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Heterosis and combining ability analysis for earliness and grain yield in bread wheat (*Triticum aestivum* L.)

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ABSTRACT

Heterosis and combining ability analysis were studied in a 10 × 10 diallel set of bread wheat. Significant heterosis over better parent was observed in HW-5018 × HI-1544 for dwarfness and grain yield per plant. The analysis of variance for combining ability revealed that the mean squares due to both general combining ability (gca) and specific combining ability (sca) were highly significant for all the characters. It indicated that both additive and non-additive genetic variances played a vital role in the inheritance of all these four traits. The GCA and SCA ratio ($\sigma^2\text{GCA}/\sigma^2\text{SCA}$) was less than unity for all the traits indicated that non-additive component play relatively greater role in the inheritance of all the four traits. On the basis of GCA, SCA effects and *per se* performance, parents HI-1544 for three traits and UAS-281 for two traits were found good general combiners and crosses HW-5018 × HI-1544 and GW-322 × GW-173 for two traits each were found good specific combiners in bread wheat.

Key words: Heterosis, general and specific combining ability, bread wheat

Wheat (*Triticum spp.*) is usually accorded a premier place among the cereals because of the vast acreage devoted to its cultivation, its high nutritive value and its association with some of the earliest and most important civilizations of the world. Wheat is the second most important staple food crop next to rice, consumed by nearly 35% of the world population and providing 20% of the total food calories. This crop occupies about 32% of total acreage in the world. The choice of suitable parents for evolving better varieties/hybrids is a matter of concern to the plant breeders. In systemic breeding programme, selection of parent with desirable characteristics having good general combining ability effects for grain yield and its components, high heterosis and high estimates of specific combining ability effects are essential. These estimates will help in formulating efficient and effective breeding

procedure to bring about rapid and suitable improvement in this crop. The present investigation was, therefore, attempt to study the extent of heterosis and combining ability for traits related to earliness and grain yield in bread wheat.

MATERIALS AND METHODS

The initial experimental material consisted of ten genotypes /varieties viz., GW-496, GW-322, LOK-1, GW-173, KYZ-300, RAJ-4136, HW-5018, K-604, UAS-281, HI-1544, GW-366 of bread wheat (*Triticum aestivum* L. Em. Thell). These genotypes were crossed in all possible combinations using diallel mating design excluding reciprocal during Rabi 2010-11 at Wheat Research Station, Junagadh Agricultural University, Junagadh. A set of 56 entries, including 10 parents, their 45 crosses and one standard check (GW-366) were sown in randomized block design with three replications during Rabi 2011-12. Each entry was sown in a single row plot of

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2.5 m long keeping row to row and plant to plant distance of 22.5 cm, and 10 cm, respectively. Five plants of each parents and hybrids were selected randomly for recording observations for four traits namely days to 50 % flowering, days to maturity, plant height (cm) and grain yield per plant (g). The plant material was evaluated by analysis of the data on heterosis and combining ability. Heterobeltiosis and standard heterosis were calculated by using formula of Fonseca and Patterson (1968). The analysis of variance for general (GCA) and specific (SCA) combining abilities were carried out according to Model 1, Method 2 (half-diallel set) of Griffing (1956).

RESULTS AND DISCUSSION

Mean square due to genotypes was highly significant for all the four characters, indicating that experimental materials had sufficient genetic variability for all the characters studied. Mean square due to parents Vs hybrids comparison was significant for all the characters indicated the performance of hybrids as a group was different than that of parents for all the characters. This revealed the presence of substantial amount of heterosis in various cross combinations due to effect of directional dominance.

For development of character in positive direction viz. days to 50 % flowering, plant height and days to maturity, negative heterosis is desirable. The heterosis was estimated over better parent and standard variety (GW 366) and results are presented in Table 1. For days to 50 % flowering, only one cross (GW-496 x GW-173) had significant heterosis over better parent, while three crosses viz; GW-496 x GW-322, GW-496 x RAJ-4136 and HW-5018 x HI-1544 showed significant and negative heterobeltiosis for dwarfness. For days to maturity, eleven crosses showed significant and negative heterobeltiosis. Five most early maturing crosses over better parent were GW-322 x Lok-1, Lok-1 x K-604, GW-322 x GW-173, GW-173 x K-604 and KYZ-300 x K-604. These crosses also exhibited negative values in desirable direction over standard check. Seven and three crosses showed heterobeltiosis

and standard heterosis estimates in desirable direction for grain yield. The crosses which exhibited significant heterobeltiosis for grain yield per plant were RAJ-4136 x UAS-281, HW-5018 x K-604, KYZ-300 x HW-5018, HW-5018 x UAS-281, KYZ-300 x RAJ-4136, GW-173 x RAJ-4136, and HW-5018 x HI-1544 and the crosses which exhibited significant standard heterosis for grain yield per plant were HW-5018 x K-604, RAJ-4136 x UAS-281, and HW-5018 x HI-1544. It indicated that high yielding varieties involved in the crosses were predominantly responsible for enhancing the yield. Similar finding were reported by Chakraborty and Tewari (1995); Sharma and Menon (1996); Nehvi *et al.*, (2000); Vanpariya *et al.*, (2006a) and Singh *et al.*, (2007).

The analysis of variance for combining ability revealed that the variances due to gca and sca were significant for all the four characters (Table 2) that indicated existence of genetic variability in the parental lines included in the present study and involvement of both additive and non-additive gene effects in the inheritance of these traits. The magnitude of gca and sca variances revealed that the sca variances were higher than their respective gca variances for all the characters. The gca and sca variance ratio was less than unity for all the traits indicated that non-additive component play relatively greater role in the inheritance of these traits.

The GCA effects of the parents (Table 3) indicated that there was close relationship between parental mean performance and GCA effects for all the characters except grain yield per plant. Thus, the perfect relationship could be established between *per se* performance and GCA effects of the parents. The GCA values indicated that four parents viz., GW-496, HI-1544, GW-322 and UAS-281 exhibited significant and negative GCA effects and were registered as good general combiners for earliness in days to 50 % flowering. Two parents viz., Lok-1 and GW-173 showed significant and negative GCA effects for plant height which is desirable in wheat and registered as good general combiners for dwarfness. Likewise, four parental lines viz., HI-1544, UAS-281, GW-173 and RAJ-4136 were good

Table 1 Estimates of heterobeltiosis (H) and standard heterosis (SH) for days to 50% flowering, plant height, days to maturity and grain yield per plant in bread wheat

Sr. No.	Hybrids	Days to 50% flowering		Plant height		Days to maturity		Grain yield per plant	
		H (%)	SH (%)	H (%)	SH (%)	H (%)	SH (%)	H (%)	SH (%)
1	GW-496 X GW-322	5.66**	9.80 **	-6.78**	0.00	4.95**	1.92**	-2.71	-2.41
2	GW-496 X Lok-1	1.96	1.96	14.90**	9.24**	-1.98**	-4.81**	-7.55	0.98
3	GW-496 X GW-173	-3.77*	0.00	26.13**	8.44**	-3.96**	-6.73**	-8.90	-8.62
4	GW-496 X KYZ-300	0.63	4.58**	3.56	13.36**	3.96**	0.96	-15.08*	-14.82*
5	GW-496 X RAJ-4136	5.66**	9.80**	-6.26**	2.51	1.98**	-0.96	-12.54	-12.27
6	GW-496 X HW-5018	7.55**	11.76**	6.43**	16.13**	8.25**	5.13**	-9.93	-9.65
7	GW-496 X K-604	5.66**	9.80**	5.67*	9.04**	3.96**	0.96	-0.40	-0.10
8	GW-496 X UAS-281	7.55**	11.76**	-0.58	7.41**	3.82**	-4.17**	-6.96	-6.67
9	GW-496 X HI-1544	2.00	0.00	4.52*	7.81**	3.16**	-5.77**	2.76	3.08
10	GW-322 X Lok-1	3.92*	3.92*	12.92**	7.35**	-8.49**	-6.73**	-20.82**	-13.51
11	GW-322 X GW-173	-1.17	10.46**	19.89**	3.08	-5.88**	-7.69**	-0.53	-0.22
12	GW-322X KYZ-300	3.51*	15.69**	-2.22	5.36*	6.15**	5.13**	-11.74	-11.47
13	GW-322X RAJ-4136	-3.03	4.58**	6.88**	15.17**	0.00	-1.92**	-19.38**	-19.13**
14	GW-322 x HW-5018	5.26**	17.65**	1.38	9.24**	5.94**	2.88**	-10.22	-9.95
15	GW-322 x K-604	7.02**	19.61**	7.65**	11.08**	6.60**	8.65**	-12.44	-12.18
16	GW-322 x UAS-281	0.00	5.88**	-2.63	4.91*	3.47**	-4.49**	-7.56	-7.27
17	GW-322 x HI-1544	10.00**	7.84**	8.35**	11.77**	8.42**	-0.96	-7.83	-7.55
18	Lok-1x GW-173	0.65	0.65	33.47**	14.75**	6.86**	4.81**	-29.99**	-23.92**
19	Lok-1x KYZ-300	28.76**	28.76**	3.27	-1.08	1.94**	0.96	-29.77**	-23.68**
20	Lok-1x RAJ-4136	28.76**	28.76**	2.98	-1.37	0.00	-1.92**	-10.06	-2.27
21	Lok-1x HW-5018	23.53**	23.53**	3.17	-1.18	10.89**	7.69**	-9.79	-1.98
22	Lok-1x K-604	21.57**	21.57**	10.06**	5.42*	-8.49**	-6.73**	-9.32	-1.46
23	Lok-1x UAS-281	15.69**	15.69**	10.11**	5.46*	7.29**	-0.96	-1.91	6.59
24	Lok-1x HI-1544	34.67**	32.03**	6.02*	1.55	4.21**	-4.81**	-3.79	4.54
25	GW-173 x KYZ-300	9.20**	24.18**	19.27**	2.00	-3.92**	-5.77**	3.40	-3.06
26	GW-173 x RAJ-4136	14.55**	23.53**	22.01*	4.34	-3.92**	-5.77**	16.42*	7.05
27	GW-173 x HW-5018	10.53**	23.53**	24.46**	6.44**	-1.98**	-4.81**	6.20	-2.35
28	GW-173 x K-604	11.11**	30.72**	17.23**	0.26	-5.88**	-7.69**	12.08	3.05
29	GW-173 x UAS-281	20.99**	28.10**	32.41**	13.24**	-1.04	-8.65**	7.95	-0.74
30	GW-173 x HI-1544	19.33**	16.99**	27.32**	8.88*	5.26**	-3.85**	-9.54	-10.62
31	KYZ-300 x RAJ-4136	1.82	9.80**	3.50	13.18**	-2.94**	-4.81**	19.53*	9.91
32	KYZ-300 x HW-5018	0.00	11.76**	-3.51	5.29*	2.97**	0.00	22.32**	12.47
33	KYZ-300 x K-604	5.17**	19.61**	8.55**	12.02**	-4.85**	-5.77**	11.00	2.06
34	KYZ-300 x UAS-281	0.00	5.88**	-3.83	3.90	2.08**	-5.77**	10.73	1.81
35	KYZ-300 x HI-1544	6.00**	3.92*	5.43*	8.75**	1.05	-7.69**	6.09	4.83
36	RAJ-4136 x HW-5018	7.27**	15.69**	2.51	11.86**	-0.99	-3.85**	7.62	-1.63
37	RAJ-4136 x K-604	14.55**	23.53**	-0.47	2.71	4.90**	2.88**	9.80	-4.96
38	RAJ-4136 x UAS-281	3.70	9.80**	5.44*	13.91**	1.04	-6.73**	39.60**	16.69*
39	RAJ-4136 x HI-1544	6.00*	3.92*	5.68*	9.01**	1.05	-7.69**	13.70	12.36
40	HW-5018 x K-604	10.53**	23.53**	13.38**	17.00**	1.98**	-0.96	30.56**	20.05**
41	HW-5018 x UAS-281	7.41**	13.73**	-3.80	3.93	0.00	-7.69**	19.76**	10.11
42	HW-5018 x HI-1544	12.00**	9.80**	-5.55*	-2.57	1.05	-7.69**	16.18*	14.81*
43	K 604 x UAS-281	5.56**	11.76**	7.02**	9.83**	3.13**	-4.81**	5.03	-7.82
44	K-604 x HI-1544	12.00**	9.80**	7.61**	10.43**	1.05	-7.69**	-6.19	-7.30
45	UAS-281 x HI-1544	12.00**	9.80**	0.54	3.71	0.00	-8.65**	4.36	3.12
	Mean heterosis (%)	8.93	13.90	7.87	7.19	1.40	-2.96	0.0031	-2.09
	SE±	0.86	0.86	1.32	1.32	0.75	0.75	1.66	1.66

*, ** Significant at 5% and 1% levels, respectively

Table 2 Analysis of variance for combining ability for various characters in bread wheat

Source	Df	Days to 50% flowering	Plant height	Days to maturity	Grain yield per plant(g)
gca	9	40.94**	15.36**	55.52**	4.46**
sca	45	15.61**	10.88**	14.84**	5.69**
Error	108	0.37	0.87	0.28	1.37
σ^2 gca		3.38	1.21	4.60	0.26
σ^2 sca		15.24	10.00	14.55	4.31
σ^2 gca/ σ^2 sca		0.22	0.12	0.32	0.06

*, ** Significant at 5% and 1% levels, respectively

gca and sca denote general and specific combining ability, respectively

Table 3 Estimates of general combining ability effects for different characters in bread wheat

Parents	Days to 50% flowering		Plant height		Days to maturity		Grain yield per plant	
	Mean	GCA effect	Mean	GCA effect	Mean	GCA effect	Mean	GCA effect
GW-496	53.00	-3.20**	63.67	0.89**	101.00	1.00**	23.66	-0.42
GW-322	57.00	-1.01**	62.72	0.44*	106.33	2.78**	23.61	-1.10**
LOK-1	51.00	0.61**	55.59	-2.11**	106.00	1.92**	26.13	-0.10
GW-173	59.67	2.11**	50.27	-1.96**	102.00	-1.67**	22.30	-0.43
KYZ-300	58.00	0.38*	66.80	0.86**	103.00	0.53**	22.43	-0.06
RAJ-4136	55.00	0.11	63.93	0.80**	102.00	-0.33*	20.36	0.15
HW-5018	57.00	1.36**	63.80	0.53*	101.00	1.36**	21.87	0.92**
K-604	60.00	2.66**	60.33	0.52*	106.00	1.17**	20.71	-0.08
UAS-281	54.00	-0.78**	63.17	0.43	96.00	-3.17**	19.47	0.20
HI-1544	50.00	-2.23**	60.31	-0.39	95.00	-3.58**	23.64	0.92**
SE(gi) $\pm$		0.17		0.26		0.15		0.32
SE(gi-gj) $\pm$		0.25		0.38		0.22		0.47
Correlation between Per se performance and GCA effects		0.711*		0.919**		0.877**		0.214

*, ** Significant at 5% and 1% levels, respectively

Table 4 Estimates of specific combining ability effects for days to 50% flowering, plant height, days to maturity, grain yield per plant in bread wheat

Sr. No.	Hybrids	Days to 50 % flowering	Plant height	Days to maturity	Grain yield per plant
1	GW-496 X GW-322	2.59**	-5.23**	1.13*	1.63
2	GW-496 X Lok-1	-3.02**	2.71**	-5.01**	1.44
3	GW-496 X GW-173	-5.52**	2.10*	-3.42**	-0.53
4	GW-496 X KYZ-300	-1.46**	2.16*	2.38**	-2.38*
5	GW-496 X RAJ-4136	1.48**	-4.13**	1.24*	-1.98
6	GW-496 X HW-5018	1.23**	4.11**	5.88**	-2.12*
7	GW-496 X K-604	-1.07	-0.03	1.74**	1.17
8	GW-496 X UAS-281	3.37**	-0.89	0.74	-0.69
9	GW-496 X HI-1544	-1.18*	0.16	-0.51	0.92
10	GW-322 X Lok-1	-4.21**	2.06*	-8.79**	-1.36
11	GW-322 X GW-173	-4.38**	-0.59	-6.20**	2.16*
12	GW-322 X KYZ-300	2.01**	-2.08*	4.94**	-0.90
13	GW-322 X RAJ-4136	-3.38**	3.72**	-1.54**	-2.95**
14	GW-322 x HW-5018	2.04**	0.53	1.77**	-1.52
15	GW-322 x K-604	1.73**	1.62	7.97**	-1.05
16	GW-322 x UAS-281	-1.82**	-1.90*	-1.37**	-0.16
17	GW-322 x HI-1544	0.62	2.92**	2.72**	-0.95
18	Lok-1x GW-173	-8.99**	8.78**	7.66**	-4.51**
19	Lok-1x KYZ-300	7.07**	-3.30**	1.47**	-4.83**
20	Lok-1x RAJ-4136	7.34**	-3.40**	-0.67	0.09
21	Lok-1x HW-5018	3.43**	-3.09**	7.63**	-0.61
22	Lok-1 x K-604	1.12*	0.85	-7.17**	0.51
23	Lok-1x UAS-281	1.57**	0.96	3.16**	2.16*
24	Lok-1x HI-1544	11.34**	-0.51	-0.42	0.94
25	GW-173 x KYZ-300	3.23**	-1.65	-1.95**	0.44
26	GW-173 x RAJ-4136	3.18**	-0.21	-1.09*	2.65**
27	GW-173 x HW-5018	1.93**	1.29	-1.79**	-0.37
28	GW-173 x K-604	4.29**	-2.32**	-4.59**	1.93
29	GW-173 x UAS-281	6.40**	5.36**	-1.26	0.74
30	GW-173 x HI-1544	2.18**	3.63**	4.16**	-2.35*
31	KYZ-300 x RAJ-4136	-2.10**	2.13*	-2.29**	2.97**
32	KYZ-300 x HW-5018	-2.35**	-2.21*	1.02*	2.81**
33	KYZ-300 x K-604	0.34	1.74*	-4.79**	1.32
34	KYZ-300 x UAS-281	-3.21**	-2.92**	-0.45	0.98
35	KYZ-300 x HI-1544	-2.77**	0.73	-2.04**	0.98
36	RAJ-4136 x HW-5018	-0.07	1.70*	-2.12**	-0.77
37	RAJ-4136 x K-604	2.62**	-3.66**	5.08**	-0.57
38	RAJ-4136 x UAS-281	-0.93	2.99**	-0.59	4.33**
39	RAJ-4136 x HI-1544	-2.49**	0.94	-1.17*	2.57*
40	HW-5018 x K-604	1.37*	4.99**	-0.62	4.64**
41	HW-5018 x UAS-281	-0.18	-2.57**	-3.29**	1.99
42	HW-5018 x HI-1544	-0.74	-5.55**	-2.87**	2.38*
43	K-604(8) x UAS-281	-2.49**	0.89	-0.09	-1.30
44	K-604 x HI-1544	-2.05**	2.06*	-2.67**	-1.91
45	UAS-281x HI-1544	1.40*	-1.79*	0.66	0.31
	SE(Sij) $\pm$	0.56	0.86	0.49	1.08
	SE(Sij-Sik) $\pm$	0.83	1.27	0.72	1.59
	SE(Sij-Skl) $\pm$	0.79	1.21	0.69	1.51

*, ** Significant at 5% and 1% levels, respectively

general combiners as they showed significant and negative GCA effects for days to maturity. Two parental lines viz., HW-5018 and HI-1544 were found to be good general combiners for grain yield per plant as they had significant and positive GCA effects for this trait. On the basis of overall performance, parent HI-1544 was found to be good general combiner for early flowering, early maturity and high grain yield. The parent HW-5018 was also good for tall plant, late maturity flowering and with general combiner for higher grain yield per plant. Similar finding was reported by Sharma and Garg (2005), Vanpariya *et al.* (2006b) and Zahid *et al.* (2011).

As regard the specific combining ability effects (Table 4), nine crosses exhibited significant and positive SCA effects for grain yield per plant. The cross combination HW-5018 x K-604 (good x poor) recorded the highest SCA effect followed by RAJ-4136 x UAS-281 (average x average), KYZ-300 x RAJ-4136 (average x average), KYZ-300 x HW-5018 (average x good) and GW-173 x RAJ-4136 (average x average) and were rated as good specific cross combinations for grain yield per plant. Similar results were also reported by Singh *et al.* (1990) and Mavi *et al.* (2003). Fifteen crosses exhibited significant and negative SCA effects for days to 50% flowering. The highest, significant and negative SCA effect was observed for days to 50% flowering in cross Lok-1 x GW-173 followed by GW-322 x GW-

173, GW-322 x RAJ-4136 and KYZ-300 x UAS-281. Fourteen crosses were showed significant and negative SCA effects for plant height out of which the three best cross combinations were HW-5018 x HI-1544, GW-496 x GW-322 and GW-496 x RAJ-4136. Fourteen hybrids exhibited significant and negative SCA effects for earliness. The hybrid GW-322 x Lok-1 had maximum SCA effect for days to maturity followed by Lok-1 x K-604, GW-322 x GW-173 and GW-496 x Lok-1 in desired direction.

Considering the desired SCA effects, the best cross combinations were KYZ-300 x RAJ-4136 and KYZ-300 x HW-5018 for early flowering, early maturity and higher grain yield per plant. The GCA effects of the parents and SCA effects of their crosses indicated that the crosses between two high general combiners were not always the best specific combiners. The best specific combinations for different characters were either good x poor, average x average, average x good and vice versa general combiners.

The correlation coefficient studies (Table 5) revealed that *per se* performance of hybrids with that of heterobeltiosis and SCA effects as well as between heterobeltiosis and SCA effects showed significant and positive correlation between all parameters for all the traits indicating good association among all three parameters in this study.

Table 5 Correlation coefficient among *per se* performance of hybrids, heterobeltiosis and SCA effects in bread wheat

Sr. No.	Characters	Per se performance and heterobeltiosis	Per se performance and SCA effects	Heterobeltiosis and SCA effects
1	Days to 50% flowering	0.776**	0.850**	0.823**
2	Plant height	0.317*	0.884**	0.661**
3	Days to maturity	0.719**	0.822**	0.893**
4	Grain yield per plant	0.899**	0.949**	0.856**

*, ** Significant at 5% and 1% levels, respectively

CONCLUSION

Overall it is concluded that the cross HW-5018 x HI-1544 possessed high heterobeltiosis and high SCA effect with good general combining ability for grain yield per plant. Both additive and non-additive gene action played an important role in expression of these traits, although non-additive genetic variance was predominant. Therefore, recurrent selection which may allow intermating of the selects in different cycles and utilize both additive and non-additive gene effect could be effective in developing wheat cultivar having high grain yield with early maturity period. Dominance genetic effect shall be valuable in wheat breeding programmes when hybrid seed production is made economically feasible through an efficient cytoplasmic male sterility system.

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Gene effects for earliness and seed yield in castor (*Ricinus Communis* L.)

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ABSTRACT

The present investigation was undertaken with a view to generate genetic information on gene effects for characters related to earliness and seed yield in castor. On simple additive-dominance model, three parameters viz., 'm', additive [d] and dominance [h] were significant for days to 50 % flowering in JP 96 x JI 368. The $\chi^2_{(1)}$ at nine degrees of freedom was found non-significant for days to 50% flowering in cross JP 96 x JI 368 proving adequacy of additive-dominance model. Under six-parameters model of Hill (1966), the components 'm', additive [d], dominance [h] and digenic ([i] and [j]) were found significant for days to 50 % flowering in cross JP 96 x JI 372. The $\chi^2_{(2)}$ at six degrees of freedom was found non-significant for days to 50% flowering in cross JP 96 x JI 372 proving six-parameters model as the best fit model. For all traits in all crosses (except days to 50 % flowering in JP 96 x JI 3 and JP 96 x JI 372) were found significant for $\chi^2_{(2)}$ and were subjected to trigenic ten-parameter model. The trigenic ten-parameter model was found adequate for days to maturity in crosses JP 96 x JI 368 and JP 101 x SKI 215 along with non-significant $\chi^2_{(3)}$ with two degrees of freedom indicating major role of trigenic interaction for the inheritance of above said traits. On the other hand, $\chi^2_{(3)}$ with two degrees of freedom was found significant for remaining traits in all the three crosses showing the presence of higher order epistasis and/or linkage. Besides, all the ten-parameters were significant for seed yield per plant in all the three crosses.

