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Heterosis and Combining Ability for Yield and Yield Attributing Traits in Tossa Jute (*Corchorus olitorius* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors AR, KD and AD designed the study. Authors KD and SH taken the observation recorded in the study. Author SB performed the statistical analysis. Authors KD and SH managed the literature searches, Authors AR and KD wrote the first draft of the manuscript and finally corrected by author AD. All authors read and approved the final manuscript.

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ABSTRACT

Jute is one of the important bast fibre crop in the World next to cotton. Yield potential of this fibre crop is still under exploited and this natural fibre is facing challenges from synthetic products which calls for immediate attention to restore breeding works in a comprehensive manner. The present research has been contemplated with ten hybrids evolved from five lines of Tossa jute following half diallel matting design to ascertain gene action, combining ability and heterotic potential of the hybrids in respect of fibre yield and yield attributing traits. Methods comprised of growing of parents as well as F_1s along with standard check in randomized complete block design (RCBD) maintaining three replications followed by recording observation on fibre yield and other yield attributing traits. Results revealed that most of the studied traits were governed by non-additive gene action which justified exploitation of heterosis utilizing these traits in this crop. The specific combining ability (SCA) components of variance (σ^2 SCA) were larger than the general combining ability (GCA)

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components of variance (σ^2 GCA) for all of the five traits under study which further implied the preponderance of non-additive components of variance towards the expression of these traits. JRO 524 was detected as the best general combiner considering the economically important trait. Finally, considering dry fibre and stick yield, three hybrids, namely OIN 24 × JRO 524, OIN 39 × OIN 46 and OIN 39 × JRO 524 has been identified to be superior over their better parent as well as standard check regarding these traits. Additionally, all these three hybrids exhibited positive and significant SCA effects. These three promising specific combiners can be advanced to get better Tossa jute lines for bolstering economic returns of the farming community in future.

Keywords: Combining ability; gene action; heterosis; fibre yield; tossa jute.

1. INTRODUCTION

Jute (*Corchorus* spp. L.; 2n=14) is the member of Malvaceae family and it is considered as one of the cheapest natural fibre in the World following cotton. India and Bangladesh are the major jute growing countries in the South East Asia where the fibre is extracted from two cultivated species *viz*., Tossa jute (*C. olitorius*) and White jute (*C. capsularis*). Jute and jute-based industry plays a pivotal role in the economy of these two countries in terms of employment generation, foreign exchange earnings and for economic sustenance of the vulnerable poor farming community [1-3]. Beside these two countries, China contributes a marginal share of World's jute cultivation along with Thailand, Pakistan, Nepal and Bhutan [4]. A lion share of India's jute production is coming from West Bengal to meet up the demand of Jute based Industry which are mostly situated in this state. The area under jute in India is around 7.9 lakh ha with a production of about 102.85 lakh bales where West Bengal alone contributes approximately about 74.7% and 81.6% of national acreage and production, respectively [5,6].

Although, jute is mainly popular for its versatile fibre, however, every part of the plant is having its unique use. With low carbon and ecological footprints, this fibre crop is reviving its importance in the context of global warming in recent times. Jute fibre is eco-friendly and bio-degradable. This fibre is mainly used for preparing gunny bag of 100% food grade quality, household decorative and fabrics, shopping and hand bags, floor coverings, geo-textiles, composites and reinforcements [7]. Jute and jute-based industry occupies an imperative role in Indian economy especially in eastern India, renders direct employment to 0.37 million workers and supports the livelihood of around 4.0 million farm families along with engagement of large number of persons in the trade of jute [8].

A quantum jump in jute productivity has been observed in the recent decade due to introduction of high yielding premature-flowering resistant varieties in Indian sector, however, this achievement is not sufficient to fulfil the demands of the farming community and Industrial requirement. Meagre number of spontaneous variations is observed in jute as this crop is domesticated only 200 years ago with less chance of getting man-made artificial selection [9,10]. Additionally, interspecific hybridization between the cultivated species was detected as a futile venture as no successful hybrid of economic importance has evolved in both either direction [11,12]. Despite of availability of improved production technology coupled with decent number of high yielding varieties, jute yields have plateaued in recent years which warrants immediate intervention towards redesigning breeding programme for developing new varieties with better potential.

