RESEARCH ARTICLE

SABRAO Journal
of Breeding and Genetics
47 (2) 124-132, 2015

GENETIC ANALYSIS OF YIELD COMPONENTS AND CURD COLOR OF MID-SEASON HEAT TOLERANT INDIAN CAULIFLOWER (*Brassica oleracea* var. *Botrytis* L.)

P. SAHA[1]*, P. KALIA[1], S. JOSHI[1] and VINOD[2]

[1]Division of Vegetable Science, Indian Agricultural Research Institute, New Delhi, India
[2]Division of Genetics, Indian Agricultural Research Institute, New Delhi, India
*Corresponding authors' email address: hortparth@gmail.com
Co-authors' email addresses: pritam.kalia@gmail.com, joshi_danya@rediffmail.com, vinodk@iari.res.in

SUMMARY

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is one of the most popular and widely grown vegetable crops in India. Yield and white color of curd are most important characters of cauliflower determining the economics of cultivation of the crop. Six generation of cauliflower (P_1, P_2, F_1, F_2, B_1 and B_2) were raised by crossing 2 popular varieties and 2 lines (Pusa Himjyoti x BR-161, Pusa Himjyoti x BR-207, Pusa Sharad x BR-161, Pusa Sharad x BR-207, BR-161 x BR-207 and Pusa Himjyoti x Pusa Sharad). Over-dominance had predominant role for marketable curd weight, curd diameter and curd depth. In marketable curd weight, the presence of dominance (*h*) and dominance x dominance (*l*) component of genetic variation along with duplicate type of epistasis were present. Curd color was determined by single gene with white being recessive. So, the genetics of characters studied will provide information in the improvement of yield and quality parameters of cauliflower. Besides these, the developed elite hybrids or breeding lines may be tested for yield and quality traits under different agro-climatic conditions for commercial exploitation of hybrid vigor.

Key words: Cauliflower, genetics, yield, curd color

Key findings: It is evident from this genetic analysis study that most traits are under the control of non-additive gene action in Indian cauliflower. The cauliflower breeders, therefore, can concentrate on heterosis breeding.

Manuscript received: August 2, 2014; Decision on manuscript: February 5, 2015; Manuscript accepted: February 25, 2015.

Communicating Editor: Bertrand Collard

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis* L., 2n = 2x = 18) is an important vegetable crop cultivated throughout India (Singh *et al*., 2005; Varalaxmi, 2009). Most of the released open pollinated varieties are poor in curd quality with low yield and have variation in maturity, shape and other quality characters. Now a days, main emphasis has been given to develop F_1 hybrids having high yield with uniform curds size and good quality characters. The highly suppressed pre-floral apical meristem commonly known as 'curd' is the edible part of this crop (Sidki, 1962). For a good cauliflower crop, high yield, compact, white-colored and medium-sized curds, free from any disease or disorder, are desired (Varalaxmi, 2009).Yield in cauliflower is a complex character influenced by various component characters namely, marketable curd

weight, plant height, number of leaves per plant, curd diameter and curd depth which inherit polygenically and highly subject to environmental variations (Devaraju *et al*., 2010). Knowledge of gene action of a character is essential to formulate an effective breeding program for developing a variety or hybrid having desirable genes for yield, quality and resistance (Devaraju *et al*., 2010).. Predominance of non-additive gene action was reported for curd size and curd weight in early cauliflower (Varalaxmi, 2009). Pandey and Nayak (1991) reported that magnitude of dominance variance were predominant for total plant weight and, curd weight in bi-parental progenies of cauliflower. Gangopadhyay *et al.* (1997) reported that dominance or over-dominance gene action was responsible for the expression of yield contributing characters like curd weight of cauliflower. Color of curd is another important character which determines the preference of cauliflower to the consumer. Generally white colored cauliflower is preferred by the consumers. Ahluwallia (1977) reported that white curd color is controlled by single gene and white color is recessive. Crisp and Angell (1985) studied the genetics of curd color in a segregating cauliflower population derived from crosses between white and green curded types. They reported a gene (*Wi wi*) giving white color which is dominant over yellow. The orange color of cauliflower curd is governed by single dominant mutated *Or* gene and plants that are homozygous for the *Or* gene possess an intense orange coloration in these tissues and produce small curds, whereas the heterozygous plants are less pigmented and have normal-sized curds (Li and Garvin, 2003). A large number of varieties and hybrids have been developed in the recent past, but the yield plateau could not be broken to the extent it needed. Therefore, the present investigation was taken up with the objective of studying the gene action of different desirable characters so that inference drawn from the study could be utilized in formulating breeding strategies to develop desirable varieties or hybrids.