Key words: Scaling tests, trigenic 10-parameters model, gene effects, trigenic interaction

The information on the nature and magnitude of gene actions could be helpful in predicting the effectiveness of selection in a population. A distinct knowledge of three types of gene actions, its magnitude and composition of genetic variance are of fundamental importance to a plant breeder, which helps in formulating effective, sound and appropriate breeding procedures. In this context, genetic analysis of generation means is very useful in testing the adequacy of different type of genetic models and then estimating the genetic parameters in the form of the components of means (Marther and Jinks,

1971). The parameters obtained are useful to the plant breeders to understand the genetical structure of populations, their variation and prediction of response to selection. For these objects, the present experiment was carried out.

MATERIALS AND METHODS

The basic set of twelve generations viz., P_1 , P_2 , F_1 , F_2 , B_1 , B_2 , B_{1S} , B_{11} , B_{12} , B_{2S} , B_{21} and B_{22} derived from three castor crosses namely JP 96 x JI 368 (cross 1), JP 96 x JI 372 (cross 2) and JP 101 x SKI 215 (cross 3) were sown in Compact Family Block Design with three replications at Instructional Farm, College of

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Agriculture, J.A.U., Junagadh during Kharif, 2011-12. The plots of various generations contained different number of rows i.e., parents and F_1 in single row; B_1 and B_2 in two rows and F_2 , B_{1s} , B_{11} , B_{12} , B_{2s} , B_{21} and B_{22} in four rows. Each row was of 7.2 m in length with 90 cm and 60 cm inter and intra row spacing, respectively. All the recommended agronomical practices and necessary plant protection measures were followed timely to raise good crop condition. The observations were recorded on individual plant basis in each replication on randomly selected five plants from P_1 , P_2 and F_1 , ten plants from first backcross (B_1 and B_2) and twenty plants of F_2 , B_{1s} , B_{11} , B_{12} , B_{2s} , B_{21} , B_{22} generations for number of nodes upto main raceme, plant height upto main raceme and seed yield per plant; days to 50% flowering and days to maturity of main raceme on plot basis.

The inheritance of traits under present investigation was computed through generation mean analysis methods (Mather, 1949; Hayman and Mather, 1955; Hayman, 1958 and Hill, 1966). The $\chi^2_{(1)}$ of joint scaling test under three-parameters model gives idea about fitness of additive-dominance model. In addition to six generations and six-parameters model (Hayman, 1958), the data were subjected to ten-parameters model given by Hill (1966). He proposed estimation of first order and second order epistasis utilizing twelve generations including double backcross generations. The $\chi^2_{(2)}$ and $\chi^2_{(3)}$ values were estimated under six-parameters model at six degrees of freedom and for ten-parameters model at two degrees of freedom, respectively. This is an additional advantage of using twelve generations and ten-parameters model as it provides sufficient degree of freedom for testing validity and goodness of fit for different models. The results of models given by Hayman (1958) and Hill (1966) were compared, whenever six-parameters model was satisfactory for inheritance of the trait.

RESULTS AND DISCUSSION

The data of all the twelve generations viz., P_1 , P_2 , F_1 , F_2 , B_1 , B_2 , B_{11} , B_{12} , B_{21} , B_{22} , B_{1s} and B_{2s} were analyzed for five characters of three crosses. The gene effects were estimated in those cases where mean sum of

squares for a trait was found significant. The data were initially subjected to simple scaling tests A, B, C and D. Significant estimates of any one or more of these tests indicate the presence of digenic interactions. Further, simple scaling tests B_{11} , B_{12} , B_{21} , B_{22} , B_{1s} and B_{2s} (Hill, 1966) and X and Y (Van Der Veen, 1959) were also computed. Significant estimates of the test(s) given by Hill (1966) showed contribution of particular generation to higher order epistasis, which is indirectly indicating presence of epistasis. If any of the Van Der Veen's tests significantly deviates from zero, it also indicated presence of trigenic or higher order epistasis. The results of simple scaling tests were further confirmed by joint scaling test (Cavalli, 1952), which effectively combines the whole set of simple scaling tests. Thus, it offers a more general, convenient, adoptable and informative approach for estimating gene effects and also for testing adequacy of additive-dominance model. The $[\chi^2_{(1)}]$ test with nine degrees of freedom; $[\chi^2_{(2)}]$ at six degrees of freedom and $[\chi^2_{(3)}]$ at two degrees of freedom was applied to test the fitness of three-parameters model, six-parameters model and ten-parameters model, respectively. The ten-parameters model was used to estimate higher order epistasis (Hill, 1966). To draw inference on adequacy of ten-parameters model, chi-square test $[\chi^2_{(3)}]$ at two degrees of freedom was applied. The character and cross-wise results of scaling tests and gene effects are presented in Table 1 to 5.

The application of individual scaling test (Table 1 to 5) A, B, C and D of Mather (1949) as well as joint scaling test of Cavalli (1952) were non-significant for days to 50% flowering, days to maturity of main raceme and plant height in cross 1 and for number of nodes upto main raceme in cross 2, while special scaling tests viz., B_{11} , B_{12} , B_{21} , B_{22} , B_{1s} and B_{2s} of which, B_{21} and B_{22} were significant for days to 50% flowering in Cross 1; only B_{1s} in cross 2 and B_{11} , B_{21} , B_{22} , B_{1s} and B_{2s} in cross 3. Whereas for days to maturity of main raceme, B_{12} , B_{22} and B_{2s} were significant in cross 1; B_{11} , B_{21} , B_{1s} and B_{2s} in cross 2 and B_{11} , B_{12} , B_{21} and B_{1s} in cross 3. For plant height, B_{11} , B_{12} , B_{21} , B_{22} , B_{1s} and B_{2s} were significant in cross 1; B_{11} , B_{1s} and B_{2s}

Table 1 Scaling tests and estimation of gene effects for days to 50 % flowering of main raceme in three crosses of castor

Scaling tests / gene effects	JP 96 x JI 368 (Cross 1)	JP 96 x JI 372 (Cross 2)	JP 101 x SKI 215 (Cross 3)
A	-0.66 ± 1.24	2.60 ± 1.52	6.06** ± 1.76
B	-1.86 ± 1.53	-3.46* ± 1.41	1.06 ± 1.79
C	-1.06 ± 2.02	5.20** ± 1.98	7.93** ± 2.72
D	0.43 ± 1.28	3.03* ± 1.28	0.40 ± 1.63
B ₁₁	-1.85 ± 2.41	-1.71 ± 2.38	-22.87** ± 2.23
B ₁₂	0.40 ± 2.55	-1.68 ± 2.65	-4.93 ± 3.17
B ₂₁	-6.91** ± 2.30	-3.21 ± 2.55	-11.61** ± 2.97
B ₂₂	11.60** ± 2.52	-1.12 ± 2.18	-10.15** ± 2.49
B _{1S}	-7.79 ± 4.47	-23.21** ± 4.35	-17.58** ± 4.66
B _{2S}	1.53 ± 4.34	-6.29 ± 4.29	-18.30** ± 5.05
X	283.76** ± 1.10	281.13** ± 1.07	287.25** ± 1.12
Y	138.40** ± 1.18	139.35** ± 1.18	139.72** ± 1.31
Three parameter s model (Cavalli)			
m	71.21** ± 0.17	70.14** ± 0.14	68.45** ± 0.14
(d)	-2.68** ± 0.17	-2.10** ± 0.14	-1.24** ± 0.13
(h)	1.03** ± 0.38	1.42** ± 0.37	5.03** ± 0.42
X ² ₍₁₎ (9 df)	7.36	45.29**	129.84**
Six parameter s model (Hayman)			
m	71.58** ± 0.44	71.67** ± 0.42	71.15** ± 0.58
(d)	-1.93* ± 0.91	0.76 ± 0.96	0.70 ± 1.15
(h)	0.36 ± 2.60	-5.19* ± 2.62	1.93 ± 3.35
(i)	-0.86 ± 2.56	-6.06* ± 2.57	-0.80 ± 3.27
(j)	0.89 ± 0.93	3.03** ± 0.98	2.50* ± 1.16
(l)	2.79 ± 4.19	6.93 ± 4.35	-6.33 ± 5.35
Digenic and trigenic interactions (Hill)			
m	72.80** ± 1.27	74.79** ± 1.27	64.81** ± 1.44
(d)	-2.78** ± 0.19	-2.26** ± 0.15	-1.71** ± 0.15
(h)	-3.33 ± 3.47	-7.84* ± 3.55	23.74** ± 3.99
(i)	-1.55 ± 1.27	-4.84** ± 1.28	3.10* ± 1.44
(j)	1.33 ± 1.16	3.43** ± 1.14	5.43** ± 1.22
(l)	2.91 ± 2.44	3.98 ± 2.55	-18.99** ± 2.95
X ² ₍₂₎ (6 df)	4.57	11.45	34.38**
m	73.77** ± 3.41	76.76** ± 3.35	64.41** ± 3.92
(d)	-1.45 ± 2.72	2.73 ± 2.72	-8.77** ± 2.98
(h)	-7.55 ± 17.37	-18.13 ± 16.96	30.45 ± 20.34
(i)	-2.53 ± 3.41	-6.81 ± 4.35	3.41 ± 3.92
(j)	2.21 ± 7.50	-8.18 ± 7.52	24.43** ± 8.01
(l)	6.53 ± 26.89	19.48 ± 26.26	-43.88 ± 31.38
(w)	-1.38 ± 2.71	-5.01 ± 2.72	6.99* ± 2.98
(x)	4.55 ± 9.46	5.72 ± 9.15	4.56 ± 11.54
(y)	-6.66 ± 7.39	6.66 ± 7.28	-15.43* ± 7.61
(z)	-0.24 ± 13.16	-7.19 ± 12.93	19.96 ± 15.34
X ² ₍₃₎ (2 df)	0.41	5.42	12.01**
Type of epistasis	Duplicate	Duplicate	Duplicate

*, ** Significant at 5 and 1 % levels, respectively

Table 2 Scaling tests and estimation of gene effects for days to maturity of main raceme in three crosses of castor

Scaling tests / gene effects	JP 96 x JI 368 (Cross 1)	JP 96 x JI 372 (Cross 2)	JP 101 x SKI 215 (Cross 3)
A	3.06 ± 1.93	4.46** ± 1.40	6.40** ± 1.56
B	-3.00 ± 1.75	-2.86 ± 1.51	4.26** ± 1.57
C	1.20 ± 2.44	3.40 ± 2.21	11.33** ± 2.67
D	0.56 ± 1.52	0.90 ± 1.33	0.33 ± 1.55
B ₁₁	-1.89 ± 3.02	-6.14** ± 2.26	-18.18** ± 2.58
B ₁₂	7.13* ± 2.77	-3.26 ± 3.03	-8.2** ± 2.78
B ₂₁	-0.19 ± 2.87	-13.34** ± 2.69	-13.74** ± 2.86
B ₂₂	12.47** ± 2.76	-3.98 ± 2.68	-1.36 ± 2.55
B ₁₅	-1.42 ± 5.63	-13.96** ± 4.32	-32.86** ± 4.66
B ₂₅	24.02** ± 5.18	-11.48* ± 5.33	-9.42 ± 5.36
X	639.78** ± 1.16	645.88** ± 1.17	642.6** ± 1.14
Y	324.35** ± 1.28	318.92** ± 1.29	317.2** ± 1.29
Three parameter s model (Cavalli)			
m	161.91** ± 0.28	160.51** ± 0.17	159.43** ± 0.18
(d)	-2.39** ± 0.28	-0.99** ± 0.17	-1.83** ± 0.18
(h)	-0.99 ± 0.56	1.07* ± 0.42	1.97** ± 0.44
X ² ₍₁₎ (9 df)	41.74**	51.14**	103.30**
Six parameter s model (Hayman)			
m	162.32** ± 0.49	160.95** ± 0.47	161.45** ± 0.59
(d)	-0.86 ± 1.16	2.46** ± 0.94	-1.16 ± 1.00
(h)	-2.36 ± 3.13	-2.13 ± 2.73	-1.23 ± 3.16
(i)	-1.13 ± 3.05	-1.79 ± 2.67	-0.66 ± 3.10
(j)	3.03* ± 1.24	3.66** ± 0.96	1.06 ± 1.02
(l)	1.06 ± 5.25	0.19 ± 4.37	-10.00* ± 4.82
Digenic and trigenic interactions (Hill)			
m	161.85** ± 1.36	160.95** ± 1.36	159.72** ± 1.44
(d)	-3.59** ± 0.40	-1.30** ± 0.19	-2.08** ± 0.20
(h)	-2.51 ± 3.91	3.08 ± 3.74	9.97* ± 3.94
(i)	0.33 ± 1.36	-0.63 ± 1.36	-0.84 ± 1.45
(j)	6.91** ± 1.59	5.32** ± 1.23	5.74** ± 1.24
(l)	2.11 ± 2.89	-3.63 ± 2.69	-11.12** ± 2.86
X ² ₍₂₎ (6 df)	19.28* 	18.53**	15.84*
m	154.48** ± 3.55	168.17** ± 3.69	162.92** ± 4.00
(d)	-0.99 ± 2.80	-2.44 ± 2.97	-0.16 ± 3.07
(h)	33.81 ± 18.28	-34.72 ± 18.73	-8.03 ± 20.59
(i)	7.69** ± 3.56	-7.87* ± 3.69	-4.02 ± 4.00
(j)	5.57 ± 7.90	2.65 ± 8.15	8.60 ± 8.34
(l)	-47.85 ± 28.36	54.42 ± 29.00	17.07 ± 31.51
(w)	-2.90 ± 2.77	1.22 ± 2.96	-2.04 ± 3.06
(x)	-25.91* ± 10.20	20.57* ± 10.14	20.48* ± 9.60
(y)	-6.25 ± 7.69	9.51 ± 7.97	-12.44 ± 7.86
(z)	-20.48 ± 13.94	-27.75 ± 14.25	-13.42 ± 15.22
X ² ₍₃₎ (2 df)	4.86	9.80**	5.96
Type of epistasis	Duplicate	Duplicate	Duplicate

*, ** Significant at 5 and 1 % levels, respectively

Table 3 Scaling tests and estimation of gene effects for plant height upto main raceme in three crosses of castor

Scaling tests / gene effects	JP 96 x JI 368 (Cross 1)	JP 96 x JI 372 (Cross 2)	JP 101 x SKI 215 (Cross 3)
A	-0.0067 ± 2.25	20.34** ± 3.08	17.22** ± 4.37
B	0.16 ± 2.21	-14.08** ± 3.53	29.62** ± 2.42
C	0.68 ± 4.25	23.76** ± 6.40	56.42** ± 7.62
D	0.26 ± 2.12	8.75** ± 3.37	4.78 ± 4.35
B ₁₁	-27.75** ± 3.56	56.44** ± 6.37	-40.79** ± 5.92
B ₁₂	-12.53* ± 5.72	-5.29 ± 11.44	-44.25** ± 6.34
B ₂₁	-44.65** ± 5.21	-4.00 ± 7.61	-25.01** ± 6.22
B ₂₂	-11.99* ± 4.65	3.93 ± 8.33	-11.83 ± 9.64
B ₁₅	-54.66** ± 7.98	-43.89** ± 13.26	-124.66** ± 11.91
B ₂₅	-41.78** ± 9.33	42.71** ± 14.25	-129.86** ± 16.48
X	-242.19** ± 1.96	287.58** ± 3.88	239.99** ± 3.38
Y	107.64** ± 2.28	135.91** ± 4.17	103.26** ± 3.50
Three parameter s model (Cavalli)			
m	58.42** ± 0.35	65.01** ± 0.54	57.67** ± 0.45
(d)	-5.30** ± 0.34	-8.89** ± 0.53	-4.48** ± 0.45
(h)	2.57** ± 0.86	17.48** ± 1.27	4.29** ± 0.91
$\chi^2_{(1)}$ (9 df)	183.73**	154.00**	339.69**
Six parameter s model (Hayman)			
m	56.53** ± 0.85	77.17** ± 1.36	68.09** ± 1.83
(d)	-7.54** ± 1.25	4.43* ± 1.97	-12.62** ± 2.35
(h)	0.18 ± 4.44	-0.15 ± 6.95	-9.02 ± 8.77
(i)	-0.52 ± 4.25	-17.49** ± 6.74	-9.57 ± 8.71
(j)	-0.086 ± 1.35	17.20** ± 2.08	-62.00** ± 2.41
(l)	0.36 ± 6.59	11.23 ± 10.17	-37.27** ± 12.11
Digenic and trigenic interactions (Hill)			
m	60.21** ± 2.16	59.85** ± 3.70	73.46** ± 3.80
(d)	-6.87** ± 0.45	-12.00** ± 0.62	-5.99** ± 0.53
(h)	4.19 ± 5.84	38.00** ± 9.90	8.98 ± 9.61
(i)	-3.24 ± 2.15	3.30 ± 3.72	-19.45** ± 3.82
(j)	9.03** ± 2.07	29.32** ± 3.30	-7.41* ± 3.02
(l)	-5.83 ± 4.37	-20.30** ± 7.08	-28.35** ± 6.35
$\chi^2_{(2)}$ (6 df)	150.91**	55.03**	18.98**
m	89.91** ± 6.29	16.43 ± 10.82	91.72** ± 11.86
(d)	-9.22 ± 4.87	-16.11 ± 8.40	-13.56 ± 8.87
(h)	-149.19** ± 32.23	272.94** ± 55.69	-89.75 ± 61.12
(i)	-33.37** ± 6.29	46.15** ± 10.82	-38.00** ± 11.87
(j)	10.01 ± 12.99	72.13** ± 23.74	32.92 ± 23.59
(l)	211.23** ± 49.99	-396.86** ± 87.59	117.10 ± 92.14
(w)	2.22 ± 4.86	3.28 ± 8.39	7.20 ± 8.86
(x)	98.70** ± 17.82	-117.97** ± 29.58	58.11 ± 34.91
(y)	4.97 ± 12.91	-75.29** ± 25.14	-56.61* ± 22.15
(z)	-92.84** ± 24.66	187.75** ± 43.50	-65.49 ± 43.29
$\chi^2_{(3)}$ (2 df)	112.97**	7.32*	7.40*
Type of epistasis	Duplicate	Duplicate	Duplicate

*, ** Significant at 5 and 1 % levels, respectively

in cross 2 and B_{11} , B_{12} , B_{21} , B_{15} and B_{25} in cross 3. Likewise, for number of nodes, B_{11} , B_{12} , B_{15} and B_{25} were significant in cross 1; B_{11} , B_{21} , B_{22} and B_{15} in cross 2 and B_{11} , B_{12} , B_{21} , B_{22} and B_{15} in cross 3. On other hand, all special scaling tests viz., B_{11} , B_{12} , B_{21} , B_{22} , B_{15} and B_{25} were significant in all the three crosses for seed yield per plant. Similarly, the special scaling tests viz., X and Y were found significant for all the above traits in all the three crosses.

As non-significant $\chi^2_{(1)}$ values with nine degrees of freedom of joint scaling test of Cavalli (1952) was more reliable because of involvement of all twelve generations means at a time and hence one can concluded that additive-dominance model was found satisfactory only for days to 50% flowering in cross 1. The results revealed that all the three gene effects i.e., 'm', additive [d] and dominance [h] were found significant for days to 50% flowering in cross 1. The additive-dominance model was not found adequate for days to 50% flowering in cross 2 and cross 3. The failure of additive-dominance model was attributed mainly to the epistasis. Cockerham (1959) postulated that epistatic gene action was common in the inheritance of quantitative traits and there was no sound biological reason why this type of gene action should be less common for yield and yield related traits. Studies have also been reported in castor, which showed evidence of non-allelic interaction of economically important traits (Pathak *et al.*, 1988; Solanki *et al.*, 2003 and Golakiya *et al.*, 2004, Monpara, 2010).

When the simple additive-dominance model failed to explain the variation among generation means, a six-parameters perfect fit model involving three digenic interactions ([i], [j] and [l]) proposed by Hayman (1958) was applied. This model utilized only six basic generations viz., P1, P2, F1, F2, B1 and B2. On other hand, based on weighted least square technique, digenic interaction model of Hill (1966) was also tested which had provision of testing the adequacy of model with six degrees of freedom besides being utilizing means of all the twelve generations. The six-parameter model was adequate for days to 50% flowering in the Cross 2.

The results obtained from six-parameters model of Hayman (1958) revealed that 'm', dominance [h] and digenic [i] and [j] interactions were significant for days to 50% flowering of main raceme in cross 2, while, 'm', additive [d], dominance [h] and digenic ([i] and [j]) interactions were found significant under six-parameter model of Hill (1966) for days to 50% flowering in cross 2. Irrespective of nature, the high magnitude of dominance effect ([h] and [l]) was observed in cross 2 for days to 50% flowering. The results of present findings were in accordance with the results obtained by Pathak *et al.*, (1988) for days to flowering. The goodness of fit for six-parameters model of Hayman (1958) could not, however, be tested in the present study owing to no degrees of freedom left for testing chi-square estimates for various characters. Hence, the present study was planned and executed with means of twelve generations. The model of Hill (1966) was tested in which six degrees of freedom left for testing the adequacy of six-parameter model of Hill (1966). Chi-square test with six degrees of freedom was non-significant suggesting adequacy of six-parameters model of Hill (1966) for days to 50% flowering in Cross 2.

