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Combining ability analysis for yield and component traits in baby corn

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Abstract
A study was conducted to assess the general combining ability and specific combining ability effects for yield and component traits of some parental lines of baby corn. Using line x tester mating design, twelve inbred lines were crossed with three testers. Performance of the resulting thirty-six crosses were evaluated for nine agronomic traits including baby corn yield in randomized block design with three replications across two seasons. Mean sum of squares due to GCA of lines and SCA of line x tester interactions were found significant for yield and yield related traits studied, revealing the significance of both additive and non-additive gene effects in controlling the inheritance of these traits. Preponderance of additive gene effects was observed in the expression of plant height, ear height and baby corn girth. Conversely, non-additive gene effects appeared more important than additive gene effects for days to 50% tasselling, days to 50% silking, cob yield, cob weight, green fodder yield and baby corn length. Superior general combiners and cross combinations were identified, which appeared promising for further utilization for developing high yielding baby corn hybrids.

Keywords: Baby corn, combining ability, gene effects, inbred lines, line x tester

Introduction

Maize is the third most significant cereal crop farmed and consumed globally, behind rice and wheat. Many developed and developing nations around the globe depend heavily on this grain crop [1]. It stands out from the other cereals due to its diverse utility and ability to serve as food, fodder and a source of energy. Commercially, diverse types of maize, including baby corn, popcorn, sweet corn and quality protein maize are produced and marketed for various reasons. Increasing demand of baby corn for vegetable purpose and affordable production cost compared to other maize varieties offers great scope. India is a promising candidate to derive economic benefits as one of the potential producers of baby corn. Baby corn is a young, unfertilized cob of maize that is harvested early, within two to four days of the development of the silk [2]. Ears should be between two to four inches in length and less than two centimetres in diameter [3]. Due to its sweet and exquisite flavour, it is a highly well-liked vegetable that may be eaten either cooked or raw. Baby corn is a low-calorie, easily digestible food that is high in fibrous protein and has low caloric content [4]. Baby corn has an advantage over other crops grown for food because of its higher biological yield potential, quick growth, greater adaptability, and excellent fodder quality devoid of toxic pesticides.

Baby corn is economically profitable to peri-urban farmers, as harvested crop fetches a good price tag in the market with the advantage that the green stalk may be used as fodder. Therefore, adequate emphasis on the development of good quality high yielding hybrids of baby corn is required to ensure economic profitability [5]. Although there are many different ways to use baby corn, only scanty information based on a detailed evaluation of breeding potential is available [6]. The farmed baby corn type typically produces one to two cobs per plant. As the population and demand is rising, this number has to increase to four to five cobs per plant [7]. Many plant features and the selection for a larger cob yield are associated and a majority of these quantitative features exhibit complicated inheritance compounded by the influence of the environment. Precise information on combining ability status of parents and their crosses as well as relative contribution of additive and non-additive gene effects in the expression of traits of economic importance helps in formulation of effective breeding plan for hybrid development [8].

The present study was undertaken to elucidate the genetic nature and gene effects involved in the inheritance of cob yield and other related traits in baby corn. An attempt was made to assess the general (GCA) and specific (SCA) combining ability for yield and its components in some parental lines of baby corn for identification of superior combiners and promising cross combinations. Additionally, the testers were compared for their efficiency in evaluating inbred lines and estimate the combining ability of these lines.

Materials and Methods

Experimental material for the present study was derived by crossing twelve inbred lines with three testers from baby corn germplasm (Table 1). Thirty-six crosses generated through line x tester mating design were evaluated for nine agronomic traits including baby corn yield in randomized block design with three replications across two seasons (*rabi* and *kharif* seasons) at the research farm of TCA, Dholi, Muzaffarpur, Bihar (India). Each entry was sown in a two - rows plot of 4.8 m length and spacing was maintained as 60×20 cm. The observation were recorded on plant height (PH), ear height (EH), days to 50% tasselling (DT), days to 50% silking (DS), cob yield (CY), cob weight (CW), green fodder yield (GFY), baby corn length (BL) and baby corn girth (BG). Observations for morphological characters were recorded on five randomly selected plants in each entry, whereas phenological characters were recorded on plot basis. The data recorded in each season was initially subjected to statistical analysis separately for testing the significance of mean squares due to different sources. Subsequently, a combined analysis of variance was performed on the basis of pooled data. Combining ability analysis pooled over seasons was carried out according to model suggested by Kempthorne (1957) [9]. Biometrical genetic analysis was computed using SPAR-1 software.