MATERIALS AND METHODS

Four genetically diverse parents (Pusa Himjyoti, Pusa Sharad, BR-161 and BR-207) of mid-season maturity group (November) of cauliflower were used to develop different generation *viz.* F_1, F_2 and backcross (B_1, B_2). The parental lines were homozygous and were cross compatible. The developed generations comprising of parents (P_1, P_2), F_1, F_2, B_1 and B_2 of the 6 cross combinations (Pusa Himjyoti x BR-161, Pusa Himjyoti x BR-207, Pusa Sharad x BR-161, Pusa Sharad x BR-207, Pusa Himjyoti x Pusa Sharad and BR-161 x BR-207) were planted in RBD with 3 replications in the experimental field of Division of Vegetable Science, Indian Agricultural Research Institute (IARI), New Delhi, India located at an elevation of about 228 m above MSL, 20° 40′ North latitude and 77° 13′ East longitude.. One-month-old seedlings were transplanted in the main field during the second week of September, 2011, with a planting distance of 60 cm between rows and 45 cm within rows. Recommended packages of practices were followed for raising the crop as per Singh and Sharma (2003). The maximum temperature was 31 ^{o}C and minimum temperature was 13 ^{o}C during the growing period (Mid of September to End of November). Observations on plant height, leaf number, marketable curd weight, curd diameter, curd depth were taken at edible curd maturity stage from 30 plants of each of parents, 30 F_1 plants of each cross combinations, 90 plants from each of backcross and 120 plants from each of F_2 generations. The observation on curd color was taken as per Royal Horticultural Society color chart (Wilson, 1941) at edible maturity stage. The data for plant height, number of leaves per plant, marketable curd weight, and curd diameter and depth were tested for the adequacy of the additive-dominance model using A, B, C and D scaling test as suggested by Mather and Jinks (1971). When the additive-dominance model failed to fit the data, generation mean analysis was carried out incorporating mean (*m*), additive (*d*), dominance (*h*), additive x additive (*i*), additive x dominance (*j*) and dominance x dominance (*l*) as per Mather and Jinks (1971). Computation for Generation mean analysis was carried out by using WINDOSTAT (Version 8.0) software. The goodness of fit for curd color for the observed F_2 and backcross ratio with the expected Mendelian ratio was tested using chi-square (χ^2) formula (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

There were significant differences among 6 generations (P_1, P_2, F_1, F_2, B_1 and B_2) for all the quantitative characters of different cross combinations (Table 1). The magnitude and direction of heterosis varied from cross to cross. In case of plant height, the F_1 mean values of all the crosses were higher than their corresponding parental means and mid parental value which showed the over dominance effect. The F_2 means were lower than their corresponding F_1 means in all the crosses.

Table 1. Generation mean ± SE of yield contributing characters in 6 generation of 6 different crosses.