Correct choice of parents for hybridization programme is imperative for planning successful plant breeding programme. Moreover, uncovering the nature and magnitude of gene action as well as enumerating combining abilities of the parents are also crucial steps towards selection of superior lines which can give rise to potential segregants [4]. Unfortunately, only limited breeding work has been conducted for understanding the genetic parameters for improving fibre yield and its component traits in jute [13,14]. Keeping these in the backdrop, the present study has been delineated to estimate the combining ability and gene action towards expression of fibre yield and yield attributing traits of Tossa jute for identification of superior cross combinations with higher yield potential.

2. MATERIALS AND METHODS

The field experiment was carried out during rainy season of 2017 and 2018 at the Teaching Farm, Mondouri (22.87^{0}N latitude and 88.59^{0}E longitude at an elevation of 9.75 m above the mean sea level) of Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India. The experimental soil of the site is Gangetic alluvial sandy loam in texture, neutral in soil reaction, with medium fertility status and having good water holding capacity coupled with good drainage facilities. The experimental material comprised of 10 jute hybrids evolved from crossing between 5 accessions of *Corchorus olitorius viz.*, OIN 24, OIN 39, OIJ 03, OIN 46, JRO 524 in half diallel fashion along with one check variety (JRO 204). During first year (2017) crossing programme was attempted to develop the crosses and during second year (2018) total ten crosses along with the parents and checks were evaluated. Standard package of practices was followed to raise the crop. All the hybrids, parents along with the check variety were grown in a randomized complete block design (RCBD) with three replications maintaining proper plant geometry with a row to row distance of 30 cm as well as plant to plant distance of 6-7 cm.

Data was recorded considering five randomly selected plants from middle row of each plot for five yield attributing traits like plant height (cm), basal diameter (cm), green weight/plant (g), dry stick weight/plant (g), and dry fibre weight/plant (g) at the time of harvesting (120 DAS).

The mean data of the parents along with hybrids and check were used for statistical analysis by using MS EXCEL and OPSTAT online software. Analysis of variance (ANOVA) was performed considering each traits of the parents, check as well as hybrids to find out significant differences by 'F' test [15]. Broad sense heritability for the present study was calculated as per the formula suggested by Hanson et al. [16]. Expected genetic advance (GA), as well as genetic advance over mean (GAM), was calculated as per the standard method suggested earlier [17]. The experimental data were analysed following Model 1 and Method 2 of Griffing [18]. Estimation of Heterosis was enumerated on the basis of mean values over mid parent, better parent and standard check and test of significance was performed using the following formula [19].

Percent heterosis over mid parent (MP)= (F_1 - MP/MP) × 100

Percent heterosis over better parent (BP)= (F_1 - BP/BP) × 100

Percent heterosis over standard check (SC)= (F_1 - SC/SC) × 100

3. RESULTS AND DISCUSSION

Mean performance of the parents, checks as well as ten hybrids were depicted in the Table 1. The highest value for the plant height was observed in the check variety JR0 204 (332.33 cm) followed by the cross OIN 39 × OIN 46 (314.00 cm) and OIN 39 × OIJ 039 (313.67 cm). Basal diameter was highest in OIN 46 (1.57 cm) followed by OIJ 03 (1.55 cm), and lowest basal diameter was recorded in the cross OIN 03 × OIN 46 (1.18 cm). The average green weight/plant ranged between 143.62 g to 182.92 g. Green weight was found to be highest in OIN 46 (182.92 g) and lowest in JRO 204 (142.03 g). In case of dry stick weight as well as dry fibre weight/plant the highest value was observed in the cross OIN 39 × OIN 46 (26.16 g and 16.77 g respectively).