The additive [d] gene effect (Table 1 to 5) found significant and negative in Cross 3 for days to 50% flowering and in Cross 1 for nodes upto main raceme. Likewise, additive [d] gene effect was found significant in all the three crosses for seed yield per plant. The dominance [h] gene effect were important for inheritance of the traits like plant height in the crosses 1 and 2; number of nodes upto main raceme in Cross 2 and seed yield per plant in all the three crosses. As in the present study, the importance of additive and dominance effects was also reported by Solanki *et al.* (2003) for plant height up to main raceme and number of nodes up to main raceme and Golakiya *et al.* (2004) for number of nodes up to main raceme and seed yield per plant. Among digenic interactions, additive x additive [i] gene effect found significant in the cross 1 and cross 2 for days to maturity; in the cross 3 for number of nodes upto main raceme and in all the three crosses for plant height and seed yield per plant. Likewise, the estimates of additive x dominance [j] gene effect was

Table 4 Scaling tests and estimation of gene effects for number of nodes upto main raceme in three crosses of castor

Scaling tests / gene effects	JP 96 x JI 368 (Cross 1)	JP 96 x JI 372 (Cross 2)	JP 101 x SKI 215 (Cross 3)
A	2.86* $\pm$ 1.18	1.20 $\pm$ 1.19	10.73** $\pm$ 1.00
B	-3.33** $\pm$ 1.08	-1.60 $\pm$ 1.07	3.06* $\pm$ 1.39
C	3.53 $\pm$ 2.04	3.26 $\pm$ 2.07	6.93** $\pm$ 2.03
D	2.00 $\pm$ 1.10	1.83 $\pm$ 1.13	-3.43** $\pm$ 1.24
B ₁₁	-13.40** $\pm$ 1.94	-10.67** $\pm$ 1.68	-29.69** $\pm$ 2.09
B ₁₂	-6.60** $\pm$ 2.16	2.99 $\pm$ 2.26	-6.47** $\pm$ 1.76
B ₂₁	-2.20 $\pm$ 2.01	-7.41** $\pm$ 2.19	-16.27** $\pm$ 1.92
B ₂₂	-4.44 $\pm$ 2.38	-8.27** $\pm$ 1.65	7.67** $\pm$ 2.02
B _{1S}	-10.68** $\pm$ 3.55	-9.22* $\pm$ 3.82	-43.42** $\pm$ 3.81
B _{2S}	-23.80** $\pm$ 3.95	3.42 $\pm$ 3.86	2.18 $\pm$ 3.42
X	67.64** $\pm$ 0.87	63.48** $\pm$ 0.78	61.75** $\pm$ 0.88
Y	33.40** $\pm$ 0.97	33.97** $\pm$ 0.92	28.68** $\pm$ 0.91
Three parameters model (Cavalli)			
m	16.72** $\pm$ 0.19	15.80** $\pm$ 0.16	17.35** $\pm$ 0.16
(d)	-0.83** $\pm$ 0.19	1.18** $\pm$ 0.15	-0.68** $\pm$ 0.17
(h)	-0.77* $\pm$ 0.39	-0.72* $\pm$ 0.36	-3.42** $\pm$ 0.29
X ² ₍₁₎ (9 df)	131.91**	97.38**	308.70**
Six parameters model (Hayman)			
m	16.30** $\pm$ 0.43	15.60** $\pm$ 0.44	15.35** $\pm$ 0.47
(d)	2.40** $\pm$ 0.67	-0.10 $\pm$ 0.70	-0.06 $\pm$ 0.79
(h)	-4.29* $\pm$ 2.07	-4.43* $\pm$ 2.13	5.23* $\pm$ 2.51
(i)	-3.99 $\pm$ 2.22	-3.66 $\pm$ 2.27	6.86** $\pm$ 2.48
(j)	3.09** $\pm$ 0.74	-1.39* $\pm$ 0.62	3.83** $\pm$ 0.84
(l)	4.46 $\pm$ 3.39	4.06 $\pm$ 3.48	-20.66** $\pm$ 3.78
Digenic and trigenic interactions (Hill)			
m	19.67** $\pm$ 0.95	12.59** $\pm$ 1.04	13.65** $\pm$ 0.98
(d)	-1.01** $\pm$ 0.27	1.62** $\pm$ 0.18	-2.91** $\pm$ 0.23
(h)	-5.12* $\pm$ 2.50	10.66** $\pm$ 2.78	12.66** $\pm$ 2.68
(i)	-3.54** $\pm$ 0.97	2.86** $\pm$ 1.04	1.56 $\pm$ 1.00
(j)	2.98** $\pm$ 1.05	4.19** $\pm$ 0.92	11.54** $\pm$ 1.04
(l)	0.65 $\pm$ 2.02	-9.59** $\pm$ 2.02	-13.47** $\pm$ 1.85
X ² ₍₂₎ (6 df)	90.01**	53.26**	104.03**
m	21.17** $\pm$ 2.76	6.52* $\pm$ 2.92	20.99** $\pm$ 2.90
(d)	-12.82** $\pm$ 2.01	2.54 $\pm$ 2.17	-3.16 $\pm$ 2.09
(h)	-14.17 $\pm$ 14.60	46.85** $\pm$ 15.13	-27.56 $\pm$ 15.41
(i)	-5.31 $\pm$ 2.76	8.70** $\pm$ 2.92	-6.43* $\pm$ 2.91
(j)	37.76** $\pm$ 5.83	-9.56 $\pm$ 5.59	29.38** $\pm$ 6.00
(l)	9.05 $\pm$ 22.62	-76.24** $\pm$ 23.16	45.71 $\pm$ 23.65
(w)	11.86** $\pm$ 1.99	-4.04 $\pm$ 2.17	-0.58 $\pm$ 2.08
(x)	12.66 $\pm$ 8.32	-14.37 $\pm$ 8.75	26.55** $\pm$ 8.91
(y)	-30.73** $\pm$ 5.79	15.00** $\pm$ 5.27	-35.78** $\pm$ 5.90
(z)	-0.38 $\pm$ 11.00	37.66** $\pm$ 11.19	-26.28* $\pm$ 11.26
X ² ₍₃₎ (2 df)	39.31**	21.55**	20.55**
Type of epistasis	Duplicate	Duplicate	Duplicate

*, ** Significant at 5 and 1 % levels, respectively

Table 5 Scaling tests and estimation of gene effects for seed yield per plant in three crosses of castor

Scaling tests / gene effects	JP 96 x JI 368 (Cross 1)	JP 96 x JI 372 (Cross 2)	JP 101 x SKI 215 (Cross 3)
A	-11.86** ± 3.23	-8.90** ± 2.95	52.20** ± 3.05
B	-15.40** ± 3.49	68.86** ± 3.83	37.60** ± 2.87
C	29.46** ± 5.80	113.73** ± 5.09	144.00** ± 5.94
D	28.36** ± 2.52	26.88** ± 2.59	27.10** ± 2.45
B ₁₁	144.14** ± 6.29	1.46 ± 5.51	-212.08** ± 4.99
B ₁₂	143.80** ± 7.42	-53.94** ± 6.52	-81.62** ± 7.17
B ₂₁	163.86** ± 6.47	-107.58** ± 6.61	-103.60** ± 6.92
B ₂₂	-15.12* ± 6.79	-267.02** ± 4.35	28.42* ± 6.23
B ₁₅	46.02** ± 9.38	-75.08** ± 8.21	-147.38** ± 10.61
B ₂₅	-55.02** ± 12.74	-284.52** ± 8.80	-163.22** ± 12.12
X	647.10** ± 2.27	740.57** ± 1.96	662.81** ± 2.08
Y	388.66** ± 2.93	336.67** ± 2.66	296.01** ± 2.79
Three parameter s model (Cavalli)			
m	179.43** ± 0.57	172.18** ± 0.44	163.64** ± 0.57
(d)	10.07** ± 0.53	12.05** ± 0.42	-0.24 ± 0.49
(h)	-19.81** ± 1.19	-0.53 ± 1.01	12.39** ± 1.23
X ² ₍₁₎ (9 df)	2033.90**	4695.12**	2511.51**
Six parameter s model (Hayman)			
m	191.00** ± 0.96	179.03** ± 0.84	183.31** ± 1.04
(d)	23.50** ± 1.63	-7.48** ± 1.96	-10.76** ± 1.28
(h)	-33.46** ± 5.49	-63.23** ± 5.52	-56.26** ± 5.34
(i)	-56.73** ± 5.04	-53.76** ± 5.18	-54.20** ± 4.90
(j)	1.76 ± 1.98	-38.88** ± 2.05	-7.30** ± 1.63
(l)	84.00** ± 8.74	-61.99** ± 9.37	-35.60** ± 7.86
Digenic and trigenic interactions (Hill)			
m	221.15** ± 2.35	142.10** ± 2.25	144.52** ± 2.40
(d)	14.45** ± 0.90	22.93** ± 0.56	-4.13** ± 0.83
(h)	-123.30** ± 7.37	157.11** ± 6.84	128.03** ± 6.77
(i)	-49.45** ± 2.33	17.35** ± 2.23	1.64 ± 2.38
(j)	-25.11** ± 3.02	-66.93** ± 2.37	23.99** ± 2.72
(l)	67.36** ± 6.18	-166.04** ± 5.63	-127.63** ± 5.50
X ² ₍₂₎ (6 df)	1521.26**	2567.01**	21.77**
m	90.22** ± 6.38	118.53** ± 5.91	99.76** ± 6.84
(d)	32.70** ± 4.74	104.66** ± 4.45	-131.08** ± 5.02
(h)	625.98** ± 34.03	329.43** ± 31.30	377.41** ± 35.87
(i)	77.89** ± 6.41	37.71** ± 5.92	48.49** ± 6.85
(j)	-114.14** ± 14.28	-455.37** ± 13.01	433.09** ± 13.51
(l)	-1163.00** ± 54.28	-539.76** ± 50.26	-515.46** ± 55.99
(w)	-11.86* ± 4.65	-73.02** ± 4.42	116.36** ± 4.96
(x)	-398.67** ± 19.03	-79.51** ± 17.25	-158.22** ± 20.50
(y)	126.59** ± 14.33	523.23** ± 12.92	-421.93** ± 13.33
(z)	628.29** ± 27.85	245.72** ± 26.10	188.24** ± 28.06
X ² ₍₃₎ (2 df)	922.42**	314.30**	450.14**
Type of epistasis	Duplicate	Duplicate	Duplicate

*, ** Significant at 5 and 1 % levels, respectively.

significant for days to 50% flowering of main raceme in cross 3; plant height in cross 2; number of nodes upto main raceme in cross 1 and cross 3 and for seed yield per plant in all the three crosses. Similarly, dominance x dominance [l] gene effect was significant for plant height in cross 1 and cross 2; number of nodes upto main raceme in cross 2 and seed yield per plant in all the three crosses. This indicated that digenic epistatic interactions had also contributed a sizeable portion of variation in the genetic make up of various traits. These findings were further confirmed from the investigation done Pathak *et al.* (1988) for inheritance of days to flowering and seed yield in castor.

Trigenic epistasis additive x additive x additive [w] gene effects were significant in cross 3 for days to 50% flowering; cross 1 for number of nodes upto main raceme and all the three crosses for seed yield per plant. Additive x additive x dominance [x] was observed to be significant for plant height and number of nodes upto main raceme in the cross 3 and for days to maturity and seed yield per plant in all the three crosses. On the other hand, additive x dominance x dominance [y] gene effects were found significant for days to 50% flowering in the cross 3; plant height in the cross 2 and cross 3 and for number of nodes upto main raceme and seed yield per plant in all the three crosses. In case of dominance x dominance x dominance [z] gene effects, it was significant for plant height in the cross 1 and cross 2; number of nodes upto main raceme in cross 2 and cross 3 and for seed yield per plant in all the three crosses. Interestingly, all the types of digenic and trigenic interactions were significant in all the crosses for seed yield per plant. While, fitting trigenic epistatic model, the χ^2 (3) value at two degrees of freedom were non-significant in ten-parameter model for days to maturity in cross 1 and cross 3 suggesting the adequacy of the trigenic interaction model of Hill (1966) and Van Der Veen (1959) for days to maturity.

The opposite signs of either two or all the three gene effects viz., dominance [h], dominance x dominance [l] and dominance x dominance x dominance [z] gene effects suggested presence of duplicate type of epistasis. In present study, duplicate epistasis

was observed in all the crosses for all the characters. Duplicate type of epistasis for plant height, number of nodes and seed yield per plant was also reported by Golakiya *et al.* (2004). Solanki *et al.* (2003) observed additive, dominance and all the epistasis with high magnitude of (l) for plant height and number of nodes up to main raceme. Singh and Yadava (1981) also reported partial and over dominance for days to flowering of main raceme and seed yield per plant, respectively.

It can be concluded from the present study that seed yield per plant and traits related to earliness in three castor crosses were governed by additive, dominance and digenic and/or trigenic epistasis gene effects along with duplicate type of gene action. When additive as well as non-additive effects are involved, a breeding scheme efficient in exploiting both types of gene effects should be employed. Reciprocal recurrent selection could be followed which would facilitate exploitation of both additive and non-additive gene effects simultaneously.

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Heterosis for yield and yield attributing traits in castor, *Ricinus communis* L.

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ABSTRACT

Heterosis, heterobeltiosis and standard heterosis for seed yield and its attributes were studied in 45 hybrids developed through diallel mating design (ten parents) without reciprocal in castor. The magnitude of heterosis over mid parent (MP) and better parent (BP) for seed yield ranged from 47.73 % to 131.77 % and 39.15 % to 123.9 %, respectively. None of the hybrids exhibited significant positive heterosis over standard check i.e., GCH 5 for seed yield. The cross combination DCS 89 x PCS 124 (131.77 %) and JI 321 x PCS 124 (123.9 %) exhibited significant positive heterosis over mid parent and better parent, respectively. These superior cross combinations also exhibited significant and positive heterosis for raceme length, number of capsules on main raceme, number of branches per plant and test weight, which are yield attributes.

Key words : Heterosis, heterobeltiosis, castor

Castor (*Ricinus communis* L.) is an important non-edible oil seeds crop of Gujarat state. In Gujarat, the common practice of castor growing is an intercrop under rainfed and as sole crop under irrigated condition. Yield potentiality of castor has considerably increased through exploitation of hybrid vigour on commercial scale. In order to assess the extend of heterotic parents in F₁ hybrid, it essential to evaluate newly developed inbred lines in cross combination for seed yield and its components.

MATERIALS AND METHODS

The experimental material comprised of ten inbred lines of castor viz., 48-1, SKI 321, SKI 314, JI 321, DCS 89, PCS 124, DCS 9, SKI 291, SKI 281 and SKI 215, 45 hybrids using half diallel mating design and GCH-5 as standard check were evaluated in Randomized Block Design with three replications during year 2007-08 and 2008-09 at Main Castor-Mustard Research Station, S.D. Agricultural

University, Sardarkrushinagar. Each entry was planted in a single row of 10 dibbles keeping 90 cm row to row and 60 cm plant to plant distances. Recommended package of practices were followed for raising the normal crop. Observations on five randomly selected competitive plants were recovered for 10 traits. (Table 1). However, days to flowering and days to maturity were recorded on plot basis. Each characters was analyzed separately using analysis of variance technique suggested by Panse and Sukhatme (1969) and heterosis was calculated in F₁ hybrids over mid parent, better parent and standard check GCH 5.

RESULTS AND DISCUSSION

Analysis of variance was carried out to test the differences among parents and hybrids for ten characters. The results revealed that the mean squares due to genotypes were highly significant for seed yield per plant as well as all its components studied. Mean squares due to parents and hybrids (F₁'s) exhibited highly significant differences. This indicates the presence of considerable amount of variability among the parents and hybrids for various

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Table 1 Analysis of variance and variance estimates for combining ability for seed yield and its components in castor.

Source of variation	d.f.	Days to 50 per cent flowering (Primary raceme)	Days to 80% maturity (Primary raceme)	Plant height (cm)	Number of nodes on main stem	Effective raceme length (cm)	Number of capsules on primary raceme	Number of branches per plant	Seed yield per plant (g)	100-seed weight (g)	Oil content (%)
Replications	2	0.947	2.77	1.72	0.01	12.30	89.88	0.02	150.02	0.09	0.10
Parents	9	47.76**	45.45**	572.80**	3.98**	120.26**	535.50**	3.55**	122.57	8.79**	1.95**
F ₁ 's	44	38.98**	43.49**	401.91**	3.39**	182.74**	429.82**	2.495**	1053.2**	12.66**	3.88**
Parents vs F ₁ 's	1	89.65**	30.87*	3731.2**	39.84**	177.03**	272.85*	0.685**	86618.1**	7.28**	3.64**
σ^2 gca	9	65.38**	102.73**	511.44**	7.13**	21.79**	735.58**	4.22**	622.43**	11.39**	1.68**
σ^2 sca	45	25.27**	75.14**	462.02**	5.90**	228.42**	928.36**	1.06**	1897.16**	9.21**	6.33**
Error	198	13.98	19.20	9.33	0.32	4.52	94.21	0.046	887.65	3.95	1.22
σ^2 gca/ σ^2 sca		2.59	1.38	1.11	1.21	0.096	0.79	23.04	0.33	1.24	0.27

* = Significance at P = 0.05 level. ** = Significance at P = 0.01 level.

characters. The mean squares due to parents vs. hybrids were significant for all the traits, which revealed that the performance of parents was different to that of F₁ hybrids as well as presence of overall heterosis for all the characters studied. The crosses exhibiting heterosis in negative direction are of immense value for earliness. The hybrid JI 321 x PCS 124 exhibited maximum significant and negative mid parent heterosis (-16.25 %) heterobeltiosis (-15.50 %) and standard heterosis (-14.07 %) for days to 50% flowering. For early maturity the cross SKI 314 x SKI 215(-6.79 %), JI 321 x PCS 124(-8.89 %) and JI 321 x DCS 9 (-6.24 %) depicted significant relative heterosis, heterobeltiosis and standard heterosis in desired direction, respectively. The hybrid 48-1 x SKI 291 exhibited significant and desirable relative heterosis (-39.06 %) and heterobeltiosis (34.91 %), respectively for the plant height and for the number of nodes up to primary raceme SKI 321 x SKI 215 having high heterotic value in desired direction for mid parent heterosis (-21.01 %) and the cross PCS 124 x SKI 291 having high heterotic value in desired direction for heterobeltiosis (-17.20 %) and standard heterosis (-21.36 %) over check hybrid, GCH 5, respectively. The cross PCS 124 x SKI 291 showed significant and positive mid parent heterosis (38.59 %) and cross PCS 124 x DCS 9 expressed significant and positive heterobeltiosis (32.73 %) while none of the hybrids showed significant and positive standard heterosis over check hybrid GCH 5 for the character effective raceme length. The maximum relative heterosis was recorded in SKI 314 x PCS 124 (93.67), maximum heterobeltiosis was recorded in JI 321 x DCS 9 (47.58) and none of the hybrids showed standard heterosis for the characters number of capsules on primary raceme. The number of branches per plant the heterosis over mid-parental was recorded by the cross SKI 321 x JI 321 (53.04 %), the heterobeltiosis for this character was registered by the cross SKI 321 x JI 321 (46.67 %). The maximum relative heterosis (13.61 %) and heterobeltiosis (7.80 %) was registered in cross 48-1 x SKI 314, while none of the hybrid showed positive significant over registered standard check GCH 5 for the character test weight in castor. The oil content trait observed in cross combination SKI 321 x SKI 291 recorded maximum and positive heterotic effect over mid-

Table 2 Promising crosses for seed yield /plant with heterosis over mid parent (MP), better parent (BP) and standard check GCH 5 (SC) in castor

Sr. No.	Characters studied	Heterosis over	Range of heterosis		Best heterotic hybrid	No. of hybrids in desirable direction
1	Days to 50 per cent flowering	MP	-16.25	13.59	JI 321 x PCS 124	24
		BP	-15.50	24.80	JI 321 x PCS 124	17
		SC	-20.34	4.07	SKI 321 x DCS 9	37
2	Days to 80% maturity	MP	-6.79	5.33	SKI 314 x SKI 215	14
		BP	-8.89	9.93	JI 321 x PCS 124	05
		SC	-6.24	6.48	JI 321 x DCS 9	03
3	Plant height	MP	-39.06	39.68	48-1 x SKI 291	35
		BP	-34.91	85.47	48-1 x SKI 291	22
		SC	-37.11	32.29	SKI 314 x PCS 124	37
4	Number of nodes on main stem	MP	-21.01	5.03	SKI 321 x SKI 215	29
		BP	-17.20	33.91	PCS 124 x SKI 291	11
		SC	-21.36	-1.46	PCS 124 x SKI 291	38
5	Effective raceme length	MP	-24.08	38.59	PCS 124 x SKI 291	19
		BP	-28.07	32.73	PCS 124 x DCS 9	16
		SC	-35.76	1.10	SKI 314 x SKI 215	01
6	Number of capsules on primary raceme	MP	-33.54	93.67	SKI 314 x PCS 124	10
		BP	-46.21	47.58	JI 321 x DCS 9	05
		SC	-49.49	-0.13	DCS 89 x PCS 124	00
7	Number of branches per plant	MP	-31.58	53.04	SKI 321 x JI 321	18
		BP	-43.48	46.67	SKI 321 x JI 321	09
		SC	-56.79	-19.75	PCS 124 x SKI 215	00
8	100-seed weight	MP	-15.65	13.61	48-1 x SKI 314	20
		BP	-17.19	7.80	48-1 x SKI 314	13
		SC	-21.42	4.09	SKI 314 x SKI 281	00
9	Oil content	MP	-5.73	6.48	SKI 321 x SKI 291	22
		BP	-5.91	5.51	SKI 321 x SKI 291	16
		SC	-7.48	1.98	DCS 89 x DCS 9	02
10	Seed yield per plant	MP	47.73	131.77	DCS 89 x PCS 124	45
		BP	39.15	123.9	JI 321 x PCS 124	45
		SC	-39.36	-7.09	SKI 291 x SKI 281	00

Table 3 Relative heterosis, heterobeltiosis and standard heterosis of superior crosses for seed yield and other components in castor

Sr. No	Crosses	Mean seed yield	Hete rosis	Days to 50 per cent flowering	Days to 80% maturity	Plant height	Number of nodes on main stem	Effective raceme length	Number of capsules on primary raceme	Number of branches per plant	Seed yield per plant	100- seed weight	Oil content
1	SKI 291 x SKI 281	171.6	MP BP SC	1.49 4.07** -13.22**	-0.47 2.15 -1.20	-7.01** -8.67** 8.19**	-12.55** 26.34** -15.05**	20.93** 14.29** -4.54	-32.56** -40.06** -36.63**	12.82** -2.22 -27.16**	117.77** 99.53** -7.09	0.89* -0.17 -3.21**	5.75** 5.50** -0.14
2	PCS 124 x SKI 291	168.3	MP BP SC	-2.29* 8.33** -9.66**	-1.88 2.40 -0.96	-25.63** -7.43** -28.55**	-13.73** -17.20** -21.36**	38.59** 28.58** -4.81*	36.35** 8.51 -10.41	-0.28 -1.67 -27.16**	120.33** 96.16** -8.88*	6.04** 3.46** -1.15*	1.01* 0.08 -3.71**
3	SKI 281 x SKI 215	168.2	MP BP SC	-4.76** 1.74** -10.68**	1.08 2.28 0.40	-1.76 6.13* 16.87**	-8.32** 2.91* -7.28**	16.30** 15.6** -1.79	-4.37 -21.26* -17.10	20.39** -0.54 -24.69**	123.03** 113.3** -8.93*	1.31** -0.27 -3.33**	-4.02** -6.15** -7.48**
4	PCS 124 x SKI 215	167.7	MP BP SC	-7.81** -6.66** -7.29**	-0.54 -0.88 -0.48	-10.06** -19.81** -10.84**	-6.22** 0.00 -9.71**	33.79** 16.74** -0.83	62.8** 39.72** -4.76	6.04* 4.89 -19.75**	129.99** 112.7** -9.20*	3.75** 0.51 -2.57**	1.07** -0.15 -1.56**
5	DCS 89 x PCS 124	166.0	MP BP SC	-11.32** -10.81** -10.51**	-2.40 -6.57** -3.28	-2.68 8.25** -10.48**	0.76 5.70** -3.88	16.54** -2.25 -8.53**	55.9** 25.27 -0.13	14.29** 9.09** -25.93**	131.77** 118.5** -10.07*	3.30** 2.11** -4.09**	4.22** 2.78** -0.42

*=Significance at P = 0.05 levels.
**=Significance at P = 0.01 levels.

Table 4 Best heterotic crosses and their performance for some related parameters for seed yield

Sr. No	Best crosses	Mean yield per plant (g)	Heterobeltiosis	sca effect	Significant heterobeltiosis for other traits in desire direction
1.	JI 321 x PCS 124	154.5	123.9**	24.089**	DF, PH, NN, RL, NC, NB, TW
2.	PCS 124 x SKI 281	158.8	121.8**	20.875**	PH, RL, TW, OC,
3.	DCS 89 x PCS 124	166.0	118.5**	33.659**	DF, NB, TW, OC
4.	SKI 281 x SKI 215	168.2	113.3**	35.536**	NN, RL,
5.	PCS 124 x SKI 215	167.7	112.7**	32.136**	DF, RL, NC,
6.	PCS 124 x DCS 9	151.3	104.1**	26.042**	DF, PH, RL, NB, OC
7.	SKI 321 x DCS 89	153.9	99.91**	35.884**	NN, NC, NB, OC
8.	SKI 291 x SKI 281	171.6	99.53**	34.381**	NN, RL, OC, WI
9.	SKI 321 x JI 321	151.5	96.75**	35.447**	DF, DM, PH, NN, NB, TW, OC
10.	PCS 124 x SKI 291	168.3	96.16**	28.247**	PH, NN, RL, TW
11.	SKI 314 x SKI 281	156.0	95.00**	31.011**	PH, NB, TW
12.	DCS 89 x SKI 215	151.6	92.30**	24.453**	PH, OC

* = Significance at P = 0.05 levels.

