytoplasmic-atomic male-sterility (CMS) system (Stephens *et al.,* 1954). From that point forward, many hybrids have been created and improved agriculture in Asia, the Americas, Australia and Africa. The hybrids have afforded essentially to expanded grain and forage yields in a few nations. As of now, most of the sorghum hybrids are sown in USA, Australia and China. Kambal and Webster (1965) have pointed the significance of both: general and combining ability is the consequence of added additive gene impact, while specific combining ability is viewed as made of non-allelic interaction. According to Kempthorne (1957) Line x testers mating system for combining ability, which is the useful method to choose hybrids and superior parents relied on GCA and SCA. As indicated by Makanda *et al.,* 2010, growing environment plays an important role on sorghum production. Uses of genetic fluctuation is one the most significant tools for breeders especially in sorghum breeding. Hence the main objectives of the present study was to evaluate hybrid sorghum containing high lysine, threonine, ion and zinc content. Determine the combining ability of hybrids for grain yield, and its components for four sites. And to estimate the heterosis effect of hybrids across environments compared to parents.

Material and methods

The experiment was carried out at Sotuba, Kolombada, Farako and Samanko Agricultural Research Stations and Sub-stations located respectively in the regions of Bamako, Koulikoro and Sikasso (Figure 1).

During 2018 and 2019 from all localities, the average rainfall observed varied from 454.3 to 1235.9. The production of F_1 fortified hybrid sorghum's seed was conducted during two off seasons (2018 and 2019 years) at Sotuba Agricultural Research Station located in the region of Bamako. In order to avoid cross pollination, all panicles are protected with selfing bags. Finally, manual crosses were used to produce F_1 hybrid seeds. The abbreviations and parameters for data collection is given in table1.

Figure 1: Maps of the testing locations (Source: SIG, Sotuba 2020)



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The data collection on the trials as per Line x Tester model of Kempthorne (1957) were subjected to analysis of variance as per the Line x Tester model given by Singh and Chaudhary (1985) on alpha lattice design using the software AGD-R. The evaluation of genetic gain for each hybrid about their parents gave an estimation of the heterosis. The heterosis of better parent was estimated by the following formula:

Better parent Heterosis (%)=$(MF_1 - BP/MF_1) \times 100$

MF_1 = Hybrid mean

BP =Better parent

Least significant difference (LSD) was used for mean separation.

Table 1: Parameters for data collection

Parameters	Abbreviations	Unit
Plant height	PH	Cm
Number of harvested hills	NHH	Number
Panicle harvested number	PHN	Number
Panicle weight	PW	g/plot
Grain weight	GW	g/plot
Panicle length	PL	cm
Grain number/panicle	GN/P	Number
Number de whorls /panicle	NW/P	Number
Primary branches number/panicles	PBN/P	Number
1000grains weight	1000GW	g/plot
Grain of quality (Endosperm texture)	GQ	Scores: 1(Completely corneous; 2 (Mostly corneous); 5 (Intermediate); 7(Mostly starchy) and 9 (Completely starchy).
Biochimical analysis (lysine, threonine, ion and zinc)	BA	Content in g

Results and discussion

Over two years (2018 and 2019), variance due to lines (GCA MP) were significant for all the parameters measured showing that the genetic variability is due to the male parents. Variance due to testers (GCA FP) was also significant for all trait except lysine and threonine content. There was significant difference for the hybrids (SCA, MP-FP) for all traits exclude number of whorls per panicle, iron and zinc content. This showed the presence of non-additive gene action for this characteristic, which is demonstrative of huge hybrid deviations from the parents. The lack of variability observed in the combining ability of the hybrids could be explained by the fact that the female and male parents are almost similar for the number of whorls per panicle (Table2).

Table 2: **Mean squares of GCA and SCA over two years for studied traits of parents and their F_1 hybrids for two years**

Parameters	GCA MP	GCA FP	SCA (FP.MP)
Cycle	250.38**	2003.51**	202.18**
PH	21253.51**	126.99**	6687.78**
PL	81.36**	482.06**	31.15**
PBN/P	1596.48**	45229.91**	367.67*
GN/P	5452929.63**	10228743.63**	5591740.81**
NW/P	17.15**	31.70*	7.01ns
Yield	11493415.07**	14036080.10**	3187757.83**
GQ	1.36**	35.68**	1.42*
Lysine	6.97*	3.047ns	0.25*
Threonine	36.10*	6.54ns	2.90*
Iron	150.42**	224.51*	77.12ns
Zinc	64.61**	113.28*	24.97ns