The estimation of phenotypic coefficient of variation (PCV) ranged from 7.14% for plant height to 17.41% in dry stick weight/plant, whereas in case of genotypic coefficient of variation (GCV) it was 5.45% to 10.63% for dry fibre weight and dry stick weight/plant respectively (Table 2). All the five tested traits revealed low to moderate (10-20 %) GCV and PCV. Traits like plant height, basal diameter and green weight/plant exhibited very low difference between PCV and GCV which affirmed the insignificant influence of environment and larger impact of genetic factors for controlling these traits. The present finding was in accordance with the previous findings for plant height, basal diameter and green weight/plant [14,20,21]. In case of dry stick weight and dry fibre weight/plant environmental influence was greater. High heritability coupled with moderate genetic advance (GA) was observed for plant height and green weight/plant. On contrary, in case of character like basal diameter high heritability with low GA was detected. In case of dry stick weight and dry fibre weight/plant both heritability and GA was low. From the results it can be concluded that all these traits might be controlled by non-additive gene action where high heritability is the result of favourable environmental condition during growing period rather than the influence of genetic factors. Therefore, improvement of these traits following simple breeding method like selection may not be rewarding in bringing improvement towards desired direction. The findings of this study are similar to the earlier reports by previous authors [4,14,20].

Analysis of variance for combining ability revealed highly significant specific combining ability (SCA) variance for all the traits and significant general combining ability (GCA) variance for plant height and green weight/ plant (Table 3). Presence of significant GCA and SCA variance for plant height and green weight/plant reflected influence of both additive and non-additive gene action towards expression of these traits. On contrary, high SCA effects for rest of the three traits revealed preponderance of non-additive gene action.

Combining ability study is vital towards selection of suitable parent. The high general combiners for the tested traits were JRO 524 for plant height as well as for dry stick weight/plant and OIN 39, OIN 46 and JRO 524 for green weight/plant (Table 4). These parents might be useful donors in the hybridization programme for exploitation of heterosis. Previous work in jute suggested that parents of good combining ability for a specific trait signified influence of additive gene action [13].

Table 1. Mean performance of 16 lines of Tossa jute for five yield attributing traits

Sl. No.	Entries	Plant height (cm)	Basal diameter (cm)	Green weight/ plant(g)	Dry stick weight/ plant (g)	Dry fibre weight/ plant (g)
1.	OIN 24	237.10	1.54	169.67	20.68	13.98
2.	OIN 39	274.15	1.54	176.18	20.01	14.87
3.	OIJ 03	275.97	1.55	182.87	20.50	13.96
4.	OIN 46	285.00	1.57	182.92	19.48	13.19
5.	JRO 524	306.93	1.51	167.82	21.55	14.08
6.	OIN 24 × OIN 39	298.67	1.25	143.62	17.36	13.26
7.	OIN 24 × OIJ 03	306.31	1.31	157.32	24.16	14.59
8.	OIN 24 × OIN 46	303.76	1.21	162.15	20.21	15.36
9.	OIN 24 × JRO 524	308.00	1.26	173.06	24.25	16.10
10.	OIN 39 × OIJ 03	313.67	1.28	146.21	17.33	14.38
11.	OIN 39 × OIN 46	314.00	1.28	171.66	26.16	16.77
12.	OIN 39 × JRO 524	304.44	1.25	175.74	24.43	16.13
13.	OIJ 03 × OIN 46	293.67	1.18	148.93	17.13	14.38
14.	OIJ 03 × JRO 524	307.06	1.22	158.41	22.93	13.97
15	OIN 46 × JRO 524	294.30	1.26	156.22	20.03	14.04
16	JRO 204 (Check)	332.33	1.41	142.00	24.15	10.60
	Grand Mean	294.87	1.35	164.85	21.08	14.60
	SEm(±)	4.11	0.03	4.21	1.68	0.69
	CD at 5%	11.90	0.08	12.20	4.86	2.01

Table 2. Genetic parameters of 16 lines of Tossa jute for five yield attributing traits