** = Significance at P = 0.01 levels

DF = Days to flowering

PH = Plant height

NC = Number of capsules on main raceme

DM = Days to maturity

RL = Raceme length

NN = Number of nodes on main raceme

TW = Test weight

OC = Oil content

NB = Number of branches per plant

WI = Wilt incidence

parent (6.48 %) and better parent (5.51 %), while cross DCS 89 x DCS 9 (1.98 %) recorded maximum and positive heterotic effect over standard check GCH 5. The best five crosses for yield (SKI 291 x SKI 281, PCS 124 x SKI 291, SKI 281 x SKI 215, PCS 124 x SKI 215 and DCS 89 x PCS 124) observed based on *per se* performance, heterosis over mid parent and better parent indicated that most superior hybrids were accompanied by significant and positive heterosis over MP, BP and Standard check for yield attributing like effective length of raceme, number of capsule on primary raceme, number of branches per plant and test weight advocating that the high heterosis for seed yield resulted through contribution of its components traits. (Table 2). On the whole, consideration of relative heterosis, heterobeltiosis and standard heterosis observed for seed yield and other associate characters suggested the presence of large genetic diversity among the inbred lines and also the unidirectional distribution of allelic constitution contributing towards desirable heterosis in the parental material. Low magnitude of desirable heterosis and heterobeltiosis was observed for some of the characters viz., oil content and test weight indicating the narrow genetic base among the inbred lines and

also the ambidirectional distribution of allelic constitution contributing towards undesirable heterosis or may be due to mutual cancellation of effect of dominant alleles present in the parental material. Similar finding were also reported in castor by Chakrabarty (1997) and Lavanya (2003).

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Genetic variability in carrot (*Daucus carota* L.) under different environments

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ABSTRACT

Present investigation was aimed to explain genetic variability under four different environments with 24 diverse lines of carrot. A wide phenotypic range was observed for most of the traits including weight of root and total biomass in environment E-II indicating environment E-II to be the most favorable for expression of maximum genetic variability present in the genotypes. The estimates for parameters GCV (%) and PCV (%) displayed relatively higher amount of genetic variability for petiole length, β -carotene content and total soluble sugar over the environments. High heritability accompanied with high genetic advance was observed for weight of root per plant, core size, harvest index, root index, β -carotene content and total soluble sugar in environment E-II. Root weight per plant was positively correlated with number of leaves per plant, length of root, plant top height, root index and total biomass. Total soluble sugar as an important quality parameter showed positive correlation with plant top height, core size and root index.

Key words : Carrot, genetic variability, heritability, genetic advance and correlation

Carrot (*Daucus carota* L.), is an important root vegetable crop worldwide, both economically and as a source of provitamin 'A' carotenes. Carrot is cultivated in India, China, Malaysia, Indonesia, Philippines, European countries, West Africa and north-south America. In India the important carrot growing states are Uttar Pradesh, Assam, Karnataka, Andhra Pradesh, Punjab and Haryana. Carrot (*Daucus carota* var. *Sativus*) belongs to family Apiaceae which also includes cumin, coriander and parsley. The cultivated types of this species crosses readily with wild *Daucus carota* L. which is distributed worldwide. Approximately 80 *Daucus* species have been identified. Almost all species, including carrot, are diploid, where $n = 7$ to 11. Carrot varieties are divided into two groups viz., Asiatic or

Tropical types and European or temperate types. Most of the tropical varieties are red coloured due to the presence of the pigment lycopene. Orange colour of the European types is due to β -carotene pigment, a precursor of vitamin 'A.' Purple and yellow colour of carrots is due to pigments anthocyanin and xanthophylls, respectively.

Estimation of genetic variability of a particular crop is prerequisite for making any effective breeding programme. Selection of genotypes to be included in the hybridization programme is possible only in presence of appropriate genetic variability. Most of the important characters including marketable yield are highly influenced by environment, since they are polygenically controlled. This makes selection process difficult. Thus, knowledge of heritability of yield component traits is the consequence of genotype and is inherited from generation to generation (Wright, 1921). Estimation of coefficient

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of variation together with heritability estimates and genetic advance gives reliable information about the amount and extent of improvement possible from selection and the nature of gene action in the inheritance of polygenic traits.

MATERIALS AND METHODS

The present investigation was carried out during rabi 2011-2012 at two different locations (Four Environments) viz., at Botanical Garden, Department of Genetics and Plant Breeding, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar and Main Potato Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa. Among 24 diverse lines of carrot obtained from different sources. Each entry was planted with a spacing of 30 cm between rows and 10 cm between plants. The experiment was laid out in a randomized block design with three replications. Observations were made for the characters viz., number of leaves per plant, petiole length (cm), length of root (cm), root diameter (cm), weight of root (g/plant), plant top height (cm), root laterals, core size (mm), harvest index (%), root index, total biomass, β -carotene contents ($\mu\text{g/g}$) and total soluble sugar. Analysis of variance was calculated on the method suggested by Panse and Sukhatme, 1978. The Genotypic and Phenotypic coefficient of variation (PCV and GCV) were estimated as per Burton, 1953. Heritability in the broad sense, suggested by Allard, 1960 and genetic advance (In term of percentage of mean) were computed according to Johnson et al., 1955.

RESULTS AND DISCUSSION

The Analysis of variance for individual environments revealed highly significant mean squares due to genotypes for all the characters except root laterals and total biomass in E-I which indicate the presence of genetic variation for different characters (Table 1). The estimates of genetic parameters of variability, viz., phenotypic and genotypic coefficient of variation (PCV and GCV) along with heritability in broad sense (h^2) and genetic advance (GA) as percentage of mean for different characters (Table

Table 1. Analysis of variance (Mean square) for individual environment

Sources of variation	d.f	Number of leaves per plant	Petiole length (cm)	Length of root (cm)	Root diameter (cm)	Weight of root (g/plant)	Plant top height (cm)	Root laterals	Core size (mm)	Harvest index (%)	Root index	Total Biomass	β -Carotene contents ($\mu\text{g/g}$)	Total Soluble sugar
ENVIRONMENT - I														
Replication	2	3.76	100.17	5.49	6.99*	1064.92	155.60	3.10	10.72	832.32	3.18	14812.40*	4.43	0.00
Genotype	23	8.01**	22.82**	8.08**	1.43**	523.41**	114.07**	27.31	38.17**	134.56**	1.57**	2451.31	669.01**	1.35**
Error	46	1.05	7.79	2.53	0.23	215.06	32.92	24.0	1.82	47.26	0.37	1347.69	5.50	0.03
ENVIRONMENT - II														
Replication	2	1.17	143.40	11.74	0.09	992.40	65.45	1.82	4.62	423.40	0.49	31610.61*	4.04	0.01
Genotype	23	4.09**	33.99*	14.38**	13.3*	2265.97**	89.83**	2.72**	27.14**	190.36*	1.84**	2931.11**	657.49**	2.89**
Error	46	0.28	15.35	5.69	0.43	232.76	24.40	0.62	2.16	88.69	0.19	437.45	4.00	0.06
ENVIRONMENT - III														
Replication	2	3.02	69.89	29.56	0.84	175.32	53.55	0.45	1.62	130.69	2.36	1251.66	3.91	0.02
Genotype	23	10.79**	42.4**	11.46**	2.26**	285.22**	89.83**	1.66**	19.1**	426.19**	5.76**	3570.93**	563.72**	4.12**
Error	46	2.69	8.83	4.41	0.16	92.44	22.75	0.46	2.90	109.60	1.26	622.23	1.87	0.01
ENVIRONMENT - IV														
Replication	2	6.84	40.74	5.59	0.22	18.05	99.99	4.71	0.39	233.61	1.79	2931.58	3.23	0.11
Genotype	23	13.83**	48.34**	23.44**	0.84*	437.46**	137.95**	9.09**	19.10**	727.09**	2.40**	1584.33**	653.87**	1.80**
Error	46	1.23	11.77	3.04	0.12	107.95	40.29	1.49	2.43	76.69	0.30	169.05	2.01	0.02

*, ** Significant at 5 and 1 per cent levels, respectively.

Table 2 Mean, range, variability parameter, heritability and genetic advance for character in individual environment in carrot

Parameter	Number of leaves per plant	Petiole length (cm)	Length of root (cm)	Root diameter (cm)	Weight of root (g/plant)	Plant height (cm)	Root top laterals	Core size (mm)	Harvest index (%)	Root index	Total Biomass	β -Carotene contents ($\mu\text{g/g}$)	Total Soluble sugar
ENVIRONMENT - I													
Mean	8.86	26.83	15.81	4.18	94.02	67.49	2.26	20.15	51.51	3.86	186.52	35.29	5.7
Range	7.73-11.0	22.83-30.17	13.53-18.13	3.7-4.97	73.57-119.27	52.60-72.33	1.47-2.67	15.00-31.00	45.86-61.02	3.11-4.38	126.67-230.37	18.58-65.11	4.17-6.83
σ^2_g	0.32	5.01	1.85	0.4	102.78	27.05	1.10	12.11	29.1	0.4	367.84	221.17	0.44
σ^2_p	1.37	12.8	4.38	0.63	317.84	59.97	25.11	13.93	76.36	0.77	1715.56	226.67	0.47
σ^2_e	1.05	7.79	2.53	0.23	215.06	32.92	24.01	1.82	47.26	0.37	1347.72	5.5	0.03
GCV %	6.43	8.34	8.60	15.13	10.72	7.71	36.8	17.27	10.47	16.38	10.28	42.12	11.66
PCV %	13.21	13.33	13.24	18.99	18.96	11.47	175.82	18.52	16.96	22.73	22.21	42.66	12.03
Heritability	23.35	39.14	42.24	63.49	47.79	45.10	43.81	50.44	38.11	51.94	21.44	97.57	93.62
GA (% of mean)	6.35	10.75	11.52	24.18	18.66	10.64	15.57	19.07	13.27	23.88	9.81	85.24	23.04
ENVIRONMENT- II													
Mean	9.2	30.71	17.15	4.92	152.30	74.29	2.66	24.37	52.39	3.47	303.02	36.00	6.06
Range	7.60-10.87	22.43-34.67	13.87-19.13	4.13-5.47	103.87-239.30	66.53-81.93	1.80-3.60	20.00-30.33	38.67-67.97	3.01-4.14	250.17-399.83	17.03-69.08	4.00-7.90
σ^2_g	1.27	6.18	2.9	0.3	677.73	21.81	0.7	8.33	180.45	0.55	831.22	217.83	0.96
σ^2_p	1.81	21.53	5.68	0.73	910.49	46.21	1.32	10.49	269.14	0.74	1268.67	221.83	1.02
σ^2_e	0.28	15.35	5.58	0.43	232.76	24.40	0.62	2.16	88.69	0.19	437.45	4.00	0.06
GCV %	10.40	8.09	9.93	11.13	17.09	6.28	31.45	11.84	25.64	21.37	9.51	40.99	16.16
PCV %	12.40	15.10	17.08	17.36	19.81	9.15	43.19	13.29	31.31	24.79	11.75	41.37	16.66
Heritability	70.40	28.70	33.80	41.09	74.43	47.20	53.03	79.40	67.05	74.32	65.52	98.19	94.11
GA (% of mean)	17.96	8.93	11.61	14.69	30.38	8.89	47.16	21.73	43.25	37.95	15.87	86.00	32.27
ENVIRONMENT- III													
Mean	9.55	18.11	14.81	2.95	45.91	45.17	1.67	17.04	50.21	5.09	95.18	33.98	5.96
Range	7.83-11.10	14.70-23.60	11.67-17.50	2.57-3.47	26.80-73.70	36.5-56.43	1.10-2.50	14.00-19.67	39.31-56.05	3.81-6.55	73.8-151.93	17.12-67.54	4.00-7.96
σ^2_g	2.7	11.19	2.35	0.70	64.26	22.36	0.40	5.4	105.53	1.5	982.9	183.74	1.37
σ^2_p	5.39	20.02	6.76	0.86	156.7	45.11	0.86	8.39	215.13	2.76	1551.13	185.61	1.38
σ^2_e	2.69	8.83	4.41	0.16	92.44	22.75	0.46	2.90	109.60	1.26	622.23	1.87	0.01
GCV %	17.20	18.47	10.35	31.14	17.46	10.47	37.87	13.63	20.46	24.49	32.02	39.89	19.66
PCV %	24.31	24.471	17.56	31.43	27.27	14.87	49.59	16.99	29.21	32.63	41.38	40.09	19.71
Heritability	50.09	55.89	34.76	81.39	41.01	49.57	46.51	64.36	49.05	54.35	60.00	98.99	99.20
GA (% of mean)	25.08	28.44	12.57	52.70	23.03	15.18	52.62	22.41	29.48	31.18	51.14	71.29	40.19
ENVIRONMENT- IV													
Mean	9.37	25.93	16.63	3.66	81.62	62.52	2.59	20.24	43.32	4.56	197.19	34.97	5.67
Range	7.47-10.83	17.4-33.4	14.57-18.63	2.97-4.1	62.56-109.83	47.07-69.53	1.63-3.8	13.67-24.00	33.91-52.66	3.79-5.16	135.93-237.93	16.39-70.08	4.20-6.66
σ^2_g	4.2	12.19	6.8	0.24	109.84	32.58	2.4	4.44	216.8	0.7	471.76	217.29	0.59
σ^2_p	5.43	23.96	9.84	0.36	217.79	72.79	3.89	6.87	293.49	1.00	640.81	219.29	0.61
σ^2_e	1.23	11.77	3.04	0.12	107.95	40.21	1.49	2.43	76.69	0.30	169.05	2.00	0.02
GCV %	21.87	13.46	14.00	13.06	12.84	8.60	59.81	10.41	33.98	18.34	11.01	42.21	13.58
PCV %	24.86	18.87	16.94	16.18	18.08	13.64	76.15	12.94	35.72	21.92	12.83	42.35	13.77
Heritability	77.34	50.87	69.10	65.10	50.43	44.76	61.70	64.62	73.86	69.31	73.62	99.08	96.72
GA (% of mean)	39.4	19.44	24.10	21.81	18.78	12.57	95.69	17.23	19.5	31.17	19.30	86.21	27.30

2). The range was wide for weight of root (83.94 to 125.92 g), total biomass (170.5 to 226.33 g) and β -carotene content (18.28 to 66.57 $\mu\text{g/g}$). Moderate range was observed for plant top height (55.25 to 68.23 cm), harvest index (42.27 to 56.07 %), petiole length (19.47 to 28.15 cm) and core size (18.0 to 23.17 mm). The range was narrow in case of remaining characters i.e., number of leaves per plant (8.09 to 10.22), length of root (14.43 to 17.76 cm), root diameter (3.67 to 4.13 cm), root laterals (1.74 to 2.87), root index (3.89 to 4.83) and total soluble sugar (4.09 to 7.15). Over all averages of different characters indicated that in general, genotypes performed better in E-II. High total biomass with higher range (250.17 to 399.83 g) was observed in E-II. Similarly, the lowest total biomass was (73.8 to 151.93 g) observed in E-III. The average biomass over environments was (170.5 to 226.33 g). Similarly, the highest weight of root with the widest range (103.87 to 239.30 g) was observed in E-II. While, the lower weight of roots with narrow range (26.8 to 73.7 g) was observed in E-III.

In environment-I (E-I), the higher values of genotypic and phenotypic variances were observed for total biomass (367.84 and 1715.56), weight of root (102.78 and 317.84) and β -carotene (221.17 and 226.67). In E-II, higher values of genotypic and phenotypic variances were recorded for total biomass (831.22 and 1268.67) and weight of root (677.73 and 910.49). Moderate amount of σ^2_g and σ^2_p values were recorded by harvest index (180.45 and 269.14) and β -carotene content (217.83 and 221.83). In E-III, total biomass (982.90 and 1551.13), β -carotene content (183.74 and 185.61), harvest index (105.53 and 215.13) and weight of root (64.26 and 156.70) showed higher σ^2_g and σ^2_p values. The moderate to low values at σ^2_g and σ^2_p were exhibited by the remaining characters. In E-IV, higher values of genotypic and phenotypic variance were recorded by total biomass (471.76 and 640.81), β -carotene content (217.29 and 219.29), harvest index (216.8 and 293.49) and weight of root (109.84 and 217.79). Moderate values were observed for plant top height (32.58 and 72.79) and petiole length (12.19 and 23.96) Table-2. The remaining characters showed low variation. The variance components estimated

Table 3 Mean, range, variability parameter, heritability and genetic advance for character in pooled over environment in carrot

Parameter	Number of leaves per plant	Petiole length (cm)	Length of root (cm)	Root diameter (cm)	Weight of root (g/plant)	Plant top height (cm)	Root laterals	Core size (mm)	Harvest index (%)	Root index	Total Biomass	β -Carotene contents ($\mu\text{g/g}$)	Total Soluble sugar
Mean	9.23	25.39	16.10	3.93	93.46	62.34	2.29	20.41	49.34	4.25	195.48	35.03	5.84
Range	8.09-10.22	19.47-28.15	14.43-17.76	3.67-4.13	83.94-125.92	55.25-68.23	1.74-2.87	18.00-23.17	42.27-56.07	3.89-4.83	170.5-226.33	18.28-66.57	4.09-7.15
σ^2_g	0.09	3.31	0.16	0.002	3.83	0.76	0.001	0.27	3.58	0.013	34.74	13.06	0.57
σ^2_p	0.25	4.74	0.62	0.023	75.83	5.82	0.071	1.58	15.53	0.05	236.81	16.70	0.64
σ^2_e	0.135	0.91	0.32	0.020	13.50	2.91	0.05	0.19	6.71	0.04	167.18	1.60	0.002
GCV %	3.25	7.16	2.48	1.14	2.09	1.40	1.37	2.54	3.83	2.68	3.02	10.31	12.86
PCV %	5.42	8.57	4.86	3.86	9.32	3.87	11.58	6.15	7.98	5.26	7.88	11.66	13.63
Heritability	36.00	69.83	25.82	8.69	5.01	13.06	1.41	17.09	23.05	26.00	14.67	78.97	88.99
GA (% of mean)	4.01	12.18	2.50	0.80	0.96	1.04	0.33	2.20	3.79	2.80	2.27	18.97	25.03

Where, σ^2_g , σ^2_p and σ^2_e are the genotypic, phenotypic and environmental variance, respectively.

GCV % and PCV % are genotypic and phenotypic coefficient of variation, respectively.

GA (% mean) is genetic advance expressed as per cent of mean.

Table 4. Genotypic (G) and Phenotypic (P) correlation coefficient in carrot over pooled environment

Character	Number of leaves per plant	Petiole length (cm)	Length of root (cm)	Root diameter (cm)	Plant top height (cm)	Root laterals	Core size (mm)	Harvest index (%)	Root index	Total biomass (g)	β -Carotene contents ($\mu\text{g/g}$)	Total Soluble sugar
Weight of root (g/plant)	g	0.499*	0.163	0.828**	0.187	0.733**	-0.573**	-0.151	0.379	0.883**	-0.506*	-0.625**
	p	0.087	0.155	0.247*	0.297*	0.151	0.010	0.004	0.163	-0.054	-0.153	-0.094
Number of leaves per plant	g		0.786**	0.038	0.716**	0.360	0.358	0.071	-0.132	0.310	0.254	-0.429*
	p		0.126	0.128	0.215	-0.046	-0.003	0.198	-0.390	-0.121	0.045	-0.083
Petiole length (cm)	g			0.229	0.796**	0.182	-0.045	-0.383	0.919**	0.574**	-0.014	0.029
	p		0.167	0.167	-0.068	0.147	0.024	-0.057	0.347**	0.111	-0.030	0.004
Length of root (cm)	g			-0.183	0.820**	0.764**	-0.056	0.434*	0.162	0.469*	0.198	-0.446*
	p			0.165	0.052	0.052	-0.018	0.117	-0.198	0.649**	0.033	-0.081
Root diameter (cm)	g				-0.838**	0.540**	0.650**	0.045	-0.312	-0.090	-0.695**	-0.759**
	p				0.014	0.050	0.262*	-0.133	-0.470**	0.307**	-0.092	-0.044
Plant top height (cm)	g					0.807**	-0.207	-0.047	-0.070	0.552**	0.641**	0.976**
	p					0.024	0.072	-0.149	0.016	0.304**	0.017	0.063
Root laterals	g						0.105	0.529**	0.961**	-0.601**	0.620**	-0.955**
	p						0.001	0.042	-0.039	-0.034	0.051	-0.124
Core size (mm)	g							0.148	-0.794**	-0.094	0.445*	0.538**
	p							-0.145	-0.088	0.236*	-0.085	0.195
Harvest index (%)	g								0.133	0.201	0.065	-0.090
	p								-0.048	-0.702**	0.027	-0.009
Root index	g									0.385	0.107	0.448*
	p									-0.005	0.072	0.059
Total biomass (g)	g										-0.611**	-0.337
	p										-0.066	-0.051
β -Carotene contents ($\mu\text{g/g}$)	g											-0.174
	p											-0.112

*, ** Significant at 5 and 1 per cent levels, respectively.

from pooled data Table 3 naked the values of genotypic and phenotypic variances *i.e.*, 34.74 and 236.81 for total biomass, 3.83 and 75.83 for weight of root, 13.06 and 16.70 for β -carotene and 3.58 and 15.53 for harvest index, respectively. The moderate values of σ^2_g and σ^2_p were recorded for petiole length *i.e.*, 3.31 and 4.74 and plant top height *i.e.*, 0.76 and 5.82, respectively. The rest of the characters exhibited low values of genotypic and phenotypic variances. On pooled basis range of all the thirteen traits were compared, maximum variation was observed for total biomass pursued by weight of root per plant (Table 3). The comparable results were obtained by Amin and Singla (2010) and Kumar *et al.*, (2011). The study further revealed that the narrow range of phenotypic variation was observed for number of leaves per plant. This may be due to optimization of number of leaves per plant under natural selection pressure.

Heritability indicates the effectiveness with which selection of genotypes can be based on phenotypic performance. High broad sense heritability estimates were observed for petiole length, β -carotene content and total soluble sugar in pooled analysis. The characters weight of root, root diameter, plant top height, root laterals and total biomass registered very low heritability estimates on pooled basis (Table 3). Similar results of lower heritability for root yield by Gupta *et al.*, (2012) and for root diameter core size and root length were observed by Amin and Singla, (2010). The heritability for weight of root was highest in environment E-II. From this result, it can be concluded that environment E-II was most favourable for expression of maximum genetic potential of genotypes. The expected genetic advance estimated over four environments was higher for total soluble sugar, while moderate values were observed for β -carotene content and petiole length. For all other traits including weight of root per plant, the genetic advance was very low. The root yield and root yield attributes like length of root, root diameter, harvest index, root index and total biomass registered lower heritability and lower genetic advance under selection. This shows influence of environment and G x E interaction in

expression of phenotypes. Thus the selection is possible only after selecting a particular environment where heritability values and genetic advance are higher for the characters under improvement. Accordingly, heritability and genetic advance were higher for weight of root in environment-II (E-II). Therefore, selection for higher weight of root will be fruitful under environment-II (E-II). Similarly, yield components like harvest index, root index and total biomass having higher heritability and higher expected genetic advance can be improved under environment-II (E-II). The weight of root per plant was highly and positively correlated with root index, plant top height, length of root and number of leaves per plant. Thus, four characters were turned out to be the principle component traits of weight of root. Strong and positive correlation coefficients for weight of root per plant with these traits indicated that the selection for any of these traits will simultaneously improve the yield, depending upon the magnitude of correlation (Table 4). The above results are in accordance with the finding of earlier workers for correlation of weight of root with length of root, plant top height Natarajan and Arumugam (1980) and Bhagchandani and Chaudhary (1980) weight of root with number of leaves per plant by Bhatia *et al.*, (2002) and Singh *et al.*, (2005). The weight of root was negatively correlated with root laterals, β -carotene content and total soluble sugar. Singh *et al.* (2005) noticed negative correlation of weight of root with total soluble sugar and β -carotene content. Thus, important characters positively correlated with weight of root per plant were number of leaves per plant, length of root, plant top height, root index and total biomass.