General and specific combining ability effects on yield and yield related traits and grain quality parameters

Cycle

The gca effects for cycle of male parents over two years ranged from -0.07 to 1.04 . Female parent 216-2AP4-5 (1.24) obtained the highest positive gca effects over the female 12 A (-1.24). Indicating that 216-2AP4-5 is a good combiner for earliness (Table not shown).The combination of Line x Testers showed that, 12A / SB-BC1-F6-1053 (4.29), 12A / KO-BC1-F6-1053 (3.01), 216-2AP4-5 / SB- BC1-F6-1068 (1.25) and 216-2AP4-5 / KO-BC1-F6-1086 (1.06) had highest positive significant sca effects. The ratio of variance due to GCA/SCA was 1.48 (Table 4), indicating the presence of additive gene action in the transmission of this trai. A similar trend in this result was reported by Can *et al.,* (1997), Andrews *et al.,* (1997) while the action of non-additive genes controlling this trait has been reported by Chaudhary *et al.,*. (2006). Hovny *et al.,* (2005) and El-Mottaleb (2009) reported the predominance of additive and non-additive gene action for the transmission of this character. The cycle gain of the hybrids over the better parent ranged from 7.55 to -1.87% (Table 3). The hybrids 12A / KO-BC1-F5-9 (-6.64%) recorded the highest negative value of better parent heterosis. Eight hybrids from the female 12 A and one from the female 216-2AP4-5 were found to be earliness. These findings of heterosis for earliness are in accordance with those reported by Kenga *et al.,* (2005).

Plant height

The gca effects of male parent for plant height ranged from -11.61 to 23.12 (Table 5.10). The lines BE-BC1-F6-73 (23.12), BE-BC1-F6-1105 (12.81) recorded the largest positive values of gca for male parents (Table not shown). The line 216-2AP4-5 (1.88) recorded negative significant gca effect of female parent while 12A recorded positive (-1.88) one.The combination of line by testers revealed that, the hybrids 12A/ SB- BC1-F6-1090 (3.61) and 216-2AP4-5 / BE- BC1-F6-73 (6.48) had significant positive sca effects while significant negative sca effects were obtained by 12A / BE- BC1-F6-1048 (-7.13) and 216-2AP4-5 / BE- BC1-F6-2070 (-4.13) (Table 3).The ration of GCA to SCA variance was more than the unity for plant height revealed that the predominance of additive gene action for the inheritance of this character. Additive variance was more than dominance variance for this trait. This result concurred with those reported by Tadesse *et al.,* (2008) and Degu *et al.,* (2009). The inheritance of this trait by both additive and non-additive gene was illustrated by El-Mottaleb (2009) and Mahdy *et al.,* (2011).

Panicle length

The range of gca effects varied from -0.05 to 1.20 among male parents regards to panicle length. The lines BE-BC1-F5-1048 (0.68) and BE-BC1-F6-CT-2016 (-0.71) recorded significant positive gca effects while the line SB-BC1-F6-1105 (-0.79) recorded the highest negative gca effects .The line 12A (0.65) recorded positive significant gca effect of female parent while 216-2AP4-5 recorded negative (-0.65) gca effect .The combination of line by testers shown that, the hybrids 12A/ BE-BC1-F6-CT-2016 (1.19) and 216-2AP4-5 / KO-BC1-F5-1050 (0.93) obtained the highest sca effects. Higher magnitude of GCA variance than SCA variance showed the preponderance of additive gene action in the inheritance of panicle length. this outcome is in accordance with the results found by Tadesse *et al.,* (2008) opposite to those results obtained by El-Mottaleb and Asran (2004), El-Menshawi (2005) and Chaudhary *et al.,* (2006).

The hybrids gain for panicle length over the better parent varied between 4.37 and 30.55% (Table 3). The highest positive value of better parent heterosis were obtained by the hybrids 12A / BE-BC1-F6-CT-2016 (30.55%) and 12A / BE-BC1-F6-1048 (26.80%). A significant positive better parent heterosis was found.

