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GENE ACTION AND COMBINING ABILITY FOR YIELD AND YIELD COMPONENT TRAITS IN DOLICHOS BEAN (*Dolichos lablab* var. *typicus*)

I. DAS[1], T. SETH[1], S.V. DURWAS[2], S. DUTTA[3], A. CHATTOPADHYAY[3] and B. SINGH[4]

[1]Department of Vegetable Crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741252, Nadia, West Bengal, India
[2]Department of Plant Breeding, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741252, Nadia, West Bengal, India
3 AICRP on Vegetable Crops, Directorate of Research, Bidhan Chandra Krishi Viswavidyalaya, Kalyani-741235, Nadia, West Bengal, India
[4] AICRP on Vegetable Crops, Indian Institute of Vegetable Research, Varanasi- 221305, India
*Corresponding author's email: chattopadhyay.arup@gmail.com

SUMMARY

A 5 x 5 half diallel analysis was carried out involving 5 diverse genotypes of dolichos bean comprising pole and bush type growth habits to characterize the gene action involved in the inheritance of some of the quantitative traits and to identify good general-and specific-combiners. The results indicated additive genetic effects for number of inflorescences per plant, number of nodes per inflorescence, number of flower buds per inflorescence and protein content of pod was evident. In contrast, length of inflorescence, number of pods per inflorescence, pod length and number of seeds per pod were influenced by non-additive gene effects, while the characters like days to first flowering, days to 50% flowering, number of pods per plant, pod width, pod weight, shelling percentage of fresh pod and pod yield per plant were controlled by both additive and non-additive gene effects. Three parents namely, BCDB 1, DOLP VAR 10 and DOLP VAR 5 and 4 cross combinations i.e., DOLP VAR 10 x DOLB VAR 2, DOLP VAR 10 x Arka Jay, BCDB 1 x DOLB VAR 2 and DOLP VAR 5 x Arka Jay were identified as good general-and specific-combiners which could be exploited in future breeding programme. As high as 20.0% heterobeltiosis for pod yield per plant has been recorded through pod weight in this crop.

Keywords: Dolichos bean, heterobeltiosis, combining ability, gene action

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INTRODUCTION

The vegetarian populations in India consume large amounts of legumes, particularly, vegetable beans in their diet. Among the legumes, dolichos bean [*Dolichos lablab* L., Syn: *Lablab purpureus* (L.) Sweet] (2n = 22) belonging to family Leguminosae, is one of the most ancient among the cultivated plants and is presently grown throughout the tropical regions in Asia, Africa and America. The crop is mainly grown for its green edible pods (*Dolichos lablab* var. *typicus*) as a vegetable, while the dry seeds (*Dolichos lablab* var. *lignosus*) are used in various vegetable preparations. The crop is grown under varied agricultural practices as a single crop, mixed cropping, inter-cropping, forage crop, cash crop or, kitchen garden (Shivashankar and Kulkarni, 1989; Pengelly and Maass, 2001; Maass, 2006) and constitutes an important source of therapeutic agents used in the modern as well as traditional systems of medicine (Morris, 2003; Morris, 2009).

The flavonoid, genistein found in dolichos bean may play a role in the prevention of cancer (Kobayashi *et al*., 2002) and as a chemotherapeutic and/or chemopreventive agent for head and neck cancer (Alhasan *et al.*, 2001). Tryrosinase (polyphenol oxidase) is present in plant tissue of dolichos bean has potential for the treatment of hypertension in humans (Naeem *et al*., 2009) and prevent of browning of foods, enzymatic or non-enzymatic, has long been a concern of food scientists (Sanchez-Ferrer *et al*., 1995; Paul and Gowda, 2000).