Results and Discussion

Pooled analysis of variance for general and specific combining ability across seasons that mean sum of squares due to GCA of lines and SCA of line x tester interactions were found significant for yield and yield related traits studied. Analysis of variance therefore revealed the significance of both additive and non-additive gene effects in controlling the inheritance of these traits. It is highly intriguing that SCA variance for characteristics days to 50% tasselling, days to 50% silking, cob yield, cob weight, green fodder yield and baby corn length is higher than that for general combining ability (Table 2), indicating that non-additive gene action predominated in the regulation of the expression of these characters [2, 8]. Therefore, non-additive gene effects appeared more important than additive gene effects for days to 50% tasselling, days to 50% silking, cob yield, cob weight, green fodder yield and baby corn length. The SCA variance is not stable and fixable. Proportionally, the error component was very less than SCA variance in accordance with the findings of earlier researchers [9, 10].

Mean sum of squares due to GCA was higher than the SCA for plant height and ear height. Therefore, preponderance of additive gene effects was observed in the expression of plant height and ear height. The data on relative magnitude of additive and non-additive components further revealed the importance of additive effects in controlling the expression of baby corn girth. The results indicated the lesser genetic complementation among parents for alleles which show dominance [2, 10, 11]. The importance of non-additive gene effects observed in the inheritance and expression of some of the characters under present investigation was somewhat consistent with the findings of several researchers for days to 50% tasseling [12, 13], for plat height [12, 14, 15] and for length of baby corn [16]. Conversely, the higher value of GCA variance recorded for plant height and ear height than its SCA variance indicated the predominance of additive gene effects. This is suggested that simple selection can be effective to make desirable improvement of certain character under study.

Approximation of GCA for different traits has been represented in Table 3. GCA results from the additive gene effects, and based on this impact, the parent BCL-10 was identified as a good general combiner for plant height, ear height, cob weight, baby corn girth and green fodder yield. Similarly, the parental inbred line BCL-14 was good combiner for plant height, ear height, green fodder yield and cob weight. The tester BCL-15 was good combiner for plant height, ear height green fodder yield and baby corn girth. Whereas the inbred line BCL-14 seemed to be good combiner for yield related four component traits. Similar approach based identification of good general combiners has also been reported by earlier investigators for plant height [17], baby corn length , baby corn weight and baby corn yield per plant [16].

Table 1: Description of the parental lines used in this study

S.N.	Parental line	Designation
1.	P-504	BCL-01
2.	Dholi POP-65-DS 10	BCL-02
3	HKI-1105 CIMMYT	BCL-03
4	HKI-586	BCL-04
5	P-502	BCL-05
6	POP 31C4S_5-B-85#-1-4-3-B_7*-43_8*	BCL-06
7	DTPYC_9-F46-3-4-1-1-B_8*	BCL-07
8	13486-2	BCL-08
9	G_{18} Seq C5 F_{76}-2-1-2-1-B_8*-B□	BCL-09
10	CM-139	BCL-10
11	CM-142	BCL-11
12	POP-147	BCL-12
13	HKI-323-B	BCL-13
14	2006-6-CML-471	BCL-14
15	BML-6	BCL-15

Table 2: Estimates of GCA and SCA variances for yield and component traits across the seasons

Parameter	PH	EH	DT	DS	CY	CW	BL	BG	GFY
GCA	61.950	40.410	0.610	0.740	4.320	36.240	0.006	0.007	91.390
SCA	45.140	12.910	1.420	2.530	45.960	140.700	0.057	0.008	261.700
Error	6.097	4.590	0.650	1.400	6.400	5.350	0.021	0.003	16.600
σ^2GCA /σ^2SCA	0.793	2.428	0.389	0.327	0.055	0.134	0.103	0.600	0.186
σ^2 g	30.978	20.200	0.300	0.370	2.160	18.120	0.003	0.003	45.690
σ^2s	39.050	8.320	0.770	1.130	39.560	135.350	0.029	0.005	245.100
σ^2e	6.097	4.590	0.650	1.400	6.400	5.350	0.021	0.003	16.600
σ^2D	39.050	8.320	0.770	1.130	39.560	135.350	0.029	0.005	245.100
σ^2A	61.950	40.410	0.610	0.740	4.320	36.241	0.006	0.007	91.391
σ^2A/ σ^2D	1.586	4.856	0.792	0.654	0.109	0.267	0.207	1.400	0.372

PH = Plant height,; EH = Ear height; DT = Days to 50% tasselling; DS = Days to 50% silking; CY = Cob yield; CW = Cob weight; GFY = Green fodder yield; BL = Baby corn length; BG = Baby corn girth.