Traits	Grand mean	Range		Coefficient of variation %		Heritability broad sense (%)	Genetic advance	Genetic advance as % of mean
		Min	Max	GCV	PCV			
Plant height (cm)	294.87	237.10	314.00	6.72	7.14	88.57	38.44	13.04
Basal diameter (cm)	1.35	1.18	1.57	10.56	11.21	88.71	0.28	20.51
Green weight/plant (g)	164.85	143.62	182.92	7.30	8.53	73.16	21.23	12.88
Dry stick weight/plant (g)	21.08	17.13	26.16	10.63	17.41	37.26	2.82	13.38
Dry fibre weight/plant (g)	14.60	13.19	16.77	5.45	9.87	30.46	0.91	6.20

Table 3. ANOVA for combining ability for five yield attributing traits in Tossa jute

Sources of variation	DF	Mean sum of squares				
		Plant height (cm)	Basal diameter (cm)	Green weight/plant (g)	Dry stick weight/plant (g)	Dry fibre weight/plant (g)
GCA	4	346.27**	0.0003	24.53*	3.63	0.5
SCA	10	433.99**	0.0300**	217.71**	9.51**	1.36*
Error	28	16.87	0.00085	17.71	2.82	0.48

** Significant at 5% level, ** significant at 1% level*

Table 4. General Combining Ability for five yield attributing traits in Tossa Jute

Parents	Plant height (cm)	Basal diameter (cm)	Green weight/plant (g)	Dry Stick weight/plant (g)	Dry fibre weight/plant (g)
OIN 24	-11.18**	0.01	-1.94	0.12	-0.05
OIN 39	1.41	0.02	0.0	-0.17	0.38
OIJ 03	0.49	0.01	-1.79	-0.56	-0.34
OIN 46	0.93	-0.01	2.24	-0.57	-0.10
JRO 524	8.35**	-0.02	1.42	1.18*	0.11

** Significant at 5% level, ** significant at 1% level*

Table 5. Specific Combing ability effects of 10 crosses of Tossa Jute for five yield attributing traits

Name of crosses	Plant height (cm)	Basal diameter (cm)	Green weight/plant (g)	Dry Stick weight/plant (g)	Dry Fibre weight/Plant (g)
OIN 24 × OIN 39	13.57**	-0.11**	-19.35**	-3.68**	-1.68**
OIN 24 × OIJ 03	22.13**	-0.04**	-3.80*	3.51**	0.38
OIN 24 × OIN 46	19.14**	-0.14**	-3.00**	-0.42	0.90**
OIN 24 × JRO 524	15.96**	-0.08**	8.73**	1.87*	1.44**
OIN 39 × OIJ 03	16.90**	-0.08**	-16.93**	-3.02**	-0.26
OIN 39 × OIN 46	16.79**	-0.07**	4.50**	5.82**	1.88**
OIN 39 × JRO 524	-0.19	-0.09**	9.40**	2.34**	1.04**
OIJ 03 × OIN 46	-2.62	-0.16**	-16.37**	-2.81**	0.22
OIJ 03 × JRO 524	3.35	-0.12**	-6.08**	1.23	-0.41
OIN 46 × JRO 524	-9.58**	-0.08**	-12.30**	-1.66*	-0.57

** Significant at 5% level,** significant at 1% level*

Table 6. Estimates of genetic components of variance and degree of dominance of five yield attributing traits studied in Tossa jute

Sources of variations	Plant height (cm)	Basal diameter (cm)	Green weight/plant (g)	Dry stick weight/plant (g)	Dry fibre weight/Plant (g)
σ^2 GCA	47.06	-0.001	0.97	0.12	0.003
σ^2 SCA	417.12	0.029	200.00	6.69	0.880
σ^2 GCA / σ^2 SCA	0.11	-0.034	0.005	0.02	0.003
$(\sigma^2$ GCA / σ^2 SCA$)^{0.5}$	0.34	0.080	0.069	0.13	0.057
σ^2_A	94.11	-0.002	1.95	0.23	0.006
σ^2_D	417.12	0.029	200.00	6.69	0.880
σ^2_A / σ^2_D	0.23	-0.069	0.010	0.03	0.006
$\sigma^2_A / (\sigma^2_A + \sigma^2_D)$	0.18	-0.074	0.010	0.03	0.006