Generations	Pusa Himjyoti x BR-161	Pusa Himjyoti x BR-207	Pusa Sharad x BR-161	Pusa Sharad x BR-207	BR-161 x BR-207	Pusa Himjyoti x Pusa Sharad
			Plant height			
P1	51.01±0.15	51.11±0.13	55.10±0.19	54.92±0.15	48.99±0.14	50.99±0.12
P2	49.54±0.19	52.39±0.12	49.66±0.17	52.06±0.22	52.02±0.15	54.92±0.22
F1	60.67±0.13	65.41±0.09	60.72±0.14	62.10±0.19	58.53±0.11	58.57±0.15
F2	59.07±0.52	59.29±0.33	57.37±0.48	55.67±0.64	55.04±0.38	53.07±0.52
B1	54.42±0.48	55.74±0.23	54.29±0.46	52.06±0.30	50.95±0.41	52.68±0.19
B2	51.56±0.37	58.78±0.12	52.02±0.41	51.92±0.18	53.02±0.40	52.40±0.27
MP	50.27	51.75	52.38	53.49	50.50	52.95
			Leaf number			
P1	21.43±0.23	21.56±0.24	23.16±0.22	23.06±0.15	22.50±0.22	21.36±0.26
P2	22.30±0.23	24.03±0.14	22.20±0.18	24.06±0.16	24.3±0.16	23.03±0.18
F1	25.93±0.12	24.73±0.15	26.60±0.21	22.66±0.16	25.00±0.17	25.40±0.27
F2	23.28±0.24	23.04±0.17	21.96±0.29	21.00±0.26	21.65±0.20	21.91±0.35
B1	23.02±0.15	22.63±0.14	21.92±0.17	20.96±0.20	21.46±0.16	21.53±0.12
B2	21.10±0.14	22.52±0.17	22.68±0.14	20.97±0.14	22.77±0.19	22.61±0.18
MP	21.86	22.79	22.68	23.56	23.40	22.19
			Marketable Curd weight			
P1	534.83±1.50	536.16±1.39	695.33±1.77	536.16±1.39	403.50±1.15	534.83±1.05
P2	401.50±4.32	392.66±0.88	407.16±0.74	392.66±0.88	391.83±1.11	696.66±2.05
F1	879.33±1.67	934.70±3.60	929.16±1.42	934.70±3.60	523.33±1.55	859.16±0.86
F2	608.70±17.53	584.42±13.32	733.79±21.65	584.42±13.32	473.30±10.21	701.08±17.32
B1	647.32±15.92	865.55±6.58	866.27±6.04	865.55±6.58	510.05±1.17	796.05±0.75
B2	607.50±1.80	707.44±3.61	787.44±0.98	707.44±3.61	497.55±1.22	742.38±3.47
MP	468.16	464.41	551.24	464.41	397.66	615.74
			Curd depth			
P1	6.11±0.03	6.14±0.03	8.15±0.05	6.14±0.03	6.47±0.04	6.13±0.03
P2	6.49±0.04	5.29±0.02	6.48±0.04	5.29±0.02	5.30±0.02	8.14±0.05
F1	9.14±0.02	10.73±0.07	11.71±0.08	10.73±0.07	7.98±0.03	9.74±0.03
F2	7.13±0.15	7.17±0.12	8.78±0.22	7.17±0.12	6.12±0.08	8.31±0.16
B1	7.65±0.15	9.84±0.06	9.66±0.07	9.84±0.06	6.25±0.02	9.02±0.02
B2	7.31±0.03	8.24±0.03	9.10±0.04	8.24±0.03	6.11±0.02	8.61±0.02
MP	6.3	5.71	7.31	5.71	5.88	7.13
			Curd diameter			
P1	9.73±0.04	9.76±0.05	11.03±0.09	9.76±0.05	9.09±0.06	9.75±0.05
P2	9.02±0.06	9.25±0.03	9.10±0.70	9.25±0.03	9.25±0.03	11.02±0.09
F1	14.13±0.06	14.62±0.10	14.28±0.09	14.62±0.10	10.88±0.45	13.38±0.09
F2	10.29±0.15	10.21±0.11	11.22±0.21	10.21±0.11	9.29±0.10	11.10±0.15
B1	10.79±0.15	13.14±0.08	11.95±0.08	13.14±0.08	10.03±0.04	11.96±0.03
B2	10.49±0.04	11.41±0.05	11.36±0.06	11.41±0.05	9.45±0.04	11.66±0.02
MP	9.37	9.50	10.06	9.50	9.17	10.38

This might be due to fact that some inbreeding depression occur. The F_2 mean value were higher than their corresponding parental means in Pusa Himjyoti x BR-161, Pusa Himjyoti x BR-207, Pusa Sharad x BR-161, Pusa Sharad x BR-207. Backcross means were as per expectation and gave higher value when crossed with the parent with more plant height and lower value when crossed with parent with less plant height except cross of Pusa Himjyoti x Pusa Sharad. Data presented for leaf number showed that F_1 means were higher than parental means in all the crosses except in the cross of Pusa Sharad x BR-207 where mean value of F_1 was lower than their corresponding parental mean and mid parental value. The F_2 mean values were lower than the F_1 means in all the crosses for this trait. The observed values of B_2 generation were as per in crosses of BR-161 x BR-207 and Pusa Himjyoti x Pusa Sharad.

The perusal of data for marketable curd weight indicated that in all the crosses, F_1 means showed higher values than the corresponding parental means and mid parental values (Table 1). The F_1 hybrid of different cross combination is given in Figure 1. The F_2 means were lower than F_1 mean in all the crosses. The B_1 mean values were higher than B_2 mean in all the crosses as per expectation. The F_1 means for curd depth were higher than parental means and mid parental values in all the crosses.