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Gujarat Dantiwada Vegetable Cowpea 2 (GDVC 2): A high yielding variety of cowpea

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ABSTRACT

At present, two varieties viz., Pusa phalguni and AVC-1 are under cultivation in Gujarat State. Both the varieties are non determinant and non synchronous types. Also, they are more prone to important diseases and pest. Hence, in order to provide suitable variety, attempts were made to develop high yielding, early maturing and synchronous vegetable cowpea variety with better nutritive quality at Centre for Research on Seed Spices, SDAU, Jagudan. More than 500 germplasm lines collected from Main Pulses Research Station, SDAU, S.K.Nagar were thoroughly screened for various yield contributing characters and desirable traits including pest and diseases at Centre for Research on Seed Spices, SDAU, Jagudan during *kharif* 2007 & 2008 seasons. Among them, most promising germplasms were further screened at two different locations viz., Jagudan and Ladol during the *kharif* 2009 and five different locations viz., Jagudan, Ladol, Anand, Navasari and Junagadh during the *kharif* 2010 to 2012 in large scale trial. On an average, variety JDNVC-74 produced 103.5 q/ha green pod against 72.9 and 83.4 q/ha of Pusa phalguni and AVC-1 check variety, respectively and out yielded both the check varieties in 17/17 tests. It also significantly out yielded the check varieties viz., Pusa phalguni and AVC-1 in 12/17 and 10/17 tests with 42.0 and 24.1 per cent higher pod yield, respectively, indicating superiority in yield over the year and locations. The yield potential of this variety is 151.5 q/ha which will enhance the productivity under varying environmental conditions. The analysis of nutritional and bio-chemical properties revealed that JDNVC-74 (GDVC-2) has high soluble protein (10.3 %), total soluble sugar (4.5 %) and less crude fiber (15.1 %) makes this variety more nutritive and palatable. This genotype is less prone to cowpea mosaic virus, root rot and leaf spot diseases and also exhibited the least pod borer damage as well

Key words : Cowpea, disease/pests reaction, pod quality, yield potentiality.

Cowpea [*Vigna unguiculata* (L.) Walp.], belongs to family "*Fabaceae*" locally known as lobiya, chowla (chowli) is an annual legume. It is diploid and has $2n = 22$ chromosomes. In India, the crop is grown on a small scale especially for the immature pods as vegetable, grains, fodder and green manure. Fresh green pods are rich in protein, vitamins & minerals. In Gujarat, Vegetable Cowpea is cultivated in about

27.6 thousand hectares with a total production of 290 thousand tones resulting in an average productivity is 10.49 MTha⁻¹. (Anon., 2012). It is grown almost in all the districts of Gujarat State but the major districts are Banaskantha, Kheda, Baroda, Junagadh, Amreli, Surat, Anand and Gandhinagar.

At present, two varieties viz., Pusa phalguni and AVC-1 are under cultivation. Both the presently cultivated varieties are semi spreading and none

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synchronous types. Also they are prone to important diseases and pest. The green pods colour of varieties viz., Pusa phalguni and AVC-1 are dark and light green, respectively. However, many consumers prefer pale green pods. In order to provide suitable variety to satisfy the consumer's preference, attempts were made to develop high yielding, early maturing, synchronous vegetable cowpea variety having pale green pod with more nutritive quality at CRSS, SDAU, Jagudan for identification of promising genotypes which are high yielding as well as better quality to the farmers. JDNVC-74 (GDVC-2) has been emerged as a high yielder variety after testing in field trials since 2007.

MATERIALS AND METHODS

Large number of germplasm accessions collected from Main Pulses Research Station, SDAU, S.K.Nagar were evaluated to develop high yielding, early maturing and synchronous vegetable cowpea variety with higher nutritive value in PET during *kharif* 2008 at Jagudan. Out of them, seven high yielding entries viz., JDNVC-39, JDNVC-41, JDNVC-58, JDNVC-62, JDNVC-74, JDNVC-75 and JDNVC-76 were further evaluated at Jagudan and Ladol during the *kharif* 2009 and at Jagudan, Ladol, Anand, Navasari and Junagadh during the *kharif* 2010 to 2012 in large scale varietal trial in a randomized block design with three replications. The data pertaining to various characters were analyzed as per the procedure of Randomized Block Design given by Panse and Sukhatme (1978) for individual environments. Soluble Protein was estimated by Folin-Lowry method as described by Lowry *et al.* (1951). Total Soluble Sugar was estimated by phenol-sulphuric acid method as described by Dubois *et al.* (1956). The water content (WC) of cowpea was determined using the equation:

$$WC = 100 \times (M_1 - M_2) / M_1$$

Where: WC = Water content, %;

M_1 = Mass of sample before drying, g

M_2 = Mass of sample after drying, g

RESULTS AND DISCUSSION

GDVC-2 (JDNVC-74) is one of the promising cultures selected during the evaluation of 500

germplasm lines collected from Main Pulses Research Station, SDAU, S.K.Nagar. Initially, it was named as CGD-335 (JDNVC-335) and renamed as JDNVC-74 during multilocal testing. During 2008 to 2012, it was tested in 17 trials at five different locations viz., Jagudan, Ladol, Anand, Navasari and Junagadh. On an average, variety JDNVC-74 produced 103.5 q/ha green pod against 72.9 and 83.4 q/ha of Pusa phalguni and AVC-1 check variety, respectively and out yielded both the check varieties in 17/17 tests. It also significantly out yielded the check varieties in 12/17 and 10/17 tests by producing 42.0 and 24.1 *per cent* higher pod yield, respectively, indicating superiority in yield over the year and locations. The yield potential of this variety is 151.5 q/ha (Table 1).

The green pods are tender and fleshy, having smooth surface, medium in size, straight and round shape and pale green in colour. It possesses more pod weight and number of pods per plant. High soluble protein (10.3 %), total soluble sugar (4.5 %) and less crude fiber (15.1 %) makes this variety more nutritive and palatable (Table 4).

The genotype JDNVC-74 has an erect plant growth habit with an average plant height of 54.0 (42.5 to 72.5) cm. The pods are pale green, fleshy, 14.8 (13.2 to 17.8) cm in length with 11 to 16 seeded. First picking of green pods may start on 43 day and continue up to 90 days after sowing. This genotype is less prone to cowpea mosaic virus, root rot and leaf spot diseases and also exhibited the least pod borer damage as well as sucking pests (Table 5).

CONCLUSION

Variety GDVC-2 (JDNVC-74), with high stable green pod yield as well as better green pod quality with erect growth habit, less prone to pest and diseases will provide very good replacement for Pusa phalguni and alternative to AVC-1 under varying environmental conditions in Gujarat state. The variety GDVC-2 (JDNVC-74) has been assigned national identity number (IC.No.596962) by Division of Germplasm Conservation, National Bureau of Plant Genetic Resources, ICAR, Pusa Campus, New Delhi.

Table 1 Comparative green pod yield performance of JDNVC-74 at individual location and mean over the locations.

Location	Name of experiment and year	Green pod yield (q/ha)			% increase over		C. D. (5 %)	C. V. %
		JDNVC -74	Pusa Phalguni	AVC -1	Pusa Phalguni	AVC -1		
Jagudan	PET -2008 (5)	77.7	48.7	56.4	59.5	37.8	NS	23.1
	LSVT -2009 (11)	151.2	129.7	143.0	16.6	5.7	27.2	10.0
	LSVT -2010 (12)	98.4	78.7	83.6	25.0	17.7	20.5	12.0
	LSVT -2011 (10)	135.5 ⁺⁺	90.8	95.7	49.2	41.6	18.5	8.7
	LSVT -2012 (10)	116.3 ⁺⁺	95.0	104.4	22.4	11.4	11.7	7.0
	Mean	115.8	88.6	96.6	30.7	19.9		
Ladol	LSVT -2009 (10)	151.5 ⁺⁺	78.4	115.5	93.2	31.2	20.7	9.9
	LSVT -2010 (10)	121.7 [*]	72.7	105.2	67.4	15.7	21.2	11.0
	LSVT -2011 (9)	124.7 ⁺⁺	90.0	104.0	38.6	19.9	16.4	8.5
	LSVT -2012 (9)	135.2 ⁺⁺	75.0	104.0	80.3	30.0	11.4	6.1
	Mean	133.3	79.0	107.2	68.7	24.3		
North Gujarat Region		122.8	84.8	84.8	100.8	44.8		
Anand	LSVT -2011 (4)	87.7 ⁺⁺	67.3	61.1	30.3	43.5	10.4	7.8
	LSVT -2012 (5)	72.9 ⁺⁺	51.5	60.5	41.4	20.5	11.3	10.4
	Mean	80.3	59.4	60.8	35.2	32.1		
Junagadh	LSVT -2010 (8)	73.7 ⁺⁺	44.7	54.4	64.9	35.5	12.4	13.8
	LSVT -2011 (10)	58.3 ⁺	52.3	47.6	11.5	22.5	9.4	10.0
	LSVT -2012 (4)	56.2 [*]	48.5	51.2	15.9	9.8	6.2	7.1
	Mean	62.7	48.5	51.1	29.3	22.7		
Navasari	LSVT -2010 (9)	73.7	64.8	47.0	13.7	56.8	NS	23.7
	LSVT -2011 (9)	140.6 [*]	109.8	128.1	28.1	9.8	21.3	9.4
	LSVT -2012 (5)	83.5 ⁺⁺	41.8	55.7	99.8	49.9	17.6	19.7
	Mean	99.3	72.1	76.9	37.7	29.1		
Over all Mean (17 trials)		103.5	72.9	72.9	83.4	42.0		
Superiority over check			17/17	17/17				

Note: ^{*} and ⁺ indicate that the proposed variety JDNVC-74 (GDVC-2) is significantly superior to the respective check Pusa phalguni and AVC-1 in green pod yield.

() indicates number of pickings in their respective trials.

Table 2 Green pod yield attributing characters

Sr.No	Character	JDNVC-74	Pusa Phalguni	AVC-1
1	Days to 50% flowering	42.0 (35.0 to 44.3)	40.6 (35.0 to 43.0)	45.1 (37.3 to 50.0)
2	Days to first picking	47.0 (43 to 50)	46.5 (45 to 48)	50.0 (48 to 52)
3	Days to last picking	83.0 (77 to 90)	81.5 (74 to 85)	86.0 (79 to 90)
4	Plant height (cm)	54.0 (42.5 to 72.5)	54.3 (47.3 to 57.3)	58.8 (50.3 to 78.5)
5	Primary branches /pl.	4.1 (3.1 to 5.7)	4.1 (2.7 to 5.7)	4.6 (3.5 to 5.2)
6	Leaf length,cm	9.1	9.7	10.2
7	Leaf width, cm	6.2	6.9	6.4
8	Pods per plant	53.0	56.0	49.0
9	Pod length (cm)	14.8 (13.2 to 17.8)	12.3 (12.2 to 14.5)	14.9 (14.2 to 17.5)
10	Seeds per pod	15 (10.8 to 16.1)	14 (12.0 to 16.4)	15 (11.7 to 16.5)
11	Cluster per plant	11.0	12.0	11.0
12	Length of peduncle	18.7	30.9	30.0
13	Pods per cluster	5.0	4.1	4.6
14	Green pod weight (g)	4.1 (3.0 to 4.9)	2.6 (2.4 to 4.0)	3.0 (2.4 to 3.2)
15	Green Pod yield(q/ha)	103.5 (56.2 to 154.2)	72.8 (41.8 to 129.7)	83.2 (47.0 to 143.0)

Table 3 Morphological descriptors of cowpea variety GDVC-2

Descriptors details	Name of Variety		
	JDNVC-74	Pusa Phalguni	AVC-1
Trifoliate Leaf			
Leaf Color	Light green	Dark green	Green
Leaf Surface	Rough	More rough	Semi rough
Pigmented spot at base of two leaf attachment	Absent	Absent	Absent
Plant Characters			
Plant growth habit	Erect	Dwarf with bushy	Bushy & compact
Branching habit	Erect	Semi spreading	Semi spreading
Stem & Peduncle (stout)	Strong	Weak	Strong
Flower colour			
Outer surface of corolla	Light Cream	Light Cream	Light Yellow
Inner surface of corolla	Bluish	Light Bluish	Light Cream
Calyx colour	Creamy	Brownish green	Green
Pods Characters			
Pod colour	Pale green	Dark green	Light green
Pod surface	Very Smooth	Slight Rough	Smooth
Pod constriction	No	Prominent	Slightly prominent
Pod Shape	Straight & round	Round flat	Slightly Flat
Green Seeds colour	Light green	Green	Light green
Pod colour at maturity	White	Light brown	White
Seed colour	White	Light cream	Light cream

Table 4 Quality characters of green pod

Sr. no.	Genotypes	Moisture (%)	Per cent content (on dry basis)		
			Soluble protein	Crude fiber	Total sugar
1	JDNVC-74	88.9	10.3	15.1	4.5
2	Pusa phalguni(c)	88.1	10.0	18.3	5.3
3	AVC-1(c)	88.4	11.1	13.8	3.5

Table 5 Reaction to diseases and pest

Disease/pest infection		JDNVC-74	Pusa phalguni	AVC-1
Disease	Mosaic Virus (%)	2.0	5.0	4.0
	Root Rot (%)	3.0	8.0	9.0
	Leaf spot (%)	4.0	8.0	7.0
Pests	Pod borer damage (%)	4.1	9.9	11.2
	Leaf Hopper/leaf	1.0	2.3	3.0
	Whitefly/leaf	0.8	2.0	2.2

Table 6 Agronomic packages of practices carried out

Sr. No	Details	Vegetable Cowpea
1	Period of sowing	Kharif season, July-August
2	Spacing distance (cm)	45 x 30 cm
3	Seed rate required (kg/ha)	12-15 kg/ha
4	Irrigation	As and when required
5	Fertilizer (N.P.K) kg/ha	20-40-00

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Effect of spray treatment of plant growth substances at different stages on growth and yield of sweet pepper (*Capsicum annuum* L.) cv. Indra under green house

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ABSTRACT

Study of different spray treatment of plant growth substances on sweet pepper was carried out under green house condition. The results revealed that among different spray treatment of plant growth substances, the maximum height of plant (30.15 cm) at 30 days after transplanting was found significant with spray of GA₃ 50 ppm (P₃). The minimum days taken for edible maturity was also superior with GA₃ 50 ppm. Whereas, the maximum number of branches (5.52) and minimum days taken for initiation of flower (48.50 days) was recorded with ethrel 100 ppm (P₇) treatment. The maximum fruit set (70.78 %) was recorded with spray of GA₃ 25 ppm (P₂). Regarding yield parameter, spray treatment of GA₃ 50 ppm (P₃) was superior with respect to average weight of fruit (96.58 g), yield/plant (1.84 kg) and yield/ha (244.65 q/ha). Among two stages of spray, S₂ (Spray at 20 days after transplanting) was recorded the maximum girth of stem at 30 days after transplanting (0.47 cm). Whereas, S₁ (Spray at 20 days after sowing) was recorded initiation of first flower (49.96 days). No any beneficial effect was recorded on yield parameters.

Key words : Sweet pepper, plant growth substances, stages of spray

The genus *Capsicum* belongs to family Solanaceae which is grown in several parts of the world. Sweet pepper is believed to be originated in Tropical South America. Sweet pepper (*Capsicum annuum* L.) also known as 'Shimla mirch' or 'bell pepper' or 'capsicum' is an important Solanaceous vegetable. It provides good levels of carbohydrates and are rich in vitamins A and C (Burt, 2005). The hormonal use in the plant system and their importance is the outstanding discovery and achievement of plant sciences. A number of techniques for application of growth substances have been tried on various vegetables.

MATERIALS AND METHODS

The experiment was carried out during the year 2011-12 in Naturally Ventilated Greenhouse of Department of Vegetable Science, College of

Horticulture, S. D. Agricultural University, Sardarkrushinagar. The experiment was laid out in Completely Randomized Design with Factorial concept. There were sixteen (16) treatment combinations comprised eight levels of plant growth substances viz., P₀ (Control), P₁ (Water spray), P₂ (GA₃ 25 ppm), P₃ (GA₃ 50 ppm), P₄ (NAA 20 ppm), P₅ (NAA 40 ppm), P₆ (Ethrel 50 ppm), P₇ (Ethrel 100 ppm) and two stages of spray viz., S₁ (spray at 20 days after sowing) and S₂ (spray at 20 days after transplanting). A number of observation viz., height of plant and girth of stem at 30, 60, 90 and 120 days after transplanting (cm), number of branches, days taken for first initiation of flower after transplanting, percentage fruit set per plant, days taken for flowering to edible maturity stages, days taken for first picking, total number of fruits per plant, average weight of fruit (g), yield of fruits per plant (kg), yield per hectare (q/ha) were recorded.

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RESULTS AND DISCUSSION

Effect on growth

In the present study, the height of sweet pepper plant has been found to increase with the advancement of development stages. It is clearly seen from the data that there was an increase in the height of plant due to application of GA₃ @ 50 ppm. This increase in plant height is due to its effect on stem elongation by rapid cell elongation and multiplication of cells in sub-apical meristem. The rapid growth that occurs is a result of both the greater number of cells formed and elongation of individual cells. The increase in plant height by GA₃ application has also been reported by Patel (1998), Naruka and Paliwal (1999), Sorte *et al.*, (2001) in brinjal, Kore, *et al.*, (2003) in bottle gourd and Natesh *et al.*, (2005) in chilli and the highest number of branches (5.52) was observed due to application of ethrel. The above results were

in consonance with those of Das and Das (1996) in pumpkin, Bharadwaj *et al.*, (1998) in capsicum, Dixit *et al.*, (2001) in watermelon, Girde *et al.*, (2006) in sponge gourd and Hilli, *et al.*, (2010) in ridge gourd.

Effect on flowering and fruit setting

The first initiation of flower was found due to the application of ethrel. The above results were in agreement with those of Krishnappa, (2002) in tomato, Kooner *et al.*, (2000) in bottle gourd and Dixit *et al.*, (2001) in watermelon and the maximum per cent of fruit setting (70 %) was recorded with the application of GA₃. Whereas, minimum fruit setting (39.44%) was recorded in control. Similar finding have also been obtained by Irulappan and Muthukrishnan (1974) in tomato, Chattopadhyay and Sen (1974) in chilli, Nair *et al.*, (1974) in tomato, Sorte *et al.*, (2001) in okra and Natesh *et al.*, (2005) in chilli.

Table 1 Effect of spray treatment of plant growth substances at different stages on height of plant, girth thickness of stem, number of branches and days taken for initiation of first flower.

Treatments	Height of plant at 30 DAT (cm)	Girth of stem at 30 DAT (cm)	Number of branches	First initiation flowering
Plant growth substances(P)				
P ₀ - Control (No spray)	28.17	0.47	4.33	49.00
P ₁ - Water spray	28.03	0.47	3.67	48.56
P ₂ - GA 3-25 ppm	29.08	0.44	4.87	52.83
P ₃ - GA 3-50 ppm	30.15	0.46	4.28	56.61
P ₄ - NAA - 20 ppm	20.89	0.42	4.33	54.06
P ₅ - NAA - 40 ppm	21.72	0.46	4.11	55.04
P ₆ - Ethrel - 50 ppm	28.87	0.48	5.21	48.50
P ₇ - Ethrel - 100 ppm	26.57	0.46	5.52	48.50
S.E.m. ±	1.69	0.02	0.21	1.22
C.D. at 5%	4.88	NS	0.60	3.52
Stages of spray(S)				
S ₁ -At Seedling stage (20 days after seed sowing)	26.56	0.44	4.50	49.96
S ₂ -After transplanting (20 days after transplanting)	26.81	0.47	4.58	53.32
S.E.m. ±	0.85	0.01	0.10	0.61
C.D. at 5%	NS	0.03	NS	1.76
Interaction (P X S)				
S.E.m. ±	2.39	0.03	0.30	1.73
C.D. at 5%	NS	NS	NS	4.98
C.V.%	15.53	9.62	11.28	5.79

Table 2 Effect of spray treatment of plant growth substances at different stages on per cent fruit set, days taken for flowering to edible maturity and days taken for first picking.

Treatments	Fruit set per plant (%)	Days taken for flowering to edible maturity	Days taken for first picking
Plant growth substances (P)			
P ₀ - Control (No spray)	39.44	38.72	87.72
P ₁ - Water spray	41.67	33.17	82.22
P ₂ - GA ₃ -25 ppm	70.78	27.94	80.61
P ₃ - GA ₃ -50 ppm	60.89	26.55	82.94
P ₄ - NAA -2 ppm	61.95	36.94	90.89
P ₅ - NAA -40 ppm	62.83	36.67	91.44
P ₆ - Ethrel -5 ppm	60.28	37.28	85.61
P ₇ - Ethrel -100 ppm	58.06	35.77	84.27
S.E.m. $\pm$	4.61	1.83	2.23
C.D. at 5%	13.27	5.27	6.43
Stages of spray (S)			
S ₁ -At Seedling stage (20 days after seed sowing)	56.40	34.35	84.26
S ₂ -After transplanting (20 days after transplanting)	57.57	33.91	87.16
S.E.m. $\pm$	2.30	0.91	1.12
C.D. at 5%	NS	NS	NS
Interaction (P X S)			
S.E.m. $\pm$	6.52	2.58	3.16
C.D. at 5%	NS	7.45	9.10
C.V.%	19.80	13.11	6.38

The earlier edible maturity (26.55 days) was obtained by application of GA₃. Similar beneficial effect of growth substances has been reported by Dixit *et al.*, (2001) in watermelon, Bisaria and Bhatnagar (1978) in brinjal. Whereas, the effect of plant growth substances was found significant on earlier picking. The earlier picking of fruits was increased due to application of plant growth substances like GA₃. Similar finding have also been obtained by Natesh *et al.*, (2005) in chilli.

fruit (96.58 g), yield of fruit per plant (1.83 kg) and yield per hectare (244.64 q/ha) was obtained in GA₃ 50 ppm treatment. An increase in average fruit weight treated plants may further attributed to the reason that plants remain physiologically more active to build up sufficient food stock for the developing flowers and fruits. The above results were in agreement with Nimje *et al.*, (1990), Kumar and Ray (2000) in cauliflower, El-Helaly (2009) in potato, Naruka and Paliwal (1999) and Kore *et al.*, (2003) in okra.

Effect on yield attributes and yield

The maximum yield attributes viz. average weight of

Table 3 Effect of spray treatment of plant growth substances at different stages on total number of fruits per plant, average weight of fruit (g), yield of fruits per plant (kg) and yield per hectare (q/ha).