Primary branches numbers (PBN/P)

The range of gca effects varied between 6.75 and -0.48 among male parents regards to primary branches numbers. The combination of line by testers shown that, the hybrids 12A/ BE-BC1-F6-1105 (2.29), 12A / BE-BC1-F6-2070 (1.22) obtained the highest sca effects while the hybrids 12A/ KO-BC1-F6-1050 (-1.32) and 216-2AP4-5 / BE-BC1-F5-1105 (-3.74) recorded negative significant sca effects regards to line x testers. Additive gene was identified to be significant as SCA variance was less than GCA variance. A similar trend in the results was reported by Patel *et al.,* (1991).The primary branches number per panicle gain of the hybrids over the better parent ranged from 17.50 to -3.84 % .The hybrids 216-2AP4-5 / SB-BC1-F6-1036 (17.50%) and 216-2AP4-5 / SB-BC1-F6-1053 (17.41%) recorded the largest positive value of better parent heterosis. In contrast, the lowest positive value was obtained by the hybrid 216-2AP4-5 / SB-BC1-F6-1086 (3.84%). Some significant better parent heterosis was also found in this study for primary branches per panicle. The same results were obtained by Patel *et al.,* (1987).

Grain number per panicle

The range of gca effects varied between 6.04 and -0.02 among male parents regards to grain number per panicle. The lines SB-BC1-F6-1105 (6.04) recorded significant positive gca effects while the line BE-BC1-F6-1105 (-5.24) recorded highest value of gca effect. The combination of line by testers shown that, the hybrids 12A/ SB-BC1-F6-1036 (4.89), 12A / SB-BC1-F5-1068 (4.68), 216-2AP4-5 / KO-BC1-F5-1053 (8.63) and 216-2AP4-5 / SB-BC1-F6-1053 (9.77) obtained the highest sca effects while the hybrids 12A/ BE-BC1-F6-73(-8.40) and 216-2AP4-5 / SB-BC1-F6-1068 (-5.56) recorded negative significant sca effects regards to line x testers .The ration of GCA to SCA variance was more than the unity for grain number per panicle revealed that the predominance of additive gene action for the inheritance of this character. The outcome observed are in opposite with earlier works done by of Chaudhary *et al.,* (2006). The hybrids gain for grain number per panicle over the better parent varied between 23.80 and 129.45% . The grain number per panicle showed a significant positive better parent. These results concurred with those reported by Nandanwankar (1990) that grain number per panicle was the significant supporter of heterosis for grain yield in sorghum.

Number of whorls per panicle

Number of whorls per panicle is important trait to obtained maxmimum grain yield. The range of gca effects varied from -0.02 to 0.62 among male parents regards to number of whorls per panicle. The lines BE-BC1-F6-1048 (0.62) recorded significant positive gca effects while the line KO-BC1-F6-1086 (-0.45) recorded highest value of gca effects. The hybrids 12A/ BE-BC1-F6-1048 (0.05) obtained the highest sca effects. For number of whorls per panicle, grain quality and grain yield, additive gene action was identified to be preponderance in the inheritance of these traits as GCA variance was more than SCA variance. A similar trend in results was reported by Kenga *et al.,* (2005) and Tadesse et al. (2008). While the action of non-additive genes to control this trait has been reported by Kenga *et al.,* (2004), El-Menshawi (2005) and Mahdy *et al.,* (2011).

El-Mottaleb (2009) and Makanda *et al.,* (2009) emphasized the importance of additive and non-additive gene action in the transmission of this trait. The number of whorls per panicle gain of the hybrids over the better parent ranged from 10.92 to -1.70 % (Table 3). The hybrids 216-2AP4-5 / BE-BC1-CT-2016 (10.92%), recorded the largest positive value of better parent heterosis.

Yield

The range of gca effects varied from -310.97 to 305.66 among male parents regards to yield. The lines BE-BC1-F6-2070 (305.66), KO-BC1-F6-1053 (265.85), SB-BC1-F6-1036 (248.64), SB-BC1-F6-1053 (219.25) and SB-BC1-F6-1105 (281.20) recorded significant positive gca effects while the line BE-BC1-F6-73 (-310.97) recorded highest negative value of gca effects (Table not shown).The line 12A (-47.52) recorded negative significant gca effect of female parent while 216-2AP4-5 recorded positive (47.52) gca effect .The hybrids 12A/ BE-BC1-F6-2070 (478.189) and 216-2AP4-5/KO-BC1-F5-1053(454.93) obtained the highest sca effects. The hybrids 12A/ KO-BC1-F6-1050 (-521.30) and 216-2AP4-5 / KO-BC1-F6-1050 (-466.12) recorded negative significant sca effects regards to line x testers.