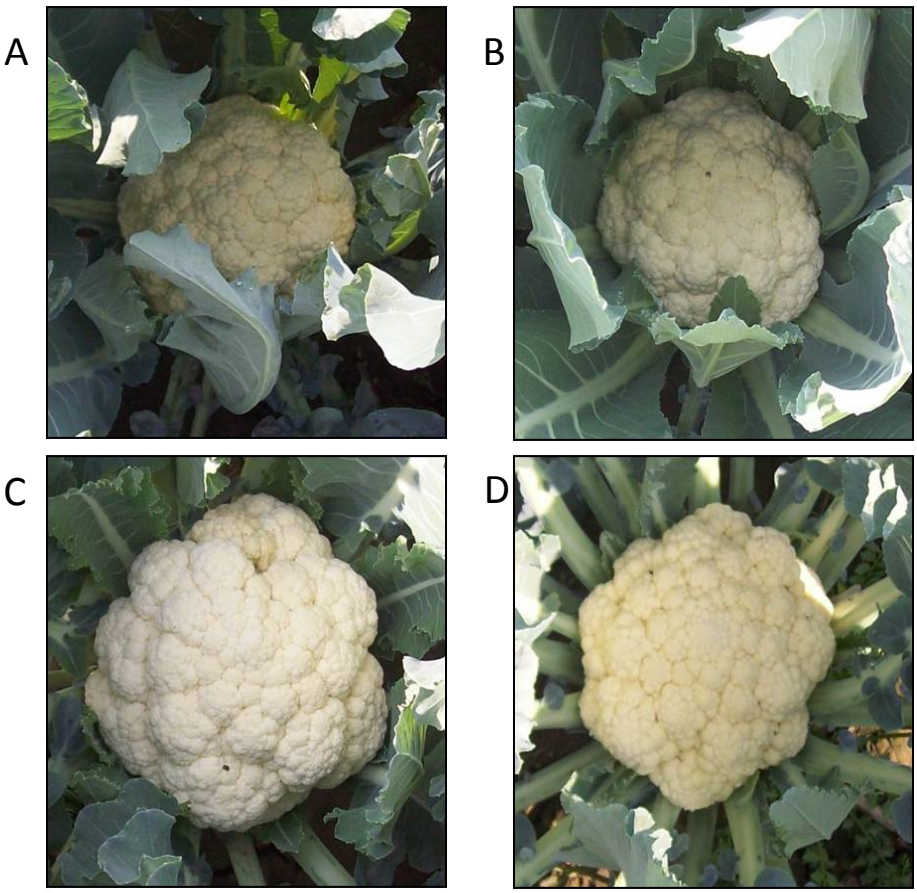

Figure 1. F_1s of different cross combinations Pusa Himjyoti x BR-161 (A), Pusa Himjyoti x BR-207 (B), Pusa Sharad x BR-161 (C), Pusa Sharad x BR-207 (D) of mid-season heat tolerant cauliflower.

Similarly, F_2 means were lower than F_1 mean in all the crosses. But in all the cross combinations transgressive segregation in both high and low direction for marketable curd yield was observed in the F_2 population. The B_1 mean values were higher in all the crosses. The F_1 values for curd diameter were more than their respective parental means and mid parental values. The F_2 means were lower than F_1 means values in all the crosses. The B_1 mean values were higher than their corresponding B_2 mean values in all the crosses. The results of scaling test with respect to different traits in all the crosses showed significance and indicated inadequacy of additive-dominance model to explain the variations of means of various generations for different traits. In such situation 6 parameters (*m*, *d*, *h*, *i*, *j* and *l*) were estimated.

The estimates of 6 parameters model including interaction for plant height (Table 2) showed that mean (*m*) effect was highly significant and positive for plant height in all the crosses. The dominance (*h*) component was negative for most of the crosses and non-significant for Pusa Himjyoti x Pusa Sharad. The additive (*d*) component was lower than dominance (*h*) component in all the crosses. Among epistasis effect dominance x dominance (*l*) was significant and predominant in all the crosses. Gene interaction is complementary when dominance (*h*) and dominance x dominance (*l*) estimates have same sign and duplicate when sign differ. The negative sign of *h* present in 4 crosses which indicate higher frequencies of decreased allele. Moreover opposite sign of h and l indicates duplicate type of epistasis in 5 crosses.