Dolichos bean is a drought tolerant crop and it is an excellent crop to be grown in dry lands with limited rainfall. Despite having many good attributes, the crop has remained unexploited owing to low productivity, long duration, photosensitivity and indeterminate growth habit. Consumer preferences also vary with pod size, shape, color and aroma. The efforts of improving the crop by utilizing indigenous and exotic germplasm have been useful in breaking the yield barriers (Shivashankar and Kulkarni, 1989, Shivashankar *et al.,* 1993) resulting in compact plant type, reduced duration and photo-insensitive types. Hence, comprehensive germplasm collection and evaluation, identification of suitable genotypes for pure crop and investigation of its value as an intercrop with other food and forage crops are essential. Wide genetic variability offer scope for selection of suitable agro-morphological traits improvement. Although dolichos bean has been cultivated throughout West Bengal state, few concerted efforts have been made (Chattopadhyay and Dutta, 2010) to collect and conserve available genetic resources for their present and future use before they become extinct.

Genetic analysis provides a guide line for the assessment of relative breeding potential of the parents or identifies best combiners in crops which could be utilized either to exploit heterosis in F_1 or the accumulation of fixable genes to evolve variety. Such studies not only provide necessary information regarding the choice of parents but also simultaneously illustrate the nature and magnitude of gene action involved in the expression of desirable traits. The impulse of progress in crop improvement through plant breeding was propelled by a better understanding and an appropriate exploitation of heterosis, the classical term coined by Shull (1914) implying the gain in vigor on crossing 2 inbreds. Dolichos bean is a self-pollinated crop where degree of heterosis was theoretically considered less. Heterosis manifestation in dolichos bean is in the form of earliness in maturity, increased productivity and better quality attributes (Valu *et al***,** 2006, Patil *et al*, 2011).

Diallel (Griffing, 1956) is one such analysis which is a useful tool for preliminary evaluation of genetic stock for use in breeding programs with a view to identify good general and specific-combiners. Keeping in view the importance of the study and lack of research works done in the Gangetic plains of West Bengal which is regarded as the most productive zone in India, this study has been formulated to assess the nature and magnitude of heterosis as well as to determine the nature of gene action for yield component characters, quality characters with a view to identify good general- and specific-combiners and to frame the breeding strategies for the genetic improvement of such characters.

MATERIALS AND METHODS

The investigation was carried out at Research Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India under the research field of All India Coordinated Research Project on Vegetable Crops, situated at 23.5^0 N latitude and 89^0 E longitude at a mean sea level of 9.75 m during the year 2011-2012 and 2012-2013. Five genetically diverse parents having contrasting growth habits were selected through multivariate analysis (Das, 2013).

Development of F_1 hybrids and their field growing

Seeds of 3 pole type (BCDB 1, DOLP VAR 5, and DOLB VAR 10) parents were sown in well-prepared field in separate plots measuring 4.5 m x 4.5 m at 1.5 m x 1.5 m spacing in both ways during the month of August, 2011. During active vegetative growth phase, all the 6 plants of pole type genotypes in each plot were supported with bamboo poles as trellis. Seeds of 2 bush type (Arka Jay and DOLB VAR 2) parents were sown in well prepared field in separate plots measuring 3.0 m x 3.0 m at spacing of 60 cm x 30 cm during the month of August, 2011. Standard management practices were followed as per Chattopadhyay *et al*. (2007).

Crossing technique of dolichos bean and collection of seeds

Dolichos bean have cleistogamous flower structure, so they are highly self-pollinated. In the young immature bud, the anthers are far behind the level of the stigma. As the bud grows the stamina filament elongate more rapidly than the style and the anther dehisce when the long stamen comes above or on a level with the stigma. Flower opens generally two days after anther dehiscence in the daytime. So, the flowers are to be emasculated and pollinated immediately before the anther dehiscence are found. During full bloom, crossing was carried out. Female parent flower buds that would open the following day were selected and emasculated between 4.00 p.m. and 5.30 p.m. A narrow slit at the back of the bud where the margins of the standard unite has been found to indicate that the anthers inside have just dehisced. For providing the pollen a bud at this stage was removed from the male parents. The keel tube with the mass of pollen inside was then slipped over the stigma of the emasculated bud ensheathing its style and stigma during the next day morning by 7.30 a.m. The use of the keel tube is superior to other methods in that the stigma surroundings approximately the naturals and also guard against the risks to handling the pollens directly. The pollinated buds were then covered with a tissue paper bag to protect against the insects. After maturing the pods, dry seeds of each cross combination were collected separately and kept in the desiccators for sowing in the next season.