A comprehensive assessment of the data in terms of SCA effects provides insight into the fact that none of the hybrids demonstrated particularly favourable significant SCA impacts for the majority of characteristics. (Table 4). SCA is the result of dominance and non-allelic interactions [18]. But cross BCL-10×BCL-12 showed significant SCA effect for days to 50% silking, cob yield per plant and cob weight and BCL-05×BCL-03 also showed significant SCA effect for cob yield per plant and cob weight. Cross BCL-05×BCL-03 also had negative significant SCA effect for baby corn length. BCL-04×BCL-03 showed significant SCA effect for plant height and cob yield per plant and BCL-08×BCL-15 showed significant effect for cob yield per plant. Crosses BCL-04×BCL-03 and BCL-08×BCL-15 exhibited a negatively significant SCA effect. Similarly, the cross combinations BCL-06×BCL-15 and BCL-13×BCL-03 expressed significant positive SCA effect for cob weight but negative significant SCA effect of plant height. The cross combination BCL-07×BCL-12, showed positively significant SCA effect for cob weight and green fodder yield, whereas the cross BCL-14×BCL-12 showed significant SCA effect for plant height and ear height. The cross combinations BCL-14×BCL-12 and BCL-05×BCL-15 showed negatively significant SCA effect for green fodder yield and ear height, respectively. The cross combination BCL-11×BCL-15 did not exhibit either significant positive or significant negative SCA for any character recorded in the present study. It was interesting to observe that none of the selected cross combinations recorded either significant positive or significant negative SCA effect for days to 50% teaselling. Many researchers noticed negative or positive SCA effects in maize for these traits in their own studies [19, 20, 21, 22, 23].

Estimates of components of genetic variances, namely, σ^2GCA, σ^2SCA and ratio of σ^2GCA/ σ^2SCA are presented in Table 2. Higher magnitude of σ^2SCA than σ^2GCA and ratio of σ^2GCA/ σ^2SCA less than one were recorded for all traits except ear height. The results highlighted the predominance of non-additive gene effects. Based on the results of genetic variance components, it is evident that non additive type of genetic actions is more clearly predominant for traits like days to 50% tasseling, days to 50% silking, cob length and cob yield per plant. Similar results were also reported earlier [24, 25, 26, 27] in maize.

Parent materials showing wide allelic differences are required for getting desirable heterotic progenies with heterosis manifestation. Analysis of variance amply signifies the presence of genetic diversity among the parental materials for majority of the traits studied. Significant differences for combining ability indicated that cross combinations of the parental materials exhibited significant differences for economic traits. Experimental materials appeared useful for the breeders to recognize the appropriate parents and good cross combinations among them [28]. Combining ability, gene action and mode of inheritance for the traits assists the breeder to implement appropriate breeding methods for their improvements [12]. The traits exhibiting the importance of non-additive gene effects in their inheritance such as days to 50% tasselling, days to 50% silking, cob yield, cob weight, green fodder yield and baby corn length can be enhanced by employing heterosis breeding. Thus, desirable hybrid can be obtained for exploitation of heterosis.

Table 3: Estimates of GCA effects of parents for yield and component traits across the seasons