In case of leaf number, dominance (h) component was higher in all the crosses except Pusa Himjyoti x BR-161 and Pusa Himjyoti x BR-207 and positive in all crosses except Pusa Himjyoti x BR-161 and Pusa Sharad x BR-207. The dominance (*h*) component was significant only for 3 crosses and additive (*d*) component was significant for 4 crosses. The dominance x dominance (*l*) was significant and higher than other component (*i* and *j*) in all the crosses (Table 2). Both additive (*d*) and dominance (*h*) played major role for this character but later with higher order and also dominance x dominance were predominant which indicate that the character is under influence of non-additive gene action. Varalaxmi *et al*. (2009) and Devaraju *et al*. (2010) found dominance x dominance effect in different cross combination of cauliflower. In our result, both complementary and duplicate type of epistasis present in that character showing lot of variability.

In marketable curd weight dominance component (*h*) was significant and positive and higher than additive effect (*d*) in all the crosses (Table 3). The interaction effects were significant for most of the crosses. The dominance x dominance (*l*) components were higher and negative in all crosses except Pusa Himjyoti x BR-161 where additive x additive (*i*) effect was higher and positive in direction. The dominance (*h*) gene effect has a major contribution towards inheritance of this character indicating the role of dominant genes in the expression of this parameter. This is in confirmation with the reports of Swarup and Pal (1966); Lal *et al.* (1977); Dhiman *et al*. (1983); Varalakshmi (2009). Besides, maximum number of crosses showed dominance x dominance (*l*) gene action with duplicate type of epistasis. A study by Mahajan *et al*. (1996); Jyoti and Vasistha (1986); Devaraju *et al.* (2010) suggested dominance x dominance gene action for marketable curd weight in other cross combination of cauliflower.

For curd depth, the magnitude of dominance (h) effect was higher than additive effect in all the crosses and positive in direction. Among the epistasis effect, all the 3 interaction parameters were significant for most of the crosses. The magnitude of dominance x dominance (*l*) effect were higher than other interaction effect in all the crosses except Pusa Himjyoti x BR-161 and Pusa Sharad x BR-161 where additive x additive (*i*) effect were predominant.

The 6 parameter models for curd diameter showed that all the component of variation were significant for Pusa Himjyoti x BR-207, Pusa Sharad x BR-207 and Pusa Himjyoti x Pusa Sharad. The magnitude of dominance (*h*) component were higher than additive (*d*) component in all the crosses except Pusa Sharad x BR-207 where, additive (*d*) component were predominant. Among interaction effect, the magnitude of additive x

Table 2. Estimation of 6 parameters based on generation mean for marketable curd weight, curd depth and curd diameter.

	m	d	h	i	J	l	Epistasis
				Plant height			
Pusa Himjyoti x BR-161	59.07**	2.85**	-13.92**	-24.31**	2.12**	34.23**	D
Pusa Himjyoti x BR-207	59.29**	-3.04**	5.56**	-8.09**	-2.40**	13.36**	D
Pusa Sharad x BR-161	57.38**	2.26**	-8.54**	-16.88**	-0.45	30.47**	D
Pusa Sharad x BR-207	55.67**	0.13	-6.12*	-14.72**	-1.29**	37.92**	D
BR-161 x BR-207	55.04**	-2.07**	-4.21*	-12.23**	-0.55	22.35**	D
Pusa Himjyoti x Pusa Sharad	53.07**	0.28	3.49	-2.11	2.24**	15.01**	C
				Leaf number			
Pusa Himjyoti x BR-161	23.28**	1.92**	-0.82	-4.88**	2.35**	12.24**	D
Pusa Himjyoti x BR-207	23.04**	0.11 ^{NS}	0.07	-1.85*	1.34**	6.61**	C
Pusa Sharad x BR-161	21.96**	-0.76**	5.27**	1.35	-1.25**	7.98**	C
Pusa Sharad x BR-207	21**	-0.01	-1.01^{NS}	-0.11	0.48	8.68**	D
BR-161 x BR-207	21.65**	-1.31**	3.45**	1.85	-0.41	6.45**	C
Pusa Himjyoti x Pusa Sharad	21.91**	-1.07**	3.82*	0.62	-0.24	6.28**	C

Table 3. Estimation of 6 parameters based on generation mean for marketable curd weight, curd depth and curd diameter.