In the next year, seeds of 10 cross combinations along with 5 parents were sown following randomized complete block design with 3 replications in the third week of August, 2012. The sowing methods and other cultural practices were same as followed previously. In each plot, 6 plants of 9 cross combinations involving 1 pole type parent were tagged and 15 plants from 1 cross involving both bush type parents were also tagged for recording the observations on days to 1^{st} flowering, days to 50% flowering, length of inflorescence (cm), number of inflorescences per plant, number of nodes per inflorescence, number of flower buds per inflorescence, number of pods per inflorescence, number of pods per plant, pod width(cm), pod length (cm), pod weight (g), number of seeds per pod, shelling percentage of fresh pod, protein content (%) of pod and pod yield per plant (kg).

Statistical analyses

Combining ability analyses were carried out as per the procedure given by Griffing's (1956) Model 1 and Method 2. Heterosis over better-parent (Heterobeltiosis) was estimated in terms of percent increase or decrease of the F_1 hybrid over its better-parent (Hayes *et al*., 1965). Heterobeltiosis was computed by using computer software program Windowstat 8.0 (developed by Indostat services 18.0, Ameerpet, Hyderabad, India).

RESULTS

Nature of gene action

The knowledge of genetic nature of quantitative traits is a basic requirement for purposeful management of genetic variability**.** In the present study, 5 parents were chosen and data from 5 x 5 half diallel were analyzed in the F_1 generation for 9 quantitatively inherited traits. This would help to know the general nature of the genetic control of important quantitative traits in tomato.

The analysis of variance indicated that mean squares due to genotypes (parents and F_1s) were significant for all the traits (Table 1). The analysis of variance thus revealed wide genetic diversity among the parents. The analysis of variance for combining ability based on

Griffing's Model 1 and Method 2 exhibited that components of GCA and SCA mean squares were highly significant for pod yield per plant along with 10 other quantitative characters in F_1 generation (Table 2). This indicated that the inheritance of pod yield per plant and most of the yield component traits were controlled by both additive and non-additive gene action.

The relative magnitude and importance of additive and non-additive variances in the genetic control of various quantitative characters were further revealed by predictability ratio as suggested by Baker (1978). This reflected the preponderance of additive genetic effects for number of inflorescences per plant, number of nodes per inflorescence, number of flower buds per inflorescence and protein content of pod as their values were more than 0.80. For the characters like days to first flowering, days to 50% flowering, number of pods per plant, pod width, pod weight, shelling percentage of fresh pod and pod yield per plant both additive and non-additive gene effects were important as the predictability ratios were between 0.5 and 0.80. In contrast, length of inflorescence, number of pods per inflorescence, pod length and number of seeds per pod recorded predictability ratios below 0.5, indicating predominant role of non-additive gene action in the expression of these traits in dolichos bean.

GCA and per se performance

The GCA effects of the parents used in the study for 15 characters are given in Table 3. Among the parental lines, the highest significant and positive GCA effects had shown by BCDB 1 for 6 characters namely, number of pods per plant, pod length, pod weight, pod width, protein content of pod and pod yield per plant. Next to BCDB 1, significantly positive GCA effects was shown by DOLP VAR 10 for 8 characters namely, number of inflorescences per plant, number of pods per plant, pod length, pod weight, pod width, shelling percentage of fresh pod, protein content of pod and pod yield per plant. The least significant and positive GCA effects had shown by DOLP VAR 5 for pod yield per plant along with number of inflorescences per plant, number of pods per plant, pod length, pod weight, number of seeds per pod and protein content of pod. Negatively significant GCA effects for days to first flowering and days to 50% flowering were displayed by DOLP VAR 5, Arka Jay and DOLB VAR 2.

On the basis of ranking of 5 parents in half-diallel, 3 parents namely, BCDB 1, DOLP VAR 10 and DOLP VAR 5 appeared consistently superior in respect of GCA effects and *per se* performance for pod yield per plant, number of pods per plant and pod weight.