GCA: general combining ability; SCA: specific combining ability; σ^2gca: gca variance; σ^2sca: sca variance; $(\sigma^2 gca/\sigma^2 sca)^{0.5}$: degree of dominance; σ^2A: additive variance; σ^2D: dominance variance; σ^2A/ (σ^2A+ σ^2D): predictability ratio

Table 7. Heterosis (%) over mid parent (MP), better parent (BP) and standard check (SC) for the five yield attributing traits studied in Tossa jute

Name of crosses	Plant height (cm)			Basal diameter (cm)			Green weight/plant (g)			Dry stick weight/plant (g)			Dry fibre weight/plant (g)		
	MP	BP	SC	MP	BP	SC	MP	BP	SC	MP	BP	SC	MP	BP	SC
OIN 24 × OIN 39	16.84**	8.94**	-2.69	-18.66**	-18.66**	-17.22**	-16.94**	-18.48**	-14.42**	-14.70	-16.08	-19.46	-8.12	-10.87	-5.85
OIN 24 × OIJ 03	19.40**	11.00**	-0.20	-15.33**	-15.70**	-13.47**	-10.75**	-13.97**	-6.26	17.31	16.79	12.10	4.45	4.36	3.65
OIN 24 × OIN 46	16.36**	6.58**	-1.03	-22.02**	-22.77**	-19.87**	-8.02*	-11.35**	-3.38	0.65	-2.29	-6.22	13.01*	9.82	9.07
OIN 24 × JRO 524	13.23**	0.35	0.35	-17.29**	-18.00**	-16.56**	2.56	2.00	3.12	14.84	12.53	12.53	14.74*	14.35*	14.35*
OIN 39 × OIJ 03	14.04**	13.66**	2.20	-17.28**	-17.63**	-15.45 **	-18.56**	-20.05**	-12.88**	-14.43	-15.45	-19.57	-0.25	-3.32	2.13
OIN 39 × OIN 46	12.31**	10.18**	2.30	-17.29**	-18.09**	-15.01 **	-4.39	-6.15	2.29	32.47**	30.70**	21.38	19.48**	12.73	19.08*
OIN 39 ×JRO 524	4.79**	-0.81	-0.81	-17.94**	-18.66**	-17.22 **	2.18	-0.25	4.72	17.54	13.35	13.35	11.44	8.47	14.58*
OIJ 03 × OIN 46	4.70*	3.04	-4.32*	-24.06**	-24.47**	-21.63 **	-18.57**	-18.58**	-11.26**	-14.28	-16.42	-20.49	5.94	3.03	2.15
OIJ 03 × JRO 524	5.36**	0.04	0.04	-20.26**	-21.29**	-19.21 **	-9.66**	-13.37**	-5.61	9.08	6.42	6.42	-0.38	-0.80	-0.80
OIN 46 × JRO 524	-0.56	-4.11*	-4.11*	-18.31**	-19.96**	-16.78 **	-10.92**	-14.59**	-6.91	-2.36	-7.05	-7.05	2.98	-0.26	-0.26