The hybrids gain for yield over the better parent varied between - 5.97 and 100.09% (Table 3). Most of the hybrids obtained moderate to high gain of better parent heterosis. The highest positive value of better parent heterosis were obtained by the hybrids 216-2AP4-5 / KO-BC1-F6-1053 (100.09 %), 216-2AP4-5 / BE-BC1-F6-1105 (90.65 %) and 12 / BE-BC1-F6-2070 (99.83 %) while the hybrid 12A / KO-BC1-F6-1050 (-5.97%) recorded lowest negative value of better parent heterosis (Table 3). In this research, better parent heterosis varied from 6.36 to 100.9 % for grain yield which is an agreement with findings obtained by El-Dardeer *et al.,* (2011). Thus, the gain of better parent heterosis confirming the performance of these hybrids compared to better parent.

Grain quality

The range of gca effects varied from -0.10 to 0.50 among male parents regards to grain quality. The lines BE-BC1-F6-1048 (0.50) and SB-BC1-F6-1053 (0.50) recorded significant positive gca effects while the lines KO-BC1-F5-9 (-0.10) and BE-BC1-F6-1105 (-0.10) recorded highest value of gca effects (Table not shown). The hybrids 12A/ BE-BC1-F6-1105 (0.08), 12A/ SB-BC1-F6-1068 (0.05), 216-2AP4-5 / SB-BC1-F6-1053 (0.19) and 216-2AP4-5 / SB-BC1-F5-1036 (0.17) obtained the highest sca effects. The hybrids gain for grain quality over the better parent varied between - 0.42 and 26.88% (Table 3). The highest positive value of better parent heterosis were obtained by the hybrids 216-2AP4-5 / SB-BC1-F6-1053 (26.88%).The range of gca effects across site varied between from -0.24 to 0.82 among male parents regards to lysine content (Table not shown). The highest positive content of better parent heterosis were obtained by the hybrids 216-2AP4-5/SB-BC1-F6-1090 (73.33%) and 12A / SB-BC1-F6-1090 (54.22%).

Threonine

The range of gca effects varied between from -0.77 to 1.63 among male parents regards to threonine content. The hybrids 12A/ SB-BC1-F6-1090 (0.33) and 216-2AP4-5 / SB-BC1-F5-1036 (0.43) obtained the highest sca effects. The highest positive content of better parent heterosis were obtaid by the hybrids 12A / SB-BC1-F6-1090 (152.21%) and 216-2AP4-5 / SB-BC1-F6-1090 (146.26%).

Iron

The range of gca effects varied from -0.25 to among 4.49 male parents regards to ion content. The hybrids 12A/ KO-BC1-F6-1050 (0.59) and 216-2AP4-5 / BE-BC1-F5-1105 (0.34) obtained the highest sca effects. The gain of iron content for the hybrids over the better parent ranged from 29.23 to -0.22 %. The hybrids 12A / KO-BC1-F6-1050 (29.23%), 12A / KO-BC1-F6-1053 (9.43%) and 216-2AP4-5 / KO-BC1-F6-1050 (7.47%) recorded the highest positive content of better parent heterosis.

Zinc

The range of gca effects varied from -0.35 to 2.35 among male parents regards to zinc content. The line 12A (0.62) recorded positive significant gca effect of female parent or tester while 216-2AP4-5 recorded positive (-0.62) gca effect. Some of the hybrids were found to involve high x low and low x high combinations in terms of gca indicating the role of the dominance gene action. Thus, it can be concluded that both inter and intra allelic interactions were involved in the expression of these traits. For amino acids (lysine and threonine) mineral content (iron and zinc), additive gene action was obtained to be predominance in the transmission of these traits as GCA variance was more than SCA variance. The preponderance of non-additive and additive gene action in the inheritance of these traits were reported by Govil and Murty (1973).

Variance components

The ratio of variances due to GCA and SCA for all parameters varied from 0.00 to 20.71 (Table 4) which indicates the greater the prediction of GCA alone then implies significant effects of additive genes actions while grain number per panicle obtained a low coefficient of GCA/SCA this implies the presence of dominant and/ or epistatic genes. GCA variances were higher than SCA variance for all characters except grain number per panicle. There was preponderance of additive gene action and promising hybrids can be recognized and selected on their prediction from GCA effects. GCA and SCA variances were equal for grain number per panicle, additive and non-additive genes were equally important in the expression of the character. Most of the characters across two years recorded moderate to high estimates of broad sense heritability (between 0.00 and 0.91) and narrow sense heritability (from 0.00 to 0.87). It indicates characters were least influenced by environment then selection for improvement of such characters may be useful.