Heterobeltiosis and SCA effects

The *per se* performance of crosses, heterobeltiosis and estimates of SCA effects for 19 characters are given in Table 4. The maximum significant heterobeltiosis in negative direction for days to first flowering was exhibited by DOLP VAR 5 x DOLP VAR 10. Selection of hybrids showing negative heterosis over their better parents for these characters may be useful for developing early commercial hybrids. The lines DOLP VAR 5 and DOLP VAR 10 emerged as the earlier pole type parents (76 days and 90 days, respectively). Good crosses showing significant heterobeltiosis in negative direction for days to 50% flowering were DOLP VAR 5 x DOLP VAR 10 (-9.1%) followed by BCDB 1 X DOLP VAR 5(-6.8%).

For length of inflorescence, the cross combination BCDB 1 x DOLP VAR 10 recorded the highest heterobeltiosis (42.9%). In case of number of inflorescences per plant, none of the cross combinations exhibited significant heterobeltiosis in desired direction. The range of heterobeltiosis for number of nodes per inflorescence varied between -40.0% and 14.2%. The hybrid BCDB 1 x DOLP VAR 10 recorded highest heterobeltiosis (14.2%), indicating predominance of non-additive gene action in this cross. In case of number of flower buds per inflorescence the range of heterobeltiosis varied between -29.6% and 25.0%. Two crosses viz., BCDB 1 x DOLP VAR 5 and DOLP VAR 5 x DOLP VAR 10 equally showed the highest positive heterosis over better-parent (25.0%) followed by BCDB 1 x DOLP VAR 10 (21.0%).The range of heterobeltiosis for number of pods per inflorescence varied between -30.0% and 16.6%.

Table 1. Analysis of variance (mean square) for 15 characters in 5 x 5 half diallel cross.

Source of variation (df)	DFF^z	D50F	LI	NIPP	NNPI	NBPI	NPPI	NPPP	PW	PL	PWt	NSPP	SPFP	PCP	YPP
Genotypes (14)	600.34**	680.78**	45.84	518.3**	8.68**	28.4	4.56	207214.7**	1.31**	16.1**	20.3**	1.72**	99.2**	.054**	23.1**
Replication (2)	3.26	4.62	20.35	8.28	3.48	9.08	19.6	9393.6	.034	.059	.21	.001	159.5	.038	.0054
Error (28)	6.98	12.05	22.50	31.6	3.89	26.5	4.47	1167.0	.011	.035	.18	.23	.54	.0002	.21

DFF^z = Days to 1st flowering; D50F = Days to 50% flowering; LI= Length of inflorescence; NIPP = Number of inflorescence per plant; NNPI = Number of nodes per inflorescence; NBPI = Number of flower buds per inflorescence; NPPI = Number of pods per inflorescence; NPPP = Number of pods per plant; PW = Pod width; PL = Pod length; PWt = Pod weight; NSPP = Number of seeds per pod; SPFP = Shelling percentage of fresh pod; PCP = Protein content of pod; YPP = Yield per plant
* Significant at 5% level; ** Significant at 1% level.

Table 2. Analysis of variance (mean square) for combining ability (Griffing's Model 1 and Method 2).

Source of variation (d.f.)	DFF^z	D50F	LI	NIPP	NNPI	NBPI	NPPI	NPPP	PW	PL	PWt	NSPP	SPFP	PCP	YPP
GCA (4)	451.65 **	566.00 **	14.30	498.00 **	7.70 **	11.90	3.80 *	164766.5 **	1.03 **	9.20 **	17.30 **	0.82 **	70.20 **	0.056 **	19.60 **
SCA (10)	99.49 **	91.29 **	15.60 *	42.60 **	0.97	8.40	5.90	30793.5 **	0.20 **	3.80 **	2.53 **	0.47 **	18.20 **	0.002 **	2.91 **
Error (28)	2.32	4.01	7.50	10.50	1.20	8.80	1.40	389.03	0.003	0.01	0.062	0.07	0.18	0.00007	0.072
$\alpha^2 a$	128.38	160.56	1.94	139.20	1.80	0.88	0.68	46964.99	0.29	2.62	4.92	0.21	20.00	0.015	5.57
$\alpha^2 na$	97.17	87.20	8.10	32.10	-0.32	-0.40	4.5	30404.47	0.19	3.79	2.52	0.40	18.02	0.001	2.83
$\frac{\alpha^2 a}{\alpha^2 a + \alpha^2 na}$	0.569	0.648	0.193	0.813	1.216	1.833	0.133	0.607	0.604	0.409	0.661	0.344	0.526	0.938	0.663