The estimates of SCA effects of ten crosses for the tested traits were presented in Table 5. Positive and significant SCA effects were observed in the crosses OIN 24 × OIN 39, OIN 24 × OIJ 03, OIN 24 × OIN 46, OIN 24 × JRO 524, OIN 39 × OIJ 03, OIN 39 × OIN 46 for plant height. In case of green weight/plant, positive and significant SCA effects were detected in the crosses OIN 24 × JRO 524, OIN 39 × OIN 46 and OIN 39 × JRO 524. In case of dry stick weight/plant crosses *viz*., OIN 24 × OIJ 03, OIN 24 × JRO 524, OIN 39 × OIN 46 and OIN 39 × JRO 524 and for the character dry fibre weight/plant crosses *viz*., OIN 24 × OIN 46, OIN 24 × JRO 524, OIN 39 × OIN 46 and OIN 39 × JRO 524 exhibited positive and significant SCA effects. From the results it could be confirmed that high specific combiners are not always obtained from crossing between high general combiners but may occur between high × low or low × low general combiners. SCA is an independent parameter for selection of desirable cross combinations for harnessing heterosis. It can be speculated that this finding is due to the presence of complementary gene interactions. Previous report stated that any parental combination can produce hybrid vigour over parents which might be due to favourable dominant, over-dominant or epistatic gene action [22]. In general, SCA effects do not make any significant contribution in the improvement of self-pollinated crops except where there is possibility of commercial exploitation of heterosis, since in these crops, breeders' attention is to get desirable transgressive segregants through crossing between diverse parents. Similar kind of results was reported both in white jute [23] as well as in tossa jute also [24].

The variances of genetic components and degree of dominance for five traits were presented in Table 6. The SCA components of variance (σ^2SCA) were larger than the GCA components of variance (σ^2GCA) for all of the five traits. A preponderance of non-additive gene action including both dominance and epistasis was observed thus, heterosis breeding may be rewarding. The ratio of σ^2GCA / σ^2SCA ratio was also less than unity which affirmed the significant of non-additive variance. The additive genetic variance (σ^2_A) was lower than the non-additive genetic variance (σ^2_D) for all the five traits. The estimates of predictability ratios of Baker [25] for plant height was highest but less than 0.50. The predictability ratios were not more than 0.5 for plant height, green weight/plant, stick weight/plant and fibre yield/plant which indicated the predominance of non-additive gene action for these traits. Negative variance, though rare, was revealed for basal diameter. Variance by nature should not be negative as they are squared quantities. The possible reasons could be assigned for occurrence of negative estimates of variances were due to small sample size and presence of aberrant values, presence of genotype × environment interaction which may inflate error variance and due to lack of random mating during designing half diallel. This was in confirmation with the previous finding [24].

Standard heterosis of all the cross combinations was presented in Table 7. It was observed that the degree and direction of heterosis varied in different crosses. Among the 10 crosses, mostly all exhibited significantly positive heterosis over mid-parent and batter parent for traits like plant height, green weight/plant, dry stick weight/plant and dry fibre weight/plant except basal diameter. Similar result of significantly positive heterosis over mid and better parent for plant height, basal diameter, stick weight and fibre yield were reported earlier [23,26]. Among the 10 crosses, three crosses (OIN 24 × JRO 524, OIN 39 × OIN 46 and OIN 39 × JRO 524) exhibited significantly positive heterosis over standard check variety and positive heterosis over better parent for dry fibre yield. These three crosses were superior over their best parent as well as standard check for dry stick weight also.

4. CONCLUSION

Significant variation was detected in all the studied traits and all the traits were governed by non-additive type of gene action which justified importance of heterosis breeding in this crop. Additionally, The SCA components of variance (σ^2SCA) were larger than the GCA components of variance (σ^2GCA) for all of the five traits which further indicated the preponderance of non-additive gene action. JRO 524 along with OIN 39 and OIN 46 detected as good general combiners and can be useful as desirable parents in future hybridization programme. The SCA effects exhibited that seven crosses for plant height, two for basal diameter and four crosses each for dry stick weight and dry fibre weight/plant had significant positive effects. As dry fibre yield and dry stick yield are the main focus area in jute breeding programme, so finally 3 hybrids *viz*., OIN 24 × JRO 524, OIN 39 × OIN 46 and OIN 39 × JRO 524 were identified as superior hybrids due to their good SCA effects coupled with presence of heterobeltiosis and economic heterosis for these traits. These 3 cross combinations can be deployed in further breeding programme for enhancement of fibre yield and stick yield towards improving production and productivity of Tossa jute.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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