Treatments	Total No. of fruits/ plant	Average wt. of fruit (g)	Yield of fruits/ plant (kg)	Yield / hectare (q/ha)
Plant growth substances(P)				
P ₀ - Control (No spray)	10.10	71.96	0.68	90.86
P ₁ - Water spray	10.78	77.75	0.61	81.02
P ₂ - GA ₃ - 25 ppm	15.05	88.82	0.71	94.56
P ₃ - GA ₃ - 50 ppm	10.61	96.58	1.83	244.64
P ₄ - NAA - 20 ppm	11.34	90.63	0.56	74.56
P ₅ - NAA - 40 ppm	12.00	84.18	0.85	113.71
P ₆ - Ethrel - 50 ppm	11.61	88.63	0.76	101.23
P ₇ - Ethrel - 100 ppm	11.22	93.00	0.66	88.16
S.E.m. $\pm$	1.10	4.80	0.06	8.04
C.D. at 5%	NS	13.83	0.17	23.17
Stages of spray(S)				
S ₁ - At Seedlingstag (20 days after seed sowing)	12.57	85.79	0.84	112.18
S ₂ - After transplanting (20 days after transplanting)	10.83	87.10	0.83	110.00
S.E.m. $\pm$	0.55	2.40	0.03	4.02
C.D. at 5%	1.59	NS	NS	NS
Interaction (P X S)				
S.E.m. $\pm$	1.56	6.78	0.09	11.37
C.D. at 5%	NS	NS	0.25	32.77
C.V.%	23.10	13.60	17.69	17.73

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Management of pearl millet rust through fungicides under artificially created epiphytotic conditions

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ABSTRACT

Six fungicides were tested *in vivo* against pearl millet rust (*Puccinia substriata* var. *indica*) at Pearl Millet Research Station, J. A. U. Jamnagar during 2007 to 2009 under artificial inoculated condition on pearl millet variety GHB 715. The fungicides mancozeb 0.2 per cent and difenoconazole 0.0125 per cent were proved the most effective with respect to disease control and they offered 62.62 and 61.29 per cent disease control, respectively. The maximum grain yield per cent was increased in the treatment difenoconazole (33.83 %) followed by mancozeb (31.31 %), hexaconazole (16.49 %) and propiconazole (12.09 %) in comparison to check. The maximum per cent fodder yield increase over control was also followed the same trend as difenconazole (39.00 %), mancozeb (35.55 %), hexaconazole (23.49 %) and propiconazole (20.73 %). The highest grain and fodder yield was recorded in the treatment difenoconazole 2069 kg/ha and 3621 kg/ha followed by mancozeb 2030 kg/ha and 3531 kg/ha, respectively. Maximum net return was obtained with two sprays of hexaconazole 0.005 per cent (1:4.37) followed by mancozeb 0.2 per cent (1:4.22) and difenoconazole 0.0125 per cent (1:3.79).

Key words : Pearl millet, rust, artificial inoculation, fungicides.

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the world's sixth and India's fourth most important cereal food crop. The pearl millet grain contains 8.42 - 14.49 per cent protein and it has good amount of iron and zinc. Pearl millet is being grown in plane as well as costal areas during kharif, rabi and summer seasons in Gujarat. This crop is affected by many diseases; viz., downy mildew, smut, rust, blast and ergot. Rust has been reported from many countries of Asia, Africa and also from the United States and Brazil (Sing and King, 1991). As the rust disease has been considered as a minor till recently, very limited work has been done on this disease and management. Worldwide, this disease is greater importance on multicut forage hybrids where even low rust

severities can result in substantial losses of digestible dry matter yield (Wilson *et al.*, 1991). In India, the disease has become prevalent due to several factors such as wide spread cultivation of high yielding and rust susceptible cultivars, large scale seed production during summer season and overlapping of cultivation in Gujarat and Tamilnadu (Hash *et al.*, 1999). Therefore, there is a need to evolve better disease management technology through chemical management approach.

MATERIALS AND METHODS

The fungicides were evaluated by creating artificial inoculated condition in the field at Pearl Millet Research Station, J. A. U. Jamnagar during semi-rabi seasons from 2007 to 2009 on variety GHB 715. To maintain the congenial condition for disease development approximately 5×10^5 uredospores per

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ml of water were sprayed with the help of sprayer in experimental plots. The uredospores inoculum were sprayed twice at five day intervals after 15 days of germination. The uredinia bearing leaves were also spread among each treatment after 30 days of germination. The crop was regularly irrigated to maintain high humid condition.

A total numbers of six fungicides were tested under field conditions. The experiment was conducted in randomized block design. The gross and net plot size was 5.0 x 3.60 m and 4.0 x 2.40 m, respectively. The inter and intra row spacing was maintained at 60 cm x 10 cm. Recommended agronomic practices were followed for all the treatments. The two sprayings of each fungicide was carried out at onset (vegetative and flowering stage *i.e.*, 35 and 50 days) of disease at 15 days intervals as below.

T₁ - Hexaconazole 5%EC0.005 %

T₂ - Difenconazole 25 % EC 0.0125 %

T₃ - Propiconazole 25 EC0.025%

T₄ - Tridemorph 80%EC 0.04 %

T₅ - Mancozeb 75 % WP 0.2%

T₆ - Iprodione 25 % + Carbedazim 25 %
(50 % WP) 0.05%

T₇ - Control (Check)

The intensity of disease was recorded from ten randomly selected plants in each treatment as per modified Cobb scale 0-6 (8) after 15 days of second spray. The grain and fodder yield were also recorded (kg per net plot) and converted to per hectare basis. The statistical analysis was carried out using standard method.

Modified Cobb scale (8).

0 = No disease.

1 = Five per cent leaf area infected.

2 = Ten per cent leaf area infected.

3 = Twenty five per cent leaf area infected.

4 = Forty per cent leaf area infected.

5 = Sixty five per cent leaf area infected.

6 = Hundred per cent leaf area infected.

The per cent disease intensity (PDI) in each treatment was worked out by using the following formula.

$$\text{PDI} = \frac{\text{Sum of the total rating}}{\text{Total plants observed}} \times \frac{100}{\text{Maximum disease rating}}$$

The percentage disease control and percentage

deviation in yield was calculated with the help of the following formula.

$$\text{Per cent disease control} = \frac{\text{PDI in check} - \text{PDI in treatment}}{\text{PDI in check}} \times 100$$

$$\text{Per cent increase in yield} = \frac{\text{Yield in treatment} - \text{Yield in check}}{\text{Yield in check}} \times 100$$

RESULTS AND DISCUSSION

Rust intensity

The results for management of rust disease were significant in all the years. The minimum rust intensity was recorded in the treatment of mancozeb 0.2 followed by difenoconazole 0.0125 and hexaconazole 0.005 per cent as compared to the check and remaining treatment during individual season of *rabi* 2007, 2008 and 2009. The pooled analysis of fungicidal control revealed that mean disease intensity was statistically significant (Table1). The pooled data on disease intensity indicated that all the treatment were statistically significant over check. The lowest disease intensity was observed with mancozeb 0.2 per cent (27.36 %) followed by difenoconazole 0.0125 per cent, hexaconazole 0.005, propiconazole 0.025, tridemorph 0.04, per cent and iprodione 25 per cent + carbedazim 25 per cent (50 % WP) 0.05; they reported 28.33, 34.86, 38.89, 46.94 and 48.19 per cent, respectively. The highest disease control (62.62 %) was achieved under the treatment of mancozeb 0.2 per cent followed by difenoconazole 0.0125, hexaconazole 0.005 and propiconazole 0.025 per cent. These treatments gave 61.29, 52.37 and 46.86 per cent disease control, respectively.

Grain and fodder yield

The maximum grain and fodder yield were recorded in the treatment of difenoconazole 0.0125 followed by mancozeb 0.2 and hexaconazole 0.005 per cent as compared to the check during individual season *rabi* 2007, 2008 and 2009. The pooled analysis of fungicidal control revealed that grain yield and fodder yield were statistically significant (Table 2). The pooled results on grain yield indicated that

Table 1 Effect of different fungicide sprays on rust disease intensity

Treatment	Mean disease intensity (%)				% disease control
	2007	2008	2009	Pooled	
Hexaconazole 5%EC0.005 %	35.49 (33.75)*	35.24 (33.33)	37.75 (37.50)	36.16 (34.86)	52.37
Difenoconazole 25 % EC 0.0125 %	31.59 (27.50)	34.48 (32.08)	30.24 (25.42)	32.10 (28.33)	61.29
Propiconazole 25 EC0.025%	38.97 (39.58)	37.24 (36.66)	39.46 (40.42)	38.56 (38.89)	46.86
Tridemorph 80%EC 0.04 %	42.35 (45.42)	45.47 (50.83)	41.88 (44.58)	43.23 (46.94)	35.87
Mancozeb 75 % WP 0.2%	30.21 (25.42)	34.23 (31.67)	29.95 (25.00)	31.46 (27.36)	62.62
Iprodione 25 % + Carbedazim 25 % (50 % WP) 0.05%	43.07 (46.67)	43.79 (47.92)	44.99 (50.00)	43.95 (48.19)	34.16
Control (Check)	59.19 (73.75)	62.85 (79.17)	54.76 (66.67)	58.93 (73.19)	-
S.Em. $\pm$ Treatment	1.13	0.82	0.91	1.21	-
S.Em. $\pm$ Year x Treat.	-	-	-	0.96	-
C. D. at 5 % Treatment	3.34	2.44	2.70	3.72	-
C. D. at 5 % Year x Treat.	-	-	-	2.73	-
C. V. %	5.61	3.93	4.56	4.73	-

* Data given in parenthesis are retransformed value.

Table 2 Effect of different fungicide sprays on grain yield

Treatment	Grain yield (kg/ha)				Yield increase (%)
	2007	2008	2009	Pooled	
Hexaconazole 5%EC0.005 %	1745	1648	2010	1801	16.49
Difenoconazole 25 % EC 0.0125 %	2083	1844	2279	2069	33.83
Propiconazole 25 EC0.025%	1716	1589	1896	1733	12.09
Tridemorph80%EC 0.04 %	1568	1497	1878	1648	6.60
Mancozeb 75 % WP 0.2%	2018	1815	2255	2030	31.31
Iprodione 25 % +Carbedazim 25 % (50 % WP) 0.05%	1638	1560	1815	1671	8.09
Control (Check)	1505	1404	1729	1546	-
S.Em. $\pm$ Treatment	91.941	78.26	114.52	51.29	-
S.Em. $\pm$ Year x Treat.	-	-	-	96.07	-
C. D. at 5 % Treatment	273	233	340	145	-
C. D. at 5 % Year x Treat.	-	-	-	NS	-
C. V. %	10.49	9.65	11.57	10.76	-

maximum grain yield was obtained in the treatment of difenoconazole 0.0125 per cent (2069 kg/ha) followed by mancozeb 0.2 per cent (2030 kg/ha). These treatments were at par with each other and statistically superior over rest of the treatments. The treatments, hexaconazole, propiconazole, iprodione 25 per cent + carbedazim 25 per cent (50 % WP) and tridemorph were remained at par with each other except hexaconazole with tridemorph.

The maximum per cent grain yield increase was found in the treatment difenoconazole 0.0125 per cent (33.83 %) followed by mancozeb 0.2 per cent (31.31 %). The remaining treatments hexaconazole 0.005, propiconazole 0.025, and iprodione 25 per cent + carbedazim 25 per cent (50 % WP) 0.05 and tridemorph 0.04, per cent, gave 16.49, 12.09, 8.09 and 6.60 per cent yield increase, respectively as compared to the check (Table 2).

The pooled data on fodder yield indicated that all the treatments were found significant over check. Maximum fodder yield observed under the treatment difenoconazole 0.0125 per cent followed by mancozeb 0.2, hexaconazole 0.005 and propiconazole 0.025 per cent, they reported 3621, 3531, 3217 and 3145 kg/ha, respectively (Table 3). The maximum fodder yield increase over control with the treatment difenoconazole (39.00 %) followed by mancozeb (35.55 %), hexaconazole (23.49 %) and propiconazole (20.73 %).

Overall, it can be concluded that spraying of either difenoconazole, mancozeb or hexaconazole reduced the disease intensity and increased the grain and fodder yield of pearl millet. These findings are in agreement with many research workers who have used different chemicals fungicides for rust disease control. Kapooria (1972) reported that Cupramar,

Table 3 Effect of different fungicide sprays on fodder yield

Treatment	Fodder yield (kg/ha)				Yield increase (%)
	2007	2008	2009	Pooled	
Hexaconazole 5%EC0.005 %	3440	2927	3284	3217	23.49
Difenoconazole 25 % EC 0.0125 %	3883	3195	3784	3621	39.00
Propiconazole 25 EC0.025%	3279	2930	3227	3145	20.73
Tridemorph 80%EC 0.04 %	2927	2536	3206	2890	10.94
Mancozeb 75 % WP 0.2%	3693	3169	3732	3531	35.55
Iprodione 25 % + Carbedazim 25 % (50 % WP) 0.05%	2977	2919	3151	3016	15.78
Control (Check)	2708	2312	2794	2605	-
S.Em. $\pm$ Treatment	176.404	153.989	170.99	92.409	-
S.Em. $\pm$ Year x Treat.	-	-	-	167.40	-
C. D. at 5 % Treatment	524.141	457.542	508.053	261.110	-
C. D. at 5 % Year x Treat.	-	-	-	NS	-
C. V. %	10.78	10.78	10.33	10.64	-

Ceresan, Dithane M-22, Dithane S-31 and o-phenanthroline at 100 ppm, spray before and at the time of inoculation, reduced the pearl millet rust incidence. Sharma and Sharma (1976) and Sokhi *et al.* (1978) they found that fungicide Dithane M-45 reduced the rust intensity thereby increasing grain yield of *bajra*. Muthusamy and Ragupathy (1980) noted that highest yield of pearl millet grain was obtained with two sprays of copper oxychloride followed by one spray of Bayleton and Bayleton dry seed treatment. Lukose *et al.* (1992) reported the maximum grain yield (1600 kg/ha) and fodder yield (3793 kg/ha) with minimum rust intensity (34.05 %) in foliar application of mancozeb followed by zineb in pearl millet. Similarly, Ahmed *et al.* (1993) noted that fungicides propiconazole, butrizol, tridemefon and mancozeb reduced the severity of leaf rust caused by *Puccinia recondita* and increased grain yield/plant and 1000 grain weight.

Jadeja *et al.* (1999) reported that trizole fungicides difenoconazole, propiconazole and hexaconazole reduced both rust and leaf spot disease of groundnut, while carbendazim was effective against leaf spot and mancozeb against rust. Tirmali and Pawar (2000) reported that the Dithane M 45 was the most effective as it resulted in the highest per cent disease control (47.77 %) and the lowest rust disease intensity (39.99 %) in groundnut. This treatment also gave the highest pod yield (24.09 q/ha) and per cent increase in yield over control (70.61 %). Gopal *et al.* (2003) reported that difenoconazole (0.1 %) treatment resulted in the highest mean yield (2150 kg/ha) followed by carbendazim (0.05 %) + tridemorph (0.1 %) treatment (2090 kg/ha) in controlling late leaf spot and rust of groundnut cultivar JL-24. Gururaj Sunkud *et al.* (2005) noted that the maximum disease control with higher dry pod and fodder yield was obtained with hexaconazole, difenoconazole and propiconazole treatments for the control of leaf spots and rust of groundnut. They also noted that mancozeb gave better control of rust.

Economics

The economics of various fungicides (Table 4) for control of pearl millet rust indicated that the highest

Table 4 Economics of various fungicides for controlling rust of pearl millet

Treatment /Concentration	Required quantity of fungicides ml or g/l	Rate (₹) Kg/L	Total cost of fungicides (₹)	Labour Charges/ha spray	Total expenditure	Grain yield kg/ha	Fodder yield kg/ha	Total income	Income increased over control	ICBR
Hexaconazole 5% EC 0.005 %	1.00	450	472.50	250	722.50	1801	3217	21227	3162	1:4.37
Difenoconazole 25 % EC 0.0125 %	0.50	2660	1396.50	250	1646.50	2069	3621	24311	6246	1:3.79
Propiconazole 25 % EC 0.025%	1.00	1250	1312.50	250	1562.50	1733	3145	20475	2410	1:1.54
tridemorph 80 % EC 0.04 %	0.50	1200	630.00	250	880.00	1648	2890	19370	1305	1:1.48
Mancozeb 75 % WP 0.2 %	2.66	400	1117.20	250	1367.20	2030	3531	23831	5766	1:4.22
Iprodione 25 % + Carbendazim 25 % (50 % WP) 0.05%	1.00	1200	1260.00	250	1510.00	1671	3016	19726	1661	1:1.10
Control	-	-	-	-	-	1546	2605	18065	-	-
Price of bajra grain ₹ 1000/100 kg, Price of bajra Fodder ₹ 100/100 kg, Labour Charges (₹ 250 /ha) Water requirement for 1 st spray 400 l/ha, Water requirement for 2 nd spray 650 l/ha										

total income of Rs. 24311/- followed by 23831/- and 21227/- were obtained in the treatments of difenoconazole, mancozeb and hexaconazole, respectively. However, the highest incremental cost benefit ratio (ICBR) was recorded in two sprays of hexaconazole 0.005 per cent (1:4.37) followed by mancozeb 0.2 per cent (1:4.22) and difenoconazole 0.0125 per cent (1:3.79).

CONCLUSION

It was observed that mancozeb and difenoconazole gave better control of rust disease with higher grain and fodder yield. It can be concluded that spraying of either mancozeb or difenoconazole gave better yield of pearl millet than control.

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Preharvest forecasting of castor yield on the basis of weather variables in Banaskantha district of Gujarat

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ABSTRACT

To suggest most suitable pre-harvest forecasting model for Banaskantha district of Gujarat state. The weather data for past 27 years (1982-83 to 2008-09) viz., weekly average of maximum and minimum temperature, morning and evening relative humidity, bright sunshine hours/day and weekly total rainfall (mm) from 32nd to 52nd meteorological standard weeks, MSW were collected from the Agro-Meteorological Observatory, Agronomy Instruction Farm, S. D. Agricultural University, Sardarkrushinagar. The time trend was also included as independent variable. The data on average castor yield (dependent variable) of Banaskantha district were obtained from the Directorate of Agriculture, Gujarat state, Gandhinagar. The step-wise regression procedure was employed by using 23 years data. The prediction equations and forecast of subsequent years were obtained separately for 21 to 23 years data set. The positive and significant effect of the time trend and beneficial effect of weekly total rainfall were observed. The correlation coefficient as weight approach was found superior compared to other approaches. This approach provided suitable pre-harvest forecasting model predicting yield 12 weeks before actual harvest and explained more than 94 % variation in castor yield. The deviations between the predicted and actual yields ranged from -19.85 % to 12.32 %.

Key words: Forecast, weather variables, castor yield, multiple linear regression.

Castor [*Ricinus communis* (L.)] is an important non-edible oil seed crop of arid and semi-arid regions of India. The crop has wide adaptability and grown in tropical, sub-tropical and temperate regions of the world. India being the largest castor producer in the world produced 11.90 lakh tonnes from an area of 8.59 lakh hectares with a productivity of 1385 Kg/ha during 2010-11. (Anonymous 2011). Weather is a major factor affecting crop production in India. The importance of timely and reliable forecast of area and yield of major crops need not be over-emphasized for the country like India where, the economy is mainly based on agricultural production. The pre-harvest estimates of crop yields are considered mainly as an aid to conjecture the final

production and therefore, sufficient attention needs to be paid towards their improvement. Pre-harvest yield forecast is one of the important tools in taking policy decisions with greater confidence in matters relating to price, export-import and for exercising several administrative measures for storage and marketing of agricultural commodities. Plenty of literature on yield forecasting of different crops is available but, such information is very scanty for castor crop, being largely grown in Gujarat, where castor seed and castor oil are economically important products. Therefore, an attempt was made to quantify the effect of weather parameters and technological advancement on castor crop for Banaskantha district of Gujarat state. Sizeable literature is available wherein authors have used either biometrical variables (Jha *et al.*, 1981) or weather variables (Khistoria *et al.*, 2004 and Malik

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et al., 2000) in pre-harvest yield forecasting of various crops. But, Kokate *et al.* (2000) used jointly both biometrical and weather variables for rice yield forecasting at Dapoli, Maharashtra.

MATERIALS AND METHODS

In present study an attempt has been made to formulate a relationship for predicting the castor yield (Y) by investigating the influences of important weather variables viz., maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, bright sunshine hours and rainfall (X_i 's) on the castor crop. To estimate the effect of weather variables with technological advances, 27 years yield data from 1982-83 to 2008-09 were collected from Annual Season and Crop Reports of respective years, published by Directorate of Agriculture, Gujarat state, Gandhinagar (Anonymous 1982-2009). Due to technological advancement, the time trend (T) was considered as one of the independent variable in the study. The weekly averages of weather variables viz., maximum temperature (X_1), minimum temperature (X_2), morning relative humidity (X_3), evening relative humidity (X_4), bright sunshine hours (X_5) and rainfall (X_6) from 32nd to 52nd meteorological standard week (MSW) of the respective year were collected from the Agro-Meteorological Observatory, Agronomy Instruction Farm, S. D. Agricultural University, Sardarkrushinagar. Following three different approaches (models) (Agarwal *et al.*, 1980) were studied.

Standard week-wise approach

$$Y = A_0 + \sum_{i=1}^p \sum_{j=1}^w a_{ij} X_{ij} + b T \quad (i)$$

Where,

Y = Average castor yield of Banaskantha district (kg/ha)

A_0 = Constant

X_{ij} = Observed value of i^{th} weather variable in j^{th} week, $i = 1, 2, \dots, p = 6$ and $j = 1, 2, \dots, w = 17, 18, 19, 20$ and 21

T = Year number included to correct the long term upward or downward trend in castor yield (T = 1 to 21)

a_{ij} and b are partial regression coefficients associated with each X_{ij} and time trend respectively.

By taking week number as weight :

$$Y = A_0 + \sum_{i=1}^p \sum_{j=0}^2 a_{ij} Z_{ij} + \sum_{i=1}^p \sum_{j=0}^2 b_{ii'j} \cdot Q_{ii'j} + cT \quad (ii)$$

Where,

Y = Average castor yield of Banaskantha district (kg/ha)

A_0 = Constant

T = Year number included to correct the long term upward or downward trend in castor yield

p = No. of weather variables ($p=1, 2, \dots, 6$)

a_{ij} , $b_{ii'j}$ and c are partial regression coefficients associated with each Z_{ij} , $Q_{ii'j}$ and time trend respectively ($ii' = 1, 2, \dots, p$ and $j=0, 1, 2$)

Z_{ij} and $Q_{ii'j}$ are generated as first and second order variables defined as under,

$$Z_{ij} = \frac{\sum_{w=1}^n w^j \cdot X_{iw}}{\sum_{w=1}^n w^j} \quad \text{and} \quad Q_{ii'j} = \frac{\sum_{w=1}^n w^j \cdot X_{iw} \cdot X_{i'w}}{\sum_{w=1}^n w^j}$$

n = number of weeks up to the time of forecast

w = week identification ($w=1, 2, \dots, n=17, 18, 19, 20$ and 21)

X_{iw} = value of the i^{th} weather variable in w^{th} week ($i \neq i' = 1, 2, \dots, 6$ and $j=0, 1, 2$)

By taking correlation coefficient as weight

$$Y = A_0 + \sum_{i=1}^p \sum_{j=0}^2 a_{ij} Z'_{ij} + \sum_{i=1}^p \sum_{j=0}^2 b_{ii'j} \cdot Q'_{ii'j} + cT \quad (iii)$$

Where,

Y = Average castor yield of Banaskantha district (kg/ha)

A_0 = Constant

a_i , b_{ij} and c are partial regression coefficients associated with each Z'_{ij} , Q'_{ij} and time trend respectively. ($i' = 1, 2, \dots, p$ and $j = 0, 1, 2$)

T = Year number included to correct for the long term upward or downward trend in castor yield

p = No. of weather variables ($p=1, 2, \dots, 6$)

Z'_{ij} and Q'_{ij} are generated first and second order variables defined as under,

$$Z'_{ij} = \frac{\sum_{w=1}^n r_{iw}^j \cdot X_{iw}}{\sum_{w=1}^n r_{iw}^j} \text{ and } Q'_{ij} = \frac{\sum_{w=1}^n r_{ii'w}^j \cdot X_{iw} \cdot X_{i'w}}{\sum_{w=1}^n r_{ii'w}^j}$$

n = number of weeks up to the time of forecast

w = week identification ($w=1, 2, \dots, n=17, 18, 19, 20$ and 21)

X_{iw} = value of the i^{th} weather variable in the w^{th} week ($i \neq i' = 1, 2, \dots, p$ and $j=0, 1, 2$)

r_{iw} = correlation coefficient of yield with the i^{th} weather variable in the w^{th} week

$r_{ii'w}$ = correlation coefficient of yield with the product of the i^{th} and i'^{th} weather variable in the w^{th} week.