DFF^z = Days to 1st flowering; D50F = Days to 50% flowering; LI = Length of inflorescence; NIPP = Number of inflorescence per plant; NNPI = Number of nodes per inflorescence; NBPI = Number of flower buds per inflorescence; NPPI = Number of pods per inflorescence; NPPP = Number of pods per plant; PW = Pod width; PL = Pod length; PWt = Pod weight; NSPP = Number of seeds per pod; SPFP = Shelling percentage of fresh pod; PCP = Protein content of pod; YPP = Yield per plant
*, ** Significant at $P < 0.05$ and 0.01, respectively

Table 3. Estimates of general combining ability (g_i) effects, *per se* performance in 5 parents over 10 F_1s.

Parents	DFF^z	D50F	LI	NIPP	NNPI	NBPI	NPPI	NPPP	PW	PL	PWT	NSPP	SPFP	PCP	YPP
BCDB 1	10.28** (95)[a]	9.59** (105)	-0.64 (17)	1.33 (70)	0.08 (7)	-0.90 (19)	-0.53 (6)	151.41** (770)	0.56** (3.1)	0.09** (10.8)	1.49** (10)	-0.09 (5)	-4.79** (25)	0.11** (17.3)	1.77** (7.7)
DOLP VAR 5	-4.15** (76)	-3.60** (87)	1.00 (21)	5.10** (76)	0.22 (8)	0.52 (20)	-0.63 (5)	98.36** (683)	-0.38** (1.8)	1.28** (12.7)	0.54** (8.3)	0.53** (6)	-1.09** (31.1)	-0.02** (14.2)	0.57** (5.7)
DOLP VAR 10	6.90** (90)	9.73** (107)	-2.14* (16.3)	10.38** (87)	-1.78** (4)	-1.76 (18)	-0.06 (6)	78.55** (695)	0.18** (2.8)	0.96** (12.6)	1.31** (9.5)	0.10 (5)	3.48** (40.3)	0.07** (16.1)	1.22** (6.5)
Arka Jay	-7.72** (49)	-7.60** (62)	0.36 (25.7)	-6.43** (45)	0.55 (9)	1.48 (27)	-0.01 (7)	-191.40** (45)	-0.32** (1.4)	-1.10** (8.9)	-1.4** (4.3)	-0.18 (5)	0.50** (32.3)	-0.07** (13.8)	-1.84** (0.22)
DOLB VAR 2	-5.30** (60)	-8.12** (66)	1.43 (25)	-10.38** (41)	0.93* (10)	0.67 (25)	1.23** (10)	-136.92** (75)	-0.03** (2.2)	-1.23** (5.5)	-1.9** (2.8)	-0.37** (4)	1.91** (35.2)	-0.10** (12.8)	-1.72** (0.25)
SE (g_i)	0.51	0.68	0.92	1.09	0.37	1.00	0.40	6.66	0.02	0.03	0.08	0.09	0.14	0.003	0.09

DFF^z = Days to 1st flowering; D50F = Days to 50% flowering; LI = Length of inflorescence; NIPP = Number of inflorescence per plant; NNPI = Number of nodes per inflorescence; NBPI = Number of flower buds per inflorescence; NPPI = Number of pods per inflorescence; NPPP = Number of pods per plant; PW = Pod width; PL = Pod length; PWt = Pod weight; NSPP = Number of seeds per pod; SPFP = Shelling percentage of fresh pod; PCP = Protein content of pod; YPP = Yield per plant
*, ** Significant at $P < 0.05$ and 0.01, respectively
[a]Bold figures in parentheses indicate *per se* performance

Table 4. Heterobeltiosis and estimates of SCA effects for 15 characters in dolichos bean hybrids.