Cross combinations	m	d	h	i	j	l	Epistatis
				Marketable curd weight			
Pusa Himjyoti x BR-161	608.70**	39.81*	485.98**	74.82	-26.85	110.52^{NS}	C
Pusa Himjyoti x BR-207	584.42**	158.11**	1278.60**	808.31**	86.36**	-1156.08**	D
Pusa Sharad x BR-161	733.79**	78.83**	750.19**	372.27**	-65.25**	-718.88**	D
Pusa Sharad x BR-207	675.37**	96.88**	293.38**	-65.94	-54.27*	330.38**	C
BR-161 x BR-207	473.30**	12.50	247.68**	122.02**	6.66	-295.24**	D
Pusa Himjyoti x Pusa Sharad	701.08**	53.66**	515.97**	272.55**	134.58**	-399.61**	D
				Curd diameter			
Pusa Himjyoti x BR-161	10.29**	0.29	6.13**	1.38*	-0.05	3.06**	C
Pusa Himjyoti x BR-207	10.21**	1.72**	13.38**	8.26**	1.47**	-9.10**	D
Pusa Sharad x BR-161	11.22**	0.58**	5.94**	1.73	-0.37**	0.34	C
Pusa Sharad x BR-207	11.22**	2.50**	-0.001	-3.03**	1.60**	7.84**	D
BR-161 x BR-207	9.29**	0.57**	3.50**	1.79**	0.65**	-0.66	D
Pusa Himjyoti x Pusa Sharad	11.10**	0.30**	5.84**	2.84**	0.93**	-2.56**	D
				Curd depth			
Pusa Himjyoti x BR-161	7.13**	0.34*	4.21**	1.37*	0.53**	-0.41	D
Pusa Himjyoti x BR-207	7.17**	1.60**	12.49**	7.48**	1.18**	-10.75**	D
Pusa Sharad x BR-161	8.78**	0.55**	6.78**	2.38**	-0.27**	-1.85	D
Pusa Sharad x BR-207	8.11**	0.77**	1.93*	-1.42	-0.64**	4.00**	C
BR-161 x BR-207	6.12**	0.14**	2.34**	0.24	-0.43**	2.76**	C
Pusa Himjyoti x Pusa Sharad	8.31**	0.40**	4.62**	2.02**	1.41**	-3.53**	D

Table 4. Inheritance of curd color in different cross combination.

White x Cream	Observed plants		Expected ratio	χ^2	P value at 5 %
	Cream	White			
Pusa Himjyoti x BR-161					
Pusa Himjyoti	0	30			
BR-161	30	0			
F_1	30	0			
F_2	86	34	3:1	0.71	0.40
B_1	48	42	1:1	0.40	0.53
B_2	90	0			
Pusa Himjyoti x Pusa Sharad	92	28			
Pusa Himjyoti	0	30			
Pusa Sharad	30	0			
F_1	30	0			
F_2	92	28	3:1	0.18	0.67
B_1			1:1	0.04	0.83
B_2					
Cream x white					
Pusa Sharad x BR-207					
Pusa Sharad	30	0			
BR-207	0	30			
F_1	30	0			
F_2	88	32	3:1	0.18	0.67
B_1	120	0			
B_2	41	49	1:1	0.71	0.40
BR-161 x BR-207					
BR-161	30	0			
BR-207	0	30			
F_1	30	0			
F_2	84	36	3:1	0.60	0.21
B_1	120	0			
B_2	43	47	1:1	0.18	0.67

additive (*i*) and dominance x dominance (*l*) were equal in the crosses. Singh and Varalaxmi (2002) and Singh *et al.* (2005) reported non-additive gene action for curd diameter in cauliflower.

The segregation of curd color in F_2 and backcross generation for the crosses between white and cream curd colored variety (Pusa Himjyoti x BR-161; Pusa Himjyoti x Pusa Sharad) and cream and white (Pusa Sharad x BR-207; BR-161 x BR-207) is given in Table 4. It was observed that the F_2 population segregated into expected 3:1 ratio (cream: white), with high degree of confidence (P = 0.40). The backcross generation showed the expected ratio of 1:1 (cream: white). In case of cream and white colour cross combination (Pusa Sharad x BR-207), segregation in F_2 generation followed 3:1 (cream: white) ratio. Similarly, backcross with respect to their parent showed expected ratio of 1:1 (cream: white). In case of BR-161 x BR-207 the ratio of cream and white color was 84:36 which also segregated in 3:1 (cream: white) ratio. Backcross generation also confirms the

segregation pattern into 1:1 (cream: white) ratio. This confirms the presence of single gene controlling curd color with white being recessive. The segregation in backcross generation in all 4 cross combinations also confirms the presence of single gene. Our result contradict the findings of Crisp and Angell (1985) who reported a dominant gene (*Wiwi*) govern the white color in a segregating cauliflower population derived from crosses between white and green curded types.