Using these approaches the forecast models were fitted based on step wise regression technique (Draper and Smith, 1966) and simulated forecast errors were worked out for the subsequent years which were not included in fitting the model. The variables included in the models corresponding to the three periods (1982-83 to 2002-03, 1982-83 to 2003-04 and 1982-83 to 2004-05) differed. Thus, a common model for all the three periods was fitted using multiple regression approach. This model included all those independent variables, which appeared in one or the other models corresponding to three periods.

RESULTS AND DISCUSSION

Week-wise approach

The values of standard error (S. E.), coefficient of determination (R^2) and deviation from average yields are summarized in Table 1. The 17 weeks crop

period model revealed that S. E. ranged from 218 to 232. The variables explained 76.2 to 76.9 per cent variation in the yield of castor crop. The simulated forecast obtained from regression equation showed -17.31 to 12.48 per cent deviations from observed yields. The 18 weeks crop period model revealed that 5 variables explained 81.8 to 83.6 per cent variation in the yield of castor crop. The simulated forecast obtained from model ranged from -38.87 to 17.30 per cent deviations from observed yields. Standard error ranged from 189 to 195. The 19 weeks crop period model revealed that S. E. ranged from 124 to 132. The variables explained around 93 per cent variation in the yield of castor crop. The simulated forecast obtained from regression equation showed -39.01 to 17.79 per cent deviations from observed yields.

The 20 weeks crop period model revealed that 7 variables explained 80 to 82 per cent variation in the yield of castor crop. The simulated forecast obtained from model ranged from -56.26 to 15.44 per cent deviations from observed yields. Standard error was ranged from 209 to 215. The 21 weeks crop period model revealed that S. E. ranged from 123 to 132. The variables explained around 94 per cent variation in the yield of castor crop. The simulated forecast obtained from regression equation showed -32.11 to 12.98 per cent deviations from observed yields. Among the models fitted under this approach, in models of 17, 18 and 20 weeks crop period R^2 was low (76.20 to 83.60 %) and deviations of simulated forecasts was ranging from -56.26 % to 17.30 %. While in case of 19 and 21 weeks crop period, R^2 was high (around 94 %), minimum standard error of estimate and deviations of simulated forecasts ranged from -39.01 % to 14.79 %, but for early forecast (11 weeks before harvest) the 19 weeks of 22 years (model-II) was found suitable for forecasting castor yield under this approach.

Week number as weight approach

In this approach, generated weather variables (week number as weight) were used. The values of S. E., R^2 and deviation from average yields are presented in Table 2. The 17, 18, 19, 20, and 21 weeks crop period models revealed that variation

Table 1 Variables selected, coefficient of determination and range of forecast errors in week-wise approach

Variables selected		R ² and simulated forecast errors (%)		
		1982-83 to 2002-03 (Model I)	1982-83 to 2003-04 (Model-II)	1982-83 to 2004-05 (Model-III)
(I) 17 weeks model X ₂₀₄ , X ₂₁₅ , X ₃₁₄ , X ₅₀₅ , X ₅₀₈ and X ₅₁₀	R ²	76.20	76.90	76.90
	S.E.	232.20	225.49	218.35
	% deviation	-17.31 to 11.41	-16.53 to 12.48	-16.35 to 12.47
(II) 18 weeks model X ₃₁₄ , X ₄₁₇ , X ₅₀₅ , X ₅₁₀ and X ₆₁₀	R ²	83.10	83.60	81.80
	S.E.	195.76	189.90	193.91
	% deviation	-38.87 to 13.10	-36.41 to 15.05	-33.66 to 17.30
(III) 19 weeks model X ₃₁₄ , X ₄₁₈ , X ₅₀₂ , X ₅₀₅ , X ₅₀₉ , X ₅₁₀ and X ₆₁₀	R ²	93.40	93.50	93.40
	S.E.	132.07	128.26	124.60
	% deviation	-39.01 to 12.36	-37.35 to 13.72	-36.45 to 17.79
(IV) 20 weeks model X ₃₁₄ , X ₅₀₅ , X ₅₀₈ , X ₅₁₀ , X ₅₁₈ , X ₆₁₀ and X ₆₁₅	R ²	82.40	82.70	80.30
	S.E.	215.72	209.43	215.34
	% deviation	-56.26 to 8.28	-53.22 to 10.89	-48.58 to 15.44
(V) 21 weeks model X ₃₁₄ , X ₄₁₈ , X ₅₀₂ , X ₅₀₅ , X ₅₀₉ , X ₅₁₀ , X ₅₁₇ and X ₆₁₀	R ²	93.90	94.10	94.00
	S.E.	132.38	127.57	123.32
	% deviation	-32.11 to 11.19	-30.54 to 12.14	-29.62 to 12.98

explained by these set of equations ranged from 59 to 70 per cent, standard error ranged from 234 to 259 and the deviation between predicted and observed yields were large. Therefore, none of the models could be considered as suitable for pre-harvest forecasting of castor yield under this approach.

Correlation coefficient as weight approach

Using five different crop periods, three models were fitted under this approach. The values of S.E., R² and deviation from average yields are presented in Table 3.

It could be observed from the above results that the variation explained (i.e. R²) by fitted models, ranged from 87.60 % to 94.60 % for all the three models. The deviation between observed yield and forecasted yield in per cent ranged from -20.39 % to 12.32 %. Among the equations fitted under this approach, in model of 20 and 21 weeks crop period, R² was low (around 88 %) and deviations of simulated forecasts

was ranging from -20.39 % to 11.83 %. While, in case of 17 and 19 weeks models R² was around 90 % and deviations of simulated forecasts was ranging from -19.65 % to 9.28 %. But in case of 18 weeks model R² was reasonably high i.e. 94 % and the simulated forecast was -19.85 % to 12.32 %, but for early forecast (12 weeks before harvest) the 18 weeks of 21 years, model-I was found suitable for forecasting castor yield under this approach as compared to rest of the models. Varmora *et al.* (2004) reported forecasting models for predicting wheat yield based on generated weather variables using correlation coefficient as weight. The present findings are on similar line.

Among the different models fitted under three approaches, two models were identified as suitable pre-harvest forecast models for Banaskantha district, first from using week wise original weather variables of 19 weeks of 22 years (model-II) and the second also using generated variables (correlation

Table 2 Variables selected, coefficient of determination and range of forecast errors in week number as weight approach.

Variables selected		R ² and simulated forecast errors (%)		
		1982-83 to 2002-03 (Model I)	1982-83 to 2003-04 (Model-II)	1982-83 to 2004-05 (Model-III)
(I) 17 weeks model Q ₁₃₂ and Q ₂₅₁	R ²	63.10	64.30	59.00
	S.E.	255.07	248.83	259.90
	% deviation	-30.07 to 2.71	-29.44 to 3.22	-26.98 to 5.27
	R ²	66.00	67.10	61.30
(II) 18 weeks model Q ₁₃₂ and Q ₂₅₁	S.E.	244.84	238.82	252.57
	% deviation	-42.66 to -3.95	-41.98 to -3.44	-38.07 to -0.51
	R ²	68.90	70.00	65.00
	S.E.	241.10	234.43	246.31
(III) 19 weeks model Q ₁₂₂ , Q ₁₃₂ and Q ₂₅₁	% deviation	-23.63 to 11.72	-23.28 to 11.99	-17.88 to 17.06
	R ²	67.60	68.70	63.90
	S.E.	253.50	246.19	257.10
	% deviation	-33.23 to 13.07	-32.35 to 13.55	-27.19 to 20.27
(IV) 20 weeks model Q ₁₂₂ , Q ₁₃₂ and Q ₂₅₁	R ²	67.60	68.80	65.90
	S.E.	246.11	239.17	243.41
	% deviation	-21.63 to 14.25	-21.69 to 14.20	-16.75 to 19.25
(V) 21 weeks model Q ₁₂₂ , Q ₁₃₁ and Q ₂₅₁				

Table 3: Variables selected, coefficient of determination and range of forecast errors in week number as weight approach.

Variables selected		R ² and simulated forecast errors (%)		
		1982-83 to 2002-03 (Model I)	1982-83 to 2003-04 (Model II)	1982-83 to 2004-05 (Model III)
(I) 17 weeks model T, Z' ₂₁ , Q' ₁₃₂ , Q' ₂₅₁ , Q' ₃₅₁ and Q' ₄₅₀	R ²	90.40	90.30	89.80
	S.E.	147.35	146.28	145.07
	% deviation	-19.65 to 7.89	-16.26 to 9.28	-19.04 to -1.36
	R ²	94.60	94.30	93.50
(II) 18 weeks model T, Z' ₂₁ , Q' ₁₂₂ , Q' ₁₃₂ , Q' ₃₅₁ , Q' ₄₅₀ and Q' ₅₆₁	S.E.	115.03	116.03	119.70
	% deviation	-17.99 to 10.85	-17.85 to 12.32	-19.85 to -1.24
	R ²	90.90	91.10	90.70
	S.E.	143.62	139.71	138.67
(III) 19 weeks model T, Z' ₂₁ , Q' ₁₂₂ , Q' ₁₃₂ , Q' ₃₅₁ , and Q' ₄₅₀	% deviation	-16.68 to 8.15	-15.20 to 9.18	-14.51 to 5.27
	R ²	88.40	88.70	88.60
	S.E.	156.40	152.29	148.64
	% deviation	-20.34 to 10.81	-18.90 to 11.83	-20.22 to 10.86
(IV) 20 weeks model T, Z' ₂₁ , Q' ₁₃₂ , Q' ₃₅₁ , and Q' ₄₅₀	R ²	88.00	87.90	87.60
	S.E.	159.40	158.33	154.89
	% deviation	-20.39 to 6.57	-17.44 to 8.36	-19.65 to 7.25
(V) 21 weeks model T, Z' ₂₁ , Q' ₁₃₀ , Q' ₃₅₁ , and Q' ₄₅₀				

coefficient as weight) of 18 weeks of 21 years (model-I). Among these two 18 weeks of 21 years (model-I), the model using generated weather variables (correlation coefficient as weight) could be preferred because of minimum standard error, high R^2 (>94 %) and less deviation of simulated forecast from actual yields. The detailed results of this model are given in Table 4 and 5. The positive and significant effect of time trend in castor yield was

observed, indicating paramount importance of castor production technology. The beneficial effect of first order generated variable Z'_{21} (Linear weight of correlation coefficients to minimum temperature) and second order generated variables Q'_{450} (Zero weight of correlation coefficients to cross products of evening relative humidity and bright sunshine hours) and Q'_{561} (Linear weight of correlation coefficients to cross products of bright

Table 4 Regression coefficients of castor yield on time trend and different generated weather variables using correlation coefficients as weight approach (18 weeks)

Variables in the equation	Years		
	1982-83 to 2002-03 (Model-I)	1982-83 to 2003-04 (Model-II)	1982-83 to 2004-05 (Model-III)
Constant	-3054.75 (847.50)	-3206.18 (843.80)	-3180.36 (870.30)
Trend	40.26** (7.58)	39.31** (7.60)	38.39** (7.81)
Z'_{21} (Linear weight of correlation coefficients to minimum temperature)	114.33** (19.05)	118.53** (18.83)	113.91** (19.13)
Q'_{122} (Quadratic weight of correlation coefficient to cross products of maximum temperature and minimum temperature)	-2.42** (0.77)	-2.48** (0.78)	-2.37** (0.80)
Q'_{132} (Quadratic weight of correlation coefficient to cross products of maximum temperature and morning relative humidity)	0.21 (0.36)	0.23 (0.36)	0.38 (0.36)
Q'_{351} (Linear weight of correlation coefficients to cross products of morning relative humidity and bright sunshine hours)	-0.03 (0.01)	-0.03 (0.01)	-0.02 (0.01)
Q'_{450} (Zero weight of correlation coefficients to cross products of evening relative humidity and bright sunshine hours)	6.71** (1.35)	6.78** (1.36)	5.95** (1.27)
Q'_{561} (Linear weight of correlation coefficients to cross products of bright sunshine hours and rainfall)	0.70 (0.33)	0.73* (0.33)	0.73* (0.34)
S. E.	115.03	116.03	119.70
R^2 (%)	94.60**	94.30**	93.50**

Figures in parenthesis indicate standard error

* Significant at 5 % level of significance ** Significant at 1 % level of significance

sunshine hours and rainfall) on castor productivity were observed significantly. At least 12 weeks before actual harvest of the crop, reliable pre-harvest forecasting of castor yield in Banaskantha district can be made using generated weather variables, correlation coefficient as weight (18 weeks) approach by the following model:

$$Y = -3054.75 + 40.26^{**} T + 114.33^{**} Z'_{2r^1} - 2.42^{**} Q'_{12r^2} + 0.21Q'_{13r^2} - 0.03Q'_{35r^1} + 6.71^{**} Q'_{45r^0} + 0.70Q'_{56r^1}$$

$$(R^2 = 94.60\%)$$

Table 5 Comparison between observed and predicted yield based on the fitted equations (correlation coefficients as weight approach) (18 weeks)

Year	Observed Yield (kg/ha)	Simulated forecasts (kg/ha)		
		1982-83 to 2002-03	1982-83 to 2003-04	1982-83 to 2004-05
2003-04	2084	2231 (-7.04)	-	-
2004-05	1712	1526 (10.85)	1501 (12.32)	-
2005-06	2132	2451 (-14.95)	2426(-13.77)	2433(-14.11)
2006-07	1552	1831 (-17.99)	1797(-15.77)	1855(-19.52)
2007-08	2225	2624 (-17.93)	2622(-17.85)	2667(-19.85)
2008-09	2159	2174 (-0.68)	2146 (0.58)	2186 (-1.24)

Figures in parenthesis are per cent deviations from observed yield.

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Constitutive expression of ch-TLR 4, IL-1 β and IFN- γ in Aseel and Kadaknath chick peripheral blood mononuclear cells

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ABSTRACT

Immune system operates through innate and adaptive arm to fight against invading pathogens and confers protection to the host. Innate and adaptive arm differs in the two main cardinal attributes *i.e.*, specificity and memory. Innate arm is non-specific arm devoid of memory while adaptive arm operates with specificity and have memory. Earlier innate arm of the immune system was viewed as of limited role and mainly concerned with initial containment of the invading pathogen before adaptive arm comes into play. However, both the arms work in highly coherent manner to thwart pathogenic attack. In the recent past, the role of components of innate arm in generation of adaptive immune response has been established more precisely. By virtue of their role as "Antigen Presenting Cells", innate cells present antigenic peptides to Th and Tc cells. Moreover, a good number of pro-inflammatory cytokines are also secreted that has profound effect on subsequent adaptive response. This improved understanding of underlying mechanism allows assessing basal constitutive expression of TLRs and other important immune markers as a novel way of evaluating general immune competence of the host. Aseel and Kadaknath, Indian native breeds of chicks are considered to be more immune competent than the commercial breeds. This study was designed to assess basal constitutive expression of ch-TLR 4, IL-1 β and IFN- γ in peripheral blood mononuclear cells (PBMCs) of Aseel and Kadaknath using real time PCR. PBMCs isolated from 21 days old Aseel chicks had 1.28, 1.59 and 2.38 times higher constitutive expression of ch-TLR4 and IL-1 β , respectively than PBMCs isolated from Kadaknath. Thus, basal constitutive expression of these two innate markers was found to be relatively higher in PBMCs from Aseel than that of Kadaknath.

Key words : Chick, immune, poultry

In the last few decades, innate immune system has acquired centre stage of research interest. Innate arm initiates operation after recognizing highly conserved molecular patterns ("Pathogen associated molecular patterns" (PAMPs)) present in micro-organisms *viz.*, LPS, lipo-proteins, LTA, lipoarabino-mannans, flagellin, ds RNA, bacterial DNA, Zymosan etc., (Aderem and Ulevitch, 2000; Takeda *et al.*, 2003). These PAMPs are recognized by receptors called Pattern recognition receptors

(PRRs). Among PRRs, Toll like receptors (TLRs) are of prime importance (Takeda *et al.*, 2003). Recognition of PAMPs by TLRs initiates a signaling cascade that involves a number of proteins including transcription factor NF- κ B and AP-1 which induce the secretion of pro-inflammatory cytokines like IL-1, IL-6, IL-12 etc. and thereby effector cytokines that directs the adaptive immune response (Andrem and Ulevitch 2000). Applications of selective breeding in fowl have brought significant improvement in production traits of the fowl in comparison to their native counterparts. However, this has largely compromised with the immune competence of the fowl which is worrying in the wake of pathogenic

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threat faced by fowls. Thus, scientists are working hard to enhance the genetic resistance of fowl with optimum production performance. This needs exploration of genetic variability in available germplasm so that they could be incorporated in future selective breeding programmes. In fowl, most of the research work in this direction had been carried out in the fowl like leghorn or synthetic broiler lines and reports on these parameters from Indian native breeds like Aseel and Kadaknath, believed to exhibit more genetic resistant, is largely missing. High immune competence of these Indian native breeds had been reported on the basis of resistance to subgroup A Rous sarcoma virus (Rout *et al.*, 1992), high classical complement pathway activity and humoral immune response to SRBCs (Baelmans *et al.*, 2005) and higher serum nitric oxide levels (Ramasamy *et al.*, 2011). To have further insight on the immune competence of these Indian native breeds of fowl, this study has been designed to evaluate the constitutive expression of ch-TLR4, IL-1b and IFN- γ .

MATERIALS AND METHODS

Day old chicks of Aseel and Kadaknath breeds were purchased from the CPRS (Central Poultry Research Station), Anand. Chicks were maintained in the Poultry Demonstration Unit, Veterinary College, SDAU under standard management and

during entire experimental period they were provided ad-libitum feeding & watering. Approx. 1.5 ml blood from Aseel and Kadaknath chicks were collected aseptically in heparin from 4 birds of both groups on 21st day of their age. Individual blood sample was mixed with PBS (1:1 dilution), 3 ml of this blood – PBS mixture was layered carefully on 3 ml of Histopaque (1.077, sigma-Aldrich) and centrifuged at 1800 rpm for exactly 20 minutes in swing out rotors. White ring at the interface containing mononuclear cells (PBMCs) was carefully aspirated and washed twice with HBSS at 800-1000 rpm for 10 minutes. PBMCs @ 1×10^6 were subjected to RNA isolation, c-DNA preparation and relative quantitation using Real time PCR (ABI, 7500). The primers used in the study were designed with the help of online available softwares (Table 1). The primers were of small amplicon size (100-300 bp), amplified at 58^o C and showed primer efficiency in the range of 1.8-2.0. β -actin gene was taken as housekeeping gene for this study. The reaction conditions were standardized with SYBR green chemistry and all the primers produced a single peak in dissociation curve analysis confirming the specificity of the products. To determine the relative expression of genes under study between Aseel and Kadaknath breeds, the constitutive expression in PBMCs from Kadaknath chicks was considered as unit for respective genes under comparison.

Table 1 List of primers used in the study

Target genes	Primer	Amplicon size (bp)
Ch-TLR 4	F: CCA CCC TGG ACT TGG ACC TCA G = 22 R: AAG GCT GCT AGA CCC AGG TGC T = 22	202
Ch- IL-1 β	F: GCC TTC CGC TAC ACC CGC TC = 20 R: ATG TCC CGC ATG ACG TCG GC = 20	293
Ch- IFN- γ	F: ACC TGG CCA AGC TCC CGA TGA = 21 R: ACT CGG AGG ATC CAC CAG CTT CT = 23	95
β -actin	F: GCACCACACTTTCTACAATGAG = 22 R: ACGACCAGAGGCATACAGG = 20	184

RESULTS AND DISCUSSION

Constitutive expression of Ch-TLR4, IL-1 β and IFN- γ
PBMCs isolated from both the Indian native breeds were found to have constitutive expression of ch-TLR 4, IL-1 β and IFN- γ . PBMCs isolated from Aseel recorded higher expression for all the genes under

study. In comparison to PBMCs from Kadaknath, PBMCs from Aseel were found to have 1.28, 1.59 and 2.38 times higher expression of ch-TLR4, IL-1 β and IFN- γ , respectively (Table 2).

Table 2 Constitutive expression of ch-TLR4, IL-1β and IFN-γ in PBMCs of Aseel and Kadaknath chicks

Parameters	Target genes		
	TLR 4	IL-1β	IFN-γ
Aseel			
Average delta Ct* values (n=3)	-4.02	-3.84	-10.31
Kadaknath			
Average delta Ct* values (n=3)	-4.38	-4.51	-11.57
ddCt**	0.36	0.67	1.25
Level of relative expression in Aseel in comparison to Kadaknath	1.288	1.59	2.38

*delta Ct = Ct of housekeeping gene-Ct of Target gene
** dd Ct = delta Ct of target gene (Aseel) - delta Ct of target gene (Kadaknath)
Relative expression was calculated using IF command in excel= IF(V4>0,2^ddCt,-(2^-ddCt))

Innate arm of the immune system acts non-specifically and work in no time following their interaction with immune system. Cells of Innate immune arm plays major role in intitiation of immune response by functioning as “antigen presenting cells” which not only process and present antigenic peptides to T helper cells but also help them by producing several pro-inflammatory cytokines (Akira and Hemmi, 2003). Thus, the cell of this non-specific arm plays a major role in shaping subsequent adaptive immune response. These cells of innate arm recognize invading pathogen by the help of Pattern recognition receptors (one of them is Toll like receptors-TLRs) which detect structural motifs associated with microbes called “Pathogen Associated Molecular Patterns” (Medzhitov and Janeway, 2000). Examples of PAMPs are LPS, LTA, Flagellin, double or single stranded RNA, bacterial

DNA or CpG etc. Interaction of innate cells with these microbial products could lead to up-regulation or down regulation in expression of various TLRs, pro-inflammatory cytokines and various co-stimulatory molecules (Andrem and Ulevitch 2000). Selective breeding in the past have enhanced the production trait in commercial poultry population but at the same time inversely affected their immune competence (Pinard *et al.*, 1998). The improved understanding of innate arm could also assist poultry scientists to meticulously look for desired genes to strengthen the genetic resistance in poultry. Keeping these facts in mind, this study was conducted on two Indian native breeds of fowl i.e., Aseel and Kadaknath which are reported to have better abilities to fight infectious diseases. An avian orthologue of mammalian TLR 4 was characterized by Leveque *et al.*, (2003). Interaction of ch-TLR 4 with its ligand leads to up-regulation of various immune related genes like IL-1β, IFN-γ, IL-10, CD80 and MHC II etc. (St Paul *et al.*, 2012) which directly influences the outcome of immune response. In the chicken, an IL-1-like biological activity was first demonstrated in supernatants of LPS-stimulated adherent spleen cells (Hayari *et al.*, 1982) and is considered as an important pro-inflammatory cytokine. Similarly, Interferon-γ (IFN-γ) represents the major macrophage-activating factor (MAF), exhibits antiviral activity and drives Th1 immune responses (Boehm *et al.*, 1997; Farrar and Schreiber, 1993). Ch IFN-γ is also known to prime heterophils for a significantly strengthened respiratory burst to subsequent stimulation with

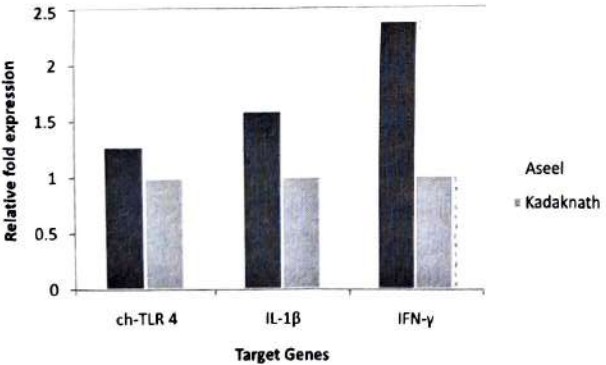


Plate 1 Relative expression of ch-TLR 4, IL-1β and IFN-γ genes in Aseel in comparison to Kadaknath chicks

opsonized zymosan (Kogut *et al.*, 2012). Th1 skewed response characterized by dominance of IFN- γ production has been correlated with resistance to MDV, Infectious Bronchitis, NDV and Salmonellosis in chicken (Zekarias *et al.*, 2002). Thus, constitutive expression of these three important genes *i.e.*, ch-TLR4, IL-1 β and IFN- γ in PBMCs from these breeds were studied which is supposed to simply reflects general immune competence of the host. In the present study, the constitutive expression of all the three genes was detected in PBMCs isolated from both the Indian native breeds of fowl. In comparison to Kadaknath, PBMCs from Aseel were found to have 1.28, 1.59 and 2.38 times higher expression of ch-TLR4, IL-1 β and IFN- γ , respectively. Contrary to our reports, Ramasamy *et al.*, (2010) reported significantly higher expression of TLR 4 and TLR 5 in heterophils from Kadaknath than in heterophils of Aseel chicks. The difference observed in the expression level in expression of ch-TLR4 in their report might be due to difference in target cells used in the studies *i.e.*, PBMCs and heterophils. Thus, these reports indicated towards difference in expression of TLRs in different immune compartments. Differential responsiveness in the expression of various important immune related genes has been correlated with the disease susceptibility or resistance pattern of the host (Adams *et al.*, 2009). They reported that in response to low pathogenic AIV H11N9 infection, the expression of IL-1 β , IFN- γ and IL-6 in chicken PBMC were found to be significantly up-regulated whereas in duck PBMC expression levels were minimal or unchanged. These results showed distinct PBMC expression patterns of pro-inflammatory cytokines and IFNs between species affecting clinical outcome. Moreover, Nerren *et al.*, (2009) reported the difference in TLR 15 gene expression by heterophils of lines A (*Salmonella* resistant) and B (*Salmonella* susceptible) which likely accounts for some of the observed differences between the lines in their susceptibility to infection. Constitutive expression of these immune markers observed in the present study give support to the report of Rout *et al.*, (1992) who injected 0.2 ml of Rous sarcoma virus containing 1000 pock forming unit /ml via chorio-allantoic membrane into the 11 day old embryos of Kadaknath, Aseel and White

leghorn breeds of fowl that hatched subsequently. This study, intending to ascertain the genetic susceptibility of these breeds to Rous sarcoma virus concluded that Aseel and Kadaknath breed were 6 and 3 times less sensitive than white leghorn. Moreover, Kundu *et al.*, (1999) also recorded highest HA antibody titre in Aseel on 12th and 19th day post immunization with SRBCs than breeds like Kadakanath, Frizzle, Dahlem Red, White Leghorn, Synthetic dam line broiler (SDL) and Naked Neck.