Characters	Better crosses in desirable direction	Heterobeltiosis (%)	Range of Heterobeltiosis	Specific combining ability effects
Days to 1st flowering	DOLP VAR 5 x DOLP VAR 10	-6.60**	-6.60 to 91.80	-9.48*
Days to 50% flowering	DOLP VAR 5 x DOLP VAR 10	-9.10**	-9.10 to 61.20	-13.56**
	BCDB1 X DOLP VAR 5	-6.80*		-11.4**
Length of inflorescence	BCDB1 X DOLP VAR 10	42.90**	-52.50 to 42.90	7.06**
Number of nodes per inflorescence	BCDB1 X DOLP VAR 10	14.20**	-40.00 to 14.20	1.46
Number of flower buds per inflorescence	DOLP VAR 5 X DOLP VAR 10	25.00**	-29.60 to 25.00	4.13*
	BCDB1 X DOLP VAR 5			2.94
	BCDB1 X DOLP VAR 10	21.05**		3.56
Number of pods per inflorescence	DOLP VAR 5 X DOLP VAR 10	16.60**	-30.00 to 16.60	0.73
	DOLP VAR 10 X Arka Jay	14.28**		1.11
Pod width	DOLP VAR 10 X DOLB VAR 2	3.50**	-60.70 to 3.50	0.48**
Pod length	DOLP VAR 10 X DOLB VAR 2	11.10**	-55.00 to 11.10	3.52**
	DOLP VAR 5 X DOLB VAR 2	4.70**		2.44**
	BCDB1 X DOLB VAR 2	0.90**		1.26**
	BCDB1 X Arka Jay			1.17**
Pod weight	BCDB1 X DOLP VAR 10	17.00**	-6.00 to 17.00	0.30
	BCDB1 X DOLP VAR 5	12.00**		0.54
	DOLP VAR 5 X DOLP VAR 10	10.50**		-0.24
	Arka Jay x DOLB VAR 2	9.30**		-0.56
Number of seeds per pod	DOLP VAR 10 X DOLB VAR 2	20.00**	-20.00 to 20.00	1.33**
Protein content of pod	DOLP VAR 5 X DOLB VAR 2	0.05**	-1.80 to 0.05	0.09**
Pod yield per plant	Arka Jay X DOLB VAR 2	20.00**	-14.20 to 20.00	-1.57**
	DOLP VAR 10 X DOLB VAR 2	9.20**		2.14**
	BCDB1 X DOLP VAR 10	5.10**		-0.28**

*, ** Significant at $P < 0.05$ and 0.01, respectively.

The highest heterobeltiosis for this character was recorded in case of DOLP VAR 5 x DOLP VAR 10 (16.6%) followed by DOLP Var10 x Arka Jay (14.2%). None of the cross combinations showed significantly positive heterobeltiosis in case of number of pods per plant. The maximum positive and significant heterobeltiosis for pod width was exhibited by DOLP VAR 10 x DOLB VAR 2 showed (3.5%). The range of heterobeltiosis for pod length varied between -55.0% and 11.1%. The cross DOLP VAR 10 x DOLB VAR 2 exhibited heterobeltiosis to the tune of 11.1% followed by DOLP VAR 5 x DOLB VAR (4.7%) and BCDB 1 x Arka Jay and BCDB 1 x DOLB VAR 2 equally exhibited heterobeltiosis of 0.9%. The maximum number of positive and significant heterobeltiosis has been observed in pod weight and the range of heterobeltiosis varied between -6.0% and 17.0%. The cross BCDB 1 x DOLP VAR 10 showed the maximum heterobeltiosis (17.0%) followed by BCDB 1 x DOLP VAR 5 (12.00%) and DOLP VAR 5 x DOLP VAR 10 (10.5%) and Arka Jay x DOLB VAR 2 (9.3%). In case of number of seeds per pod, 1 cross DOLP VAR 10 x DOLB VAR 2 exhibited significant positive heterobeltiosis (20.0%). All the cross combinations showed negative heterobeltiosis in case of shelling percentage of fresh pod. The cross DOLP VAR 5 x DOLB VAR 2 exhibited significant positive heterobeltiosis (0.05%) in case of protein content of pod and the range varied between -1.8% and 0.05%. With regard to pod yield per plant, the range varied between -14.2% and 20.0%. Two cross combinations viz., Arka Jay x DOLB VAR 2 and DOLP VAR 10 x DOLB VAR 2 exhibited heterobeltiosis to the extent of 20.0% and 9.2%, respectively. However, these 2 crosses could not be exploited commercially due to poor average crossing success (12.0% in bush x bush type combination and 23.0% in pole x bush type combinations) and less number of seeds formed after each crossing (Table 5).