CONCLUSION

The present study showed overdominace for all the characters including marketable curd weight, curd diameter and curd depth. Besides there was not much chances in fixing several characters as the additive gene effect was low for most of the characters except curd diameter. In all the characters including marketable curd weight the dominance (*h*) and dominance x dominance (*l*) component of genetic variation along with duplicate type of epistasis were present. The additive x additive gene action was low but significant. Curd color is governed by single gene with white being recessive. So the promising procedures to be adopted are use of F_1 hybrids for increasing yield with better quality curd in cauliflower.

ACKNOWLEDGEMENTS

The financial support by ICAR, New Delhi and facilities given by Division of Vegetable Science, IARI, New Delhi are gratefully acknowledged.

REFERENCES

Ahluwalia KS (1977). Genetical studies in Indian Cauliflower. PhD Thesis, Div. of Vegetable Science, Indian Agricultural research Institute, New Delhi, India.

Crisp P, Angell SM (1985). Genetic control of green curd colour in cauliflower. *Ann. App. Biol*. 107: 601–603.

Devaraju B, Varalaxmi B, Savitramma DL (2010). Genetics of yield and its component trait in cauliflower. *Indian J. Hort.* 67: 339-342.

Dhiman SC, Sharma PP, Arya PS (1983). Genetical studies in cauliflower (*Brassica oleracea* var. *botrytis* L.). *South Indian Hort.* 31: 73-81.

Gangopadhyay KK, Gill HS, Sharma SR (1997). Heterosis and combining ability studies in early group of Indian cauliflower involving self-incompatible lines. *Veg. Sci.* 24: 26-28.

Jyoti S, Vashistha RN (1986). Gene effect studies of curd weight in mid-season cauliflower (*Brassica oleracea* var. *botrytis* L.). *Haryana J. Hort. Sci.* 15: 263-266.

Li L, Garvin DF (2003). Molecular mapping of Or, a gene inducing beta-carotene accumulation in cauliflower (*Brassica oleracea* L. var. *botrytis*). *Genome* 46: 588–594.

Mahajan V, Gill HS, Sharma SR, Singh R (1996). Combining ability studies in Indian Cauliflower (*Brassica oleracea* var. *botrytis* L.) group III. *Veg. Sci.* 23: 166-170.

Mather K, Jinks JL (1971). *Biometrical Genetics*, 2nd edition, Chapman and Hall, London.

Pal AB, Swarup V (1966). Gene effects and heterosis in cauliflower-II. *Indian J. Genet*. 26: 282-94.

Pandey SC, Nayak G, (1991). Genetics and character association studies in bi parental progenies of cauliflower. *Indian J. Hort.* 48: 351-355.

Panse VG, Sukhatme PV (1967). Statistical methods for Agricultural workers, Indian Council of Agricultural Research, New Delhi, India, pp. 152-157.

Sidki S (1962). Morphology of curd of cauliflower. *Am. J. Bot*. 49: 290-297.

Singh D, Varalaxmi B (2002). Heterosis and combining ability studies in cauliflower (*Brassica oleracea* var. *botrytis* L.). Abstract published in the *proceeding of the International Conference on Vegetables*. Nov. 11-14, Bangalore pp. 98-99.

Singh D, Varalaxmi B, Reddy NMA (2005). Combining ability studies in early cauliflower (*Brassica oleracea* var. *botrytis* L.). *Indian J. Hort.* 62: 27-32.

Singh R, Sharma SR (2003). Cauliflower (*Brassica oleracea* var. *botrytis*). In: S. Thamburaj and N. Singh, Eds., *Vegetables, Tubercrops and Spices*. Directorate of Information and Publications of Agriculture, Indian Council of Agricultural Research, New Delhi, India, pp. 76-97.

Swarup V, Pal AB (1966). Gene effects and heterosis in cauliflower-I. *Indian J. Genet.* 26: 269-81.

Varalaxmi B (2009). Heterosis and combining ability for yield and its components in cauliflower. *Indian J. Hort*. 66: 198-203.