CONCLUSION

Higher constitutive expression of ch-TLR4, IL-1 β and IFN- γ observed in the PBMCs from Aseel chicks reflects towards better immune competence of Aseel than Kadaknath chicks. Since, immune response is governed by multiple genes, thus comprehensive trials with suitable infection model are warranted to test this notion further. The advantages of identifying and incorporating better alleles could be immense in the poultry industry, which is facing severe pathogenic challenges with devastating impact.

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Minerals, enzymes and electrolytes profiles of follicular fluid of surti buffaloes in relation to follicles size

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ABSTRACT

A total of 210 ovaries were collected, of which 91 were having corpus luteum and 119 were without corpus luteum. The follicles of ovaries were classified in to three categories on the basis of its diameter and the presence or absence of corpus luteum. Follicular fluid samples were assayed using commercial kits for minerals and enzymes and electrolytes were estimated by Flame photometer. The number of all the three size of follicles of all the three categories was significantly different ($P < 0.05$) on the ovaries with and without corpus luteum. The vales of calcium, inorganic phosphorus and sodium in follicular fluid were non significantly increased from small to large follicles where as the values of magnesium, acid phosphatase, alkaline phosphatase, lactate dehydrogenase and potassium in follicular fluid were significantly ($P < 0.05$) decreased in the ovaries with and without corpus luteum.

Key words: Buffalo, ovary, follicular fluid, minerals, enzymes, electrolytes.

The follicular fluid forms the minerals, enzymes and electrolytes environment of the oocyte before ovulation (Gosden *et al.*, 1988 and Józwik *et al.*, 2001) and is a vascular compartment within the mammalian ovary, separated from the perifollicular stroma by the follicular wall that constitutes a 'blood-follicle barrier' (Okuda *et al.*, 1982 and Bagavandoss *et al.*, 1983). Follicular fluid, is, in part, exudates of serum and is in addition partially composed of locally produced substances, which are related to the metabolic activity of follicular cells (Gérard *et al.*, 2002). This metabolic activity, together with the "barrier" properties of the follicular wall, is changing significantly during the growth phase of the follicle (Wise, 1987 and Gosden *et al.*, 1988). Follicular fluid composition has been under intensive investigation in recent times in a bid to increase knowledge of

follicular development, oocyte maturation and follicular atresia (Mishra *et al.*, 2003). Metabolic activity and blood-follicle barrier properties change during the growth phase of the follicle and hence a different biochemical composition of the follicular fluid in different size follicles could be expected.

MATERIALS AND METHODS

The present study was carried out on 210 Surti buffalo ovaries collected from abattoir. Ovaries were transported to the laboratory in 0.9 per cent chilled (4°C) saline supplemented with gentamicin (50 mg/ml). The ovaries were washed twice with chilled saline then cleaned with spirit or 70 per cent alcohol. The ovaries were further classified as per the presence or absence of corpus luteum. The number of ovaries were 119 and 91, respectively. The follicles present on ovaries were classified on the basis of diameter: (a) small (1 to 4 mm), (b) medium (5 to 8 mm) and (c) large (9 to 12 mm) (Leroy *et al.*, 2004, Parmar and Mehta 1990). The ovaries were

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also grouped as per the presence and absence of corpus luteum. The follicle size in both categories was measured by digital Vernier Caliper. The follicular fluid was aspirated from all three size of follicles of ovaries with and without corpus luteum by using a 22-gauge needle attached to a 1 ml plastic syringe and was pooled accordingly on a weekly basis and collected in separate eppendorf tubes. The total follicular fluid collected from ovaries with corpus luteum was 18, 18 and 33 ml, respectively for small, medium and large size follicles and the corresponding values for ovaries without corpus luteum were 9, 6 and 9 ml. The follicular fluid collected was made cell-free by centrifuging at 5°C at 1500 r.p.m. for 30 min. The aliquots of follicular fluid were stored in a deep freezer (-20°C) till minerals, enzymes and electrolytes analysis. Follicular fluid samples were assayed for minerals (calcium, inorganic phosphorus and magnesium) and enzymes (acid phosphatase, alkaline phosphatase and lactate dehydrogenase) estimated using BS-120 Chemistry Analyzer where as the Electrolytes (sodium and potassium) was estimated by Flame photometer (Hawk et al., 1954).

RESULTS AND DISCUSSION

Follicular Development

A total of 210 ovaries were collected, of which 91 were having corpus luteum and 119 were without corpus luteum. The total numbers of follicles present on the above ovaries were 1158 and they were distributed as per their size. The overall numbers of follicles of different size irrespective of presence or absence of corpus luteum on the ovaries. The mean follicle numbers of three different size present on the ovaries with and without corpus luteum was significantly different. The mean of number of small follicles (4.94 ± 0.17) on ovaries with corpus luteum was significantly higher than of their medium (0.69 ± 0.08) and large (0.41 ± 0.06) size follicles. The mean of number of small follicles (3.98 ± 0.17) on the ovaries without corpus luteum was significantly higher than there of medium (0.77 ± 0.09) and large (0.35 ± 0.05) follicles.

The overall mean numbers of follicles per ovary was significantly different among different size follicles

significantly higher number of small follicles (4.40 ± 0.12) were recored as compared to medium (0.73 ± 0.06) and large (0.38 ± 0.04) size follicles. The mean of number of the follicles per ovary with or without corpus luteum in present study was found to be higher than that reported by Parmar and Mehta (1992). They reported that the mean of number of small, medium and large size follicles per ovary was 1.34, 0.25, and 0.18 per ovary, respectively. The overall mean of number of the follicles per ovary irrespective of with or without corpus luteum in the present study was also found to be higher than that reported by Makwana and Shah (2009) but lower than that reported by Parmar and Mehta (1990), Amer *et al.* (2008) and Singh and Shah (2010). Amer *et al.* (2008) reported 6.8 follicles in type III (without corpus luteum), followed by 5.2 in type II (regressed corpus luteum) and 4.4 in type I (functional corpus luteum) ovaries in buffalo.

The results showed that the buffaloes have less number of follicles available on the ovaries. The reason for the less number of primordial follicles in buffaloes compared to cattle is not known, but it could be due to a lower number of the original germ cells, a lower rate of multiplication during the mitotic divisions or an increased frequency of atresia, especially during the fetal life (Samad and Nasser, 1979).

Follicular fluid Minerals

Calcium

The mean calcium concentration in follicular fluid of small, medium and large size follicles with and without corpus luteum on the ovary was 7.59 ± 0.25 , 8.13 ± 0.21 and 8.37 ± 0.09 mg/dl and 7.57 ± 0.23 , 8.12 ± 0.10 and 8.39 ± 0.23 mg/dl, respectively. The calcium concentration of follicular fluid of all the three size of follicles with and without corpus luteum was not significantly different and increased with the increase the size of follicle. The overall mean values of calcium in follicular fluid of small, medium and large size follicles was 7.57 ± 0.17 , 8.12 ± 0.09 and 8.38 ± 0.16 mg/dl, respectively. The calcium concentration in follicular fluid of all the three size of follicles was not significantly different and it increased with the increase in the size follicle. The

overall mean calcium concentration in follicular fluid was 8.02 ± 0.13 mg/dl and 8.11 ± 0.13 mg/dl for ovaries in which corpus luteum was present and absent, the difference being non significant among the group. The overall calcium concentration was 8.08 ± 0.1 mg/dl.

The calcium levels non significantly found to be increased with the increase in the diameter of follicle such finding correlated well with the study of Wise (1987) and Kaur *et al.* (1997). Increased calcium concentration with follicular development had a role in steroidogenic capability of growing follicle and calcium played an important role in gonadotrophin regulation of ovarian steroidogenesis and ovulation. Calcium ions are involved in the regulation of oocyte maturation. The calcium deposits were quickly depleted after oocyte isolation from the follicle (Marketa *et al.*, 2002).

Inorganic Phosphorus

The mean inorganic phosphorus concentration in follicular fluid of small, medium and large size follicles was 4.93 ± 0.26 , 5.70 ± 0.34 and 6.31 ± 0.39 mg/dl and 4.63 ± 0.23 , 5.94 ± 0.27 and 6.03 ± 0.19 mg/dl, respectively for ovaries with and without corpus luteum. The inorganic phosphorus concentration in follicular fluid of all the three size of follicle with and without corpus luteum was not significantly different and it increased as the follicular diameter increased. The overall mean values of inorganic phosphorus in follicular fluid of small, medium and large size follicles was 4.75 ± 0.17 , 5.86 ± 0.21 and 6.10 ± 0.17 mg/dl, respectively. The overall mean of phosphorus concentration in follicular fluid of all the three size of follicles was not significantly different and had showed increasing trend with the increase in the size of follicle. The overall mean inorganic phosphorus concentration in follicular fluid of follicles was 5.64 ± 0.23 mg/dl and 5.64 ± 0.15 mg/dl, respectively, for ovaries with and without corpus luteum and the difference being non significant. The overall inorganic phosphorus was 5.64 ± 0.13 mg/dl.

The phosphorus concentration increased non significantly as the follicular diameter increased in

Table 1 Distribution of different size of follicles on ovaries with and without corpus luteum of buffaloes.

Follicles	Ovaries having corpus luteum (n = 91)			Ovaries without corpus luteum (n = 119)			Overall distribution of different size of follicles irrespective of with or without CL on the ovaries (n = 210)		
	Number of follicles	Mean number of follicles/ovary	Per cent distribution	Number of Follicles	Mean number of follicles/ovary	Per cent distribution	Overall Number of follicles	Overall Mean of number of follicles/ovary	Overall Per cent distribution
Small	450	4.94 ± 0.17^a	81.82	474	3.98 ± 0.17^a	77.96	924	4.40 ± 0.12^a	79.79
Medium	63	0.69 ± 0.082^b	11.45	92	0.77 ± 0.93^b	15.13	155	0.73 ± 0.64^b	13.38
Large	37	0.41 ± 0.06^c	6.73	42	0.35 ± 0.53^c	6.91	79	0.38 ± 0.04^c	6.83
Total	550		100	608		100	1158		100

Table 2 Minerals profiles of follicular fluid in buffaloes in relation to different follicle size of follicles on the ovaries the presence and absence corpus luteum.

Ovaries	Calcium (mg/dl)			Inorganic phosphorus (mg/dl)			Magnesium (mEq/l)		
	Small Follicles	Medium Follicles	Large Follicles	Overall Mean $\pm$ S.E	Small Follicles	Medium Follicles	Large Follicles	Overall Mean $\pm$ S.E	Overall Mean $\pm$ S.E
With corpus luteum	7.59 $\pm$ 0.25 ^b	8.13 $\pm$ 0.21 ^a	8.37 $\pm$ 0.09 ^a	8.02 $\pm$ 0.13	4.93 $\pm$ 0.26 ^b	5.70 $\pm$ 0.34 ^a	6.31 $\pm$ 0.39 ^a	5.64 $\pm$ 0.23	2.61 $\pm$ 0.05 ^a 2.42 $\pm$ 0.04 ^b 2.21 $\pm$ 0.01 ^c 2.42 $\pm$ 0.04
Without corpus luteum	7.57 $\pm$ 0.23 ^a	8.12 $\pm$ 0.10 ^a	8.39 $\pm$ 0.23 ^a	8.11 $\pm$ 0.13	4.63 $\pm$ 0.23 ^b	5.94 $\pm$ 0.27 ^a	6.03 $\pm$ 0.19 ^a	5.64 $\pm$ 0.15	2.60 $\pm$ 0.07 ^a 2.40 $\pm$ 0.02 ^b 2.22 $\pm$ 0.01 ^c 2.37 $\pm$ 0.03
Overall Mean $\pm$ S.E.	7.57 $\pm$ 0.17 ^a	8.12 $\pm$ 0.09 ^a	8.38 $\pm$ 0.16 ^a	8.08 $\pm$ 0.10	4.75 $\pm$ 0.17 ^b	5.86 $\pm$ 0.21 ^a	6.10 $\pm$ 0.17 ^a	5.64 $\pm$ 0.13	2.60 $\pm$ 0.04 ^a 2.41 $\pm$ 0.02 ^b 2.22 $\pm$ 0.01 ^c 2.38 $\pm$ 0.024

Table 3 Enzymes profiles of follicular fluid in buffaloes in relation to different follicle size of follicles on the ovaries the presence and absence corpus luteum.

Ovaries	Acid phosphatase (U/L)			Alkaline phosphatase (U/L)			Lactate dehydrogenase (U/L)		
	Small Follicles	Medium Follicles	Large Follicles	Overall Mean $\pm$ S.E.	Small Follicles	Medium Follicles	Large Follicles	Overall Mean $\pm$ S.E	Overall Mean $\pm$ S.E
With corpus luteum	12.75 $\pm$ 0.16 ^a	11.65 $\pm$ 0.41 ^b	10.31 $\pm$ 0.44 ^c	11.56 $\pm$ 0.30	293.24 $\pm$ 3.44 ^a	290.51 $\pm$ 3.59 ^b	225.02 $\pm$ 3.65 ^c	267.44 $\pm$ 7.99	319.04 $\pm$ 7.12 ^a 281.45 $\pm$ 7.16 ^b 227.51 $\pm$ 7.31 ^c 275.83 $\pm$ 9.51
Without corpus luteum	12.64 $\pm$ 0.28 ^a	11.56 $\pm$ 0.29 ^b	10.14 $\pm$ 0.26 ^c	11.16 $\pm$ 0.22	307.47 $\pm$ 8.41 ^a	250.39 $\pm$ 4.48 ^b	239.22 $\pm$ 9.77 ^c	259.94 $\pm$ 6.73	320.64 $\pm$ 0.82 ^a 268.45 $\pm$ 6.56 ^b 235.43 $\pm$ 7.63 ^c 266.28 $\pm$ 7.10
Overall Mean $\pm$ S.E.	12.68 $\pm$ 0.18 ^a	11.59 $\pm$ 0.23 ^b	10.19 $\pm$ 0.22 ^c	11.29 $\pm$ 0.18	300.68 $\pm$ 5.49 ^a	264.67 $\pm$ 7.1 ^b	235.43 $\pm$ 7.28 ^c	262.37 $\pm$ 5.22	320.36 $\pm$ 6.94 ^a 272.79 $\pm$ 5.08 ^b 233.32 $\pm$ 5.9 ^c 269.37 $\pm$ 5.69

Table 4 Electrolytes (Sodium (mM/L) and Potassium (mM/L)) in follicular fluid of buffaloes in relation to different follicle size of ovaries with and without corpus luteum during peak breeding season.

Ovaries	Sodium (mM/L)				Potassium (mM/L)			
	Small Follicles	Medium Follicles	Large Follicles	Overall Mean $\pm$ S.E.	Small Follicles	Medium Follicles	Large Follicles	Overall Mean $\pm$ S.E.
With corpus luteum	126.25 $\pm$ 2.06 ^a	130.15 $\pm$ 2.07 ^b	132.65 $\pm$ 1.28 ^b	129.64 $\pm$ 1.16	9.62 $\pm$ 0.27 ^a	8.75 $\pm$ 0.40 ^b	6.47 $\pm$ 0.23 ^c	8.24 $\pm$ 0.34
Without corpus luteum	126.46 $\pm$ 1.7 ^a	127.85 $\pm$ 1.54 ^b	132.62 $\pm$ 0.93 ^b	129.77 $\pm$ 0.84	9.7 $\pm$ 0.27 ^a	8.65 $\pm$ 0.23 ^b	6.71 $\pm$ 0.17 ^c	8.00 $\pm$ 0.23
Overall Mean $\pm$ S.E.	126.38 $\pm$ 1.29 ^a	128.62 $\pm$ 1.23 ^b	132.62 $\pm$ 0.75 ^b	129.73 $\pm$ 0.67	9.69 $\pm$ 0.19 ^a	8.68 $\pm$ 0.20 ^b	6.65 $\pm$ 0.14 ^c	8.08 $\pm$ 0.19

present study was in agreement with the results of Abd Ellah *et al.* (2010); Nandi *et al.* (2007) and Mishra *et al.* (2003). The higher concentration of phosphorus in small follicles compared to those in large ones irrespective of with or without corpus luteum of ovaries was in accordance with the earlier reports by Wise, (1987), Kaur *et al.*, (1997) and Bordoloi *et al.*, (2001). Phosphorus is known to be involved in high energy bonds that link oxides of phosphate to carbon or to carbon nitrogen compounds (such as adenosine triphosphate, ATP). Phosphorus is also intimately involved in acid-base buffer systems of blood and other body fluids (Zilva *et al.*, 1991).

Magnesium

The mean magnesium concentration in follicular fluid of small, medium and large size follicles was 2.61 $\pm$ 0.05, 2.42 $\pm$ 0.04 and 2.21 $\pm$ 0.01 mEq/l and 2.60 $\pm$ 0.07, 2.40 $\pm$ 0.02 and 2.22 $\pm$ 0.01 mEq/l, respectively for ovaries having presence or absence of corpus luteum. The magnesium concentration of follicular fluid of all the three size of follicles with and without corpus luteum was significantly different and it decreased with the increase diameter of follicle. The overall mean values of magnesium in follicular fluids of small, medium and large size follicles was 2.60 $\pm$ 0.04, 2.41 $\pm$ 0.02 and 2.22 $\pm$ 0.01 mEq/l, respectively. The overall mean magnesium concentration in follicular fluid of all the three size of follicles was significantly different which decreased with increase in follicular size. The overall mean of magnesium concentration in follicular fluid of follicles with corpus luteum (2.42 $\pm$ 0.04 mEq/l) and without corpus luteum (2.37 $\pm$ 0.03 mEq/l) did not differ significantly. The overall magnesium concentration for both groups was 2.38 $\pm$ 0.24 mEq/l.

In present study the magnesium level significantly decreased as the follicular diameter of the increased which these finding corroborate with study of Arshad *et al.* (2005) and Abd Ellah *et al.* (2010) in buffaloes. Magnesium acts as a co-factor in enzymatic reactions and induces meiotic maturation of *Xenopus* oocytes (Belle *et al.* 1986). Further, low concentrations of divalent cations (Mg and Ca)

inhibit the resumption of meiosis, and the inhibitory effect of low Mg concentration is greater than that of low Ca (Jagiello *et al.*, 1982). Low concentration of Mg and Ca in the IVM medium impaired developmental competence, but did not affect the progression of nuclear maturation. On the other hand, a high Mg concentration (2 mM) and high Mg/Ca ratio (2:1) improved early embryo development because Mg regulates Ca homeostasis in zygotes (Lane *et al.* 1998). However, increasing Mg to 2 mM from 0.5 mM improved developmental competence and hastened the progression of nuclear maturation, irrespective of the Ca concentration.

The higher concentration of magnesium in the small follicles could help the mitosis of the follicular cells through the formation of thrombin, a potent mitogen. Magnesium could substitute calcium in thrombin formation under the condition of low Ca/Mg ratio that exists in small follicles. As magnesium was antagonistic to calcium, the decreased magnesium with follicular development facilitated the calcium action in large follicles (Kalmath, 2000).

Follicular fluid Enzymes

Acid phosphatase

The mean acid phosphatase concentration in follicular fluid of small, medium and large size follicles was 12.75 ± 0.16 , 11.65 ± 0.41 and 10.31 ± 0.44 U/L and 12.64 ± 0.28 , 11.56 ± 0.29 and 10.14 ± 0.26 U/L, respectively for ovaries having presence and absence of corpus luteum. The acid phosphatase concentration in follicular fluid on all the three size of follicles in both groups was significantly different and was decreased as the follicular diameter increased. The overall mean values of acid phosphatase in follicular fluids of small, medium and large size follicles was 12.68 ± 0.18 , 11.59 ± 0.23 and 10.19 ± 0.22 U/L, respectively, the difference being significant among the different size of follicles. The acid phosphatase concentration decreased with the increase in the follicular diameter. The overall mean acid phosphatase levels in follicular fluid was 11.56 ± 0.30 U/L and 11.16 ± 0.22 U/L respectively for both group, the difference being non significantly. The overall acid phosphatase levels for both group was 11.29 ± 0.18 U/L.

The present finding of the acid phosphatase concentration which significantly decreased with the increase in the follicular diameter was in agreement with study of Wise (1987) and Kalmath and Ravindra (2007) in buffaloes. Acid phosphatases are lysosomal enzymes which catalyze various reactions and involved in the active transport of phosphates across the cell membrane, synthesis of protein and DNA turnover in nucleus (Mishra *et al.*, 2003).

Alkaline phosphatase

The mean alkaline phosphatase concentration (U/L) in follicular fluid of small, medium and large size follicles was 293.24 ± 3.44 , 290.51 ± 3.59 and 225.02 ± 3.65 and 307.47 ± 8.41 , 250.39 ± 4.48 and 239.22 ± 9.77 for both the groups of ovaries respectively. The alkaline phosphatase concentration in follicular fluid of all the three size of follicles of ovaries with and without corpus luteum was significantly different and it decreased as the follicular diameter increased. The overall mean values of alkaline phosphatase in follicular