Table 5. Crossability percentage of dolichos bean.

Cross	No. of flower buds pollinated	No. of pods set	Crossing success (%)
Pole type x Pole type			
BCDB1 x DOLP VAR 5	50	15	30
BCDB1 x DOLP VAR 10	50	13	26
DOLP VAR 5 x DOLP VAR 10	50	14	28
Mean	50	14	28
Pole type x Bush type			
BCDB1 x Arka Jay	50	11	22
BCDB1 x DOLB VAR 2	50	13	26
DOLP VAR 5 x Arka Jay	50	14	28
DOLP VAR 5 x DOLB VAR 2	50	12	24
DOLP VAR 10 x Arka Jay	50	10	20
DOLP VAR 10 x DOLB VAR 2	50	9	18
Mean	50	11.5	23
Bush type x Bush type			
Arka Jay x DOLB VAR 2	50	6	12
Mean	50	6	12

Among these 2 crosses, DOLP VAR 10 x DOLB VAR 2 can be exploited in segregating generation for the improvement of yield and other component traits. While the cross Arka Jay x DOLB VAR 2 can be exploited in segregating generation for earliness in the only due to its negative significant SCA effects for days to first flowering and days to 50% flowering.

The SCA effects for hybrids pertaining to different characters are given in Table 4. It appeared that different cross combinations exhibited different SCA effects and only a few crosses showed consistently either positive or negative SCA effects for few characters. The perusal of different cross combinations revealed that the crosses involved 3 types of combinations namely, H x H, H x L and L x L where H stands for positive significant and L for negative GCA effects of the parents. In the H x H type cross combination i.e. DOLP VAR 5 x DOLP VAR 10 for days to flowering and days to 50% flowering, additive as well as additive x additive type of interactions were involved. Such cross would be very desirable in a self-pollinated crop as desirable segregants would be fixed in early advance generation. On the other hand, H x L type of cross combination involved 1 parent with high GCA effect or low GCA effect in the other parent indicated that predominantly additive effect was present in good combiner and possibly complementary epistatic effect in poor combiner and these 2 gene actions acted complementary fashion to maximize the expression. In the cross involving L x L category, SCA effect seemed to be played a very important role and high performance was due to non-additive gene action.

DISCUSSION

Not many findings were available on the genetics of quantitative characters especially in dolichos bean. It has been reported by previous workers (Kabir and Sen, 1990; Hossain, 1993; Khondker, 1995; Hossain, 2000; Basu*et al*., 2002; Kannan *et al*., 2005; Islam *et al*., 2009) that the ratio of GCA: SCA variance was equal to or more than unity for all the economically important characters studied in dolichos bean, indicating additive genetic control of these characters. On the contrary to this study, Alam and Newaz (2005) found the preponderance of both additive and non-additive gene effects for number of inflorescences per plant and number of flower buds per inflorescence under 2 environmental conditions. However, they agreed the present findings of both additive and non-additive genetic control of days to first flowering, pod weight, pod length and pod yield per plant. Preponderance of additive and non-additive gene effects for the control of days to 50% flowering corroborates the findings of Patil *et al*. (2013). The disparities in estimation by different workers may arise from differences in the genetic constitution of the parental materials used, variation in the environment, the techniques used in analyzing the data and the precision of the experiment.

While studying the nature of gene action governing 15 traits, it has been observed overwhelming response of both additive and non-additive gene action for the control of almost all the characters studied except number of inflorescences per plant, number of nodes per inflorescence, number of flower buds per inflorescence and protein content of pod for which preponderance of additive gene actions was evident. In this case some form of recurrent selection, such as diallel selective mating or bi-parental mating in early segregating generations might prove to be effective approaches. Restricted recurrent selection by intermating the most desirable segregants followed by selection might also be a useful breeding strategy for the exploitation of both additive and non-additive types of gene action. while selection of the desirable segregants from the segregating generations by adopting progeny selection method for exploiting additive genetic effects would lead to rapid improvement in this crop. Predominant role of non-additive gene action in the expression of length of inflorescence, number of pods per inflorescence, pod length and number of seeds per pod could be improved by heterosis breeding.