Parent	PH	EH	DT	DS	CY	CW	BL	BG	GFY
BCL-01	-7.34*	-1.19	-1.34*	-1.43*	-0.75	6.77**	-0.14	-0.01	-0.83
BCL-02	3.10*	3.36*	0.76	1.06	-3.21*	-2.37	0.01	-0.05	10.94*
BCL-04	-9.12**	-9.13	-0.50	-0.82	2.59	10.09*	-0.11	-0.03	-14.78*
BCL-05	-5.78**	-5.46**	-0.62	-0.76	0.28	-1.79	0.06	0.06*	-5.89*
BCL-06	0.93	-3.80*	0.21	0.009	1.42	-0.59	0.12	-0.01	2.38
BCL-07	-5.06**	1.19	-0.009	0.12	1.31	1.79	0.04	0.006	15.16*
BCL-08	-4.17*	-5.35**	-0.28	-0.49	-4.38*	-5.51**	-0.28**	-0.042	1.94
BCL-09	3.32*	-0.57	-0.17	-0.60	2.55	-5.19**	-0.03	-0.006	-1.00
BCL-10	8.046**	5.31**	0.26	2.00*	2.86	6.82**	0.13	0.08**	11.21*
BCL-11	7.71**	4.47**	0.71	0.56	0.85	-6.08**	0.02	0.009	-22.72*
BCL-13	3.60*	4.42**	0.93*	0.50	-6.80**	-20.23*	0.06	0.006	-5.28*
BCL-14	4.76*	6.75**	0.04	-0.15	3.26*	16.30	0.10	-0.003	8.88**
BCL-03	-3.78***	-4.16***	-0.57*	-0.79*	1.11	0.78	-1.30	-0.06	-0.06
BCL-12	-2.57***	-0.48	-0.07	0.38	-1.07	0.37	0.02	0.002	-5.72***
BCL-15	6.36***	4.64***	0.65**	0.41	-0.03	0.93	0.04	0.06	4.94**

*, ** Significant at 5 and 1 per cent levels, respectively; PH = Plant height; EH = Ear height; DT = Days to 50% tasselling; DS = Days to 50% silking; CY = Cob yield; CW = Cob weight; GFY = Green fodder yield; BL = Baby corn length; BG = Baby corn girth.

Table 4: Estimates of SCA effects for yield and component traits of selected crosses across the seasons

CROSS	PH	EH	DT	DS	CY	CW	BL	BG	GFY
BCL-04×BCL-03	7.23**	-0.56	0.07	0.68	12.69***	2.80	-0.08	-0.07	-7.78
BCL-08×BCL-15	-2.199	1.85	-0.04	0.14	7.71**	-1.73	-0.03	0.09	-5.99
BCL-10× BCL-12	-097	-0.35	1.46	4.33***	15.20***	25.93***	-0.15	-0.05	-7.60
BCL-05×BCL-03	1.56	2.27	-0.47	-0.37	6.83**	8.89***	-0.35*	0.04	-1.17
BCL-06×BCL-15	-8.14**	-0.69	-1.04	-0.69	4.50	8.02***	-0.14	-0.01	2.22
BCL-07×BCL-12	0.30	-0.24	-0.42	-0.27	3.02	13.32***	-0.27	0.05	24.28***
BCL-05×BCL-15	-0.42	-6.19**	0.28	0.25	1.14	-0.48	0.14	-0.01	4.50
BCL-11×BCL-15	-0.25	-0.97	0.78	1.42	2.63	2.28	0.10	-0.02	2.33
BCL-13×BCL-03	-7.65**	-3.11	0.63	0.51	1.93	5.65*	-0.10	0.09	1.71
BCL-14×BCL-12	12.52***	6.74**	0.45	-0.02	2.45	0.31	-0.23	0.05	-29.60***

*, ** Significant at 5 and 1 per cent levels, respectively; PH = Plant height; EH = Ear height; DT = Days to 50% tasselling; DS = Days to 50% silking; CY = Cob yield; CW = Cob weight; GFY = Green fodder yield; BL = Baby corn length; BG = Baby corn girth.

Conclusion

Analyses of variance for combining ability across seasons indicated that mean sum of squares due to lines and line × tester interaction was significant for yield and yield related traits studied, revealing the significance of both additive and non-additive gene effects in controlling the inheritance of these traits. However, non-additive gene effects appeared more important than additive gene effects for days to 50% tasselling, days to 50% silking, cob yield, cob weight, green fodder yield and baby corn length. The estimates of GCA effects in combined analyses revealed that BCL-10 was the best general combiner amongst the fifteen parents, followed by BCL-14 and BCL-11for majority of yield contributing traits. These parents could possibly be utilised in hybrid baby corn breeding programme with the goal of increasing yield through the addition of desirable traits. Considering the performance of specific crosses as estimated by specific combining ability effects across seasons, two cross combinations, namely, BCL-10×BCL 12 and BCL-05×BCL-03 appeared promising for enhancement of cob yield per plant along with cob weight and cob length. These crosses could be exploited to generate high yielding baby corn hybrids with desired features. Furthermore, the cross combination BCL-14× BCL-12 also appeared promising as it recorded superior combining ability for characteristics such as plant height, ear height and green fodder yield.

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