Stability analysis for grain yield performance of checks and fortified hybrids at the four zones

Based on the average yield in two years (2018 and 2019) for each locality, the grain yield performance was identified (Table 5). At Farako, the best hybrids yielded were 216-2AP4-5/SB-BC1-F6-1105 (4946.5 kg-ha), 12A/BE-BC1-F6-2070 (4858 kg-ha), they were also more productive than recurring parents and hybrids checks. At Kolombada, the best hybrids grain yield was obtained by 12A/BE-BC1-F6-2070 (4887 kg-ha) and at Sotuba, the hybrids 216-2AP4-5/SB-BC1-F6-1090 (5230 kg-ha) At Samanko, most productive hybrids was 216-2AP4-5/BE-BC1-F6-1105 (5228 kg-ha). El-Dardeer *et al.,* (2011) through their heteosis studies identified promising and stable hybrids which supports the present findings.

Table 3: Estimate of heterosis for studied parameters

Hybrids	Cycle	GQ	PL	PBN/P	GN/P	NW/P	YIELD	Iron	Zinc	Lysine	Threon.
12A/BE-BC1-F6-1048	-3.94	-8.35	26.8	-20.45	35.78	7.67	49.16	-31.2	-45.4	-	-
12A/BE-BC1-F6-1105	3.11	-0.88	16.94	-17.05	49.79	0.34	41.15	-20.3	-5.17	-	-
12A/BE-BC1-F6-2070	6.12	-9.4	18.56	-5.29	66.24	4.88	99.83	-14.3	-9.32	-	-
12A/BE-BC1-F6-73	-5.1	-12.4	22.16	-22.38	23.8	0.61	19.73	-5.2	6.47	-	-
12A/BE-BC1-F6-CT-2016	-4.03	0.63	30.55	-15.34	56.07	2.65	58.24	-12.5	-0.48	-	-
12A/KO-BC1-F5-9	-6.64	-18.6	21.41	-21.17	37.75	-1.7	63.18	-5.8	0.54	-	-
12A/KO-BC1-F6-1050	1.32	-7.01	20.76	-21.38	100	-4.75	-5.97	29.23	18.48	-	-
12A/KO-BC1-F6-1053	7.55	-5.35	21.31	-11.28	79.87	0.41	63.05	9.43	13.15	15.9	21.49
12A/KO-BC1-F6-1086	-4.87	-6.83	17.35	-23.76	38.55	-3.66	55.86	-12.5	5.93	-	-
12A/SB-BC1-F6-1036	4.76	-16.9	21.92	-6.61	68.69	6.85	81.65	-9.19	-5.01	7.68	7.15
12A/SB-BC1-F6-1068	-1.87	-0.88	24.23	-21.98	95.1	-1.83	36.87	-20.5	0.7	-	-
12A/SB-BC1-F6-1090	-4.62	-6.83	22.27	-18.59	76.68	-3.05	60.54	4.58	-1.72	54.22	152.21
12A/SB-BC1-F6-1105	-2.52	-18.6	10.72	-25.26	63.47	-3.66	76.24	-1.74	31.68	-	-
216-2AP4-5/BE-BC1-F6-1048	4.53	13.98	18.14	9.79	90.36	8.01	48.98	-11.8	-22.8	-	-
216-2AP4-5/BE-BC1-F6-1105	4.33	3.95	5.33	-13.6	61.5	-4.68	90.65	-0.22	-21.2	-	-
216-2AP4-5/BE-BC1-F6-2070	3.98	17.22	17.7	14.05	58.95	9.16	71.4	-14.1	-36.2	-	-
216-2AP4-5/BE-BC1-F6-73	-1.92	6.66	15.05	5.24	51.38	0.34	61.92	-5.95	-7.11	-	-
216-2AP4-5/BE-BC1-F6-CT-2016	3.69	5.32	13.75	2.47	64.32	10.92	55.86	-18.8	-33.8	-	-
216-2AP4-5/KO-BC1-F5-9	4.45	-0.42	9.97	-4.5	109.3	-2.51	48.98	-26.2	-10.3	-	-
216-2AP4-5/KO-BC1-F6-1050	4.57	2.15	23.02	7.89	31.31	7.46	6.36	7.47	9.64	-	-
216-2AP4-5/KO-BC1-F6-1053	5.2	12.47	20.1	10.81	118.2	1.76	100.09	-28.3	-11.2	27.68	53.66
216-2AP4-5/KO-BC1-F6-1086	5.22	-2.54	4.19	-3.84	45.9	-2.24	69.62	-33.6	-2.16	-	-
216-2AP4-5/SB-BC1-F6-1036	2.5	22.37	17.94	17.5	61.02	7.12	78.1	-25.8	0.65	50.16	74.3
216-2AP4-5/SB-BC1-F6-1053	6.14	26.88	20.52	17.41	129.5	3.46	76.03	-4.13	1.02	-	-
216-2AP4-5/SB-BC1-F6-1068	6.08	4.37	22.78	5.44	69.86	-6.92	60.97	-30.1	-11.5	-	-
216-2AP4-5/SB-BC1-F6-1090	2.69	-0.49	15.77	0.26	73.38	-3.8	89.7	-23.1	-12	73.33	146.26
216-2AP4-5/SB-BC1-F6-1105	6.76	-3.77	7.04	-1.64	100.7	-4.41	87.11	-20.3	-23.1	-	-

Table 4: **Coefficient of variability, heritability and GCA/SCA**

Traits	**Line**	**Tester**	**Line x Tester**	**Genotype**	**Additive**	**Dominance**	**Environmental**	**H²**	**h ²**	**GCA/ SCA**
	Variances									
Cycle	1.5	3.6	6.8	10.5	42.2	27.3	6.9	0.9	0.5	1.5
PH	309.3	0	56.7	367.4	1469.7	226.7	411.7	0.8	0.7	6.4
PL	1.1	1.1	0.7	2.4	9.9	3.1	2.4	0.8	0.6	3.1
PBN/P	26.5	146.4	6.3	105	420	25.5	39.1	0.9	0.8	16.4
GN/P	0.0	13400	0	0	0	0	573498	0	0	0
NW/P	0.2	0	0	0.3	1.3	0.2	1	0.6	0.5	6
Yield	1697797	12732	76312	130080	520322	0	337457	0.6	0.6	1.7
Grain quality	0.0	0	0	0	0.3	0	0.1	0.7	0.5	3.6
Lysine	0.5	0.2	0	0.6	2.5	0.1	0	0.9	0.9	20.7
Threon.	2.1	0.1	0.2	2	8.3	1.1	0	0.9	0.8	7.1
Iron	5.0	1.4	0.9	6.5	26.1	3.7	8.5	0.7	0.6	6.9
Zinc	2.5	0.9	0.2	3.2	12.9	1.1	2.8	0.8	0.7	11.2

Table 5: Top crosses grain yield performance of genotype at across localities in kg/ha

Designation	**Genotype**	**FA**	**KO**	**SB**	**SKO**	**Mean**
12A/BE-BC1-F6-2070	G03	4858	4887	3947.5	4749.5	4610.5
216-2AP4-5/KO-BC1-F6-1053	G21	4266	4174	5013	4980	4608.2
216-2AP4-5/BE-BC1-F6-1105	G15	4626.5	3637	4105.5	5228	4399.2
216-2AP4-5/SB-BC1-F6-1090	G26	3364.5	3958.5	5230	4865	4354.5
216-2AP4-5/SB-BC1-F6-1105	G27	4946.5	3717.5	3802	4843	4327.2
12A/SB-BC1-F6-1036	G10	4767	3674.5	3717	4600.5	4189.7
216-2AP4-5/SB-BC1-F6-1036	G23	3587	3436	5120	4245	4097.0
12A/SB-BC1-F6-1105	G13	4155	3389.5	3968	4753.5	4066.5
216-2AP4-5/SB-BC1-F6-1053	G24	4073	4056.5	4160.5	3880	4042.5
216-2AP4-5/BE-BC1-F6-2070	G16	3662	3418	4280	4344.5	3926.1
216-2AP4-5/KO-BC1-F6-1086	G22	3183.5	3686.5	4021.5	4681	3893.1
LSD		1092	1034	1024	1047	
CV%		20.86	21.26	25.25	28.36	

Conclusion

In the frame of determine the combining ability of hybrids for grain yield, and its components, male parents KO-BC1-F6-1053, SB-BC1-F6-1090, SB-BC1-F6-1036, SB-BC1-F6-1053 and female parent 216-2AP4-5 had a good general combining ability (GCA) for studied characters. Regarding, the estimation of the heterosis effect over the better parent of hybrids across environments, the gain in grain yield of the best hybrids varied from 6.36 to 100 % compared to the better parent. The mineral content (Iron and zinc), height hybrids obtained a better parent heterotic. The identified crosses and parents are worthy to be utilized for the development of superior hybrids, breeding material containing high lysine, threonine, iron and zinc content.

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