When the parents were assessed for their general combining ability and *per se* performance for 19 traits, 3 parents namely, BCDB 1, DOLP VAR 10 and DOLP VAR 5 could be identified as good general combiners for fruit yield per plant and other important yield contributing and quality characters and can be used in future breeding program. Significant and positive GCA effects for for number pods per plant, pod yield per plant (Kannan *et al*., 2003; Alam and Newaz, 2005; Islam *et al*., 2009; Gavali *et al*., 2011; Patil *et al*., 2013), average pod weight (Basu *et al*., 2002; Virja *et al*., 2006; Islam *et al*., 2009) and pod length (Sawant *et al*., 2006; Islam *et al*., 2009) have also been reported.

Therefore, heterobeltiosis for pod yield per plant was reflected through heterosis in pod weight. This is in partial or full confirmation with the results obtained by Hazra (1982) and Patil *et al*. (2013) in dolichos bean.

Specific combining ability effects represent dominance and epistatic components of genetic variation which are not fixable but the crosses with high SCA effects involving good general combiner parents can be exploited in future breeding program. The top 4 cross combinations DOLP VAR 10 x DOLB VAR 2 (H x L), DOLP VAR 10 x Arka Jay (H x L), BCDB 1 x DOLB VAR 2 (H x L) and DOLP VAR 5 x Arka Jay (H x L) exhibited highest significant SCA effects for pod yield per plant, number of pods per plant, pod width, pod weight, pod length and protein content of pod, having at least 1 parent is good general combiner, indicating that hybrids having 1 parent with high GCA effect. However, 2 crosses viz., DOLP VAR 5 x DOLP VAR 10 (H x H) and Arka Jay x DOLB VAR 2 (L x L) showed significant negative SCA effects for days to flowering and days to 50% flowering. Other cross combinations showed inconsistent results for rest of the characters. Significant and positive SCA effects for all the economic traits of dolichos bean involving all combinations of GCA effects of the parents i.e. H x H, H x L and L x L have also been recorded by previous workers (Alam and Newaz, 2005; Islam *et al*., 2009; Gawali *et al*., 2011; Patil *et al*., 2013).

CONCLUSIONS

This study found the importance of additive genetic effects for number of inflorescences per plant, number of nodes per inflorescence, number of flower buds per inflorescence and protein content of pod suggesting selection of the desirable segregants from the segregating generations by adopting progeny selection can be adopted for improvement of such characters. However, preponderance of non-additive gene action was exhibited by length of inflorescence, number of pods per inflorescence, pod length and number of seeds per pod which can be improved through heterosis breeding. On the other hand, predominant role of both additive and non-additive gene effects have been observed for days to first flowering, days to 50% flowering, number of pods per plant, pod width, pod weight, shelling percentage of fresh pod and pod yield per plant which could be improved by restricted recurrent selection by intermating the most desirable segregants followed by selection. Three parents namely, BCDB 1, DOLP VAR 10 and DOLP VAR 5 were identified as most promising general combiners for fruit yield along with number of pods per plant and pod weight and these parents could be used for future breeding program. Four cross combinations *viz*., DOLP VAR 10 x DOLB VAR 2, DOLP VAR 10 x Arka Jay, BCDB 1 x DOLB VAR 2 and DOLP VAR 5 x Arka Jay exhibited the highest significant SCA effects for pod yield per plant, number of pods per plant, pod width, pod weight, pod length and protein content of pod, and having at least 1 parent is good general combiner, indicating that through simple pedigree method in segregating generations these hybrids are expected to produce segregants of fixable nature. Two cross combinations viz., Arka Jay x DOLB VAR 2 and DOLP VAR 10 x DOLB VAR 2 exhibited heterobeltiosis for pod yield per plant to the extent of 20.0% and 9.2%, respectively. These heterobeltiosis for pod yield per plant were reflected through heterosis in pod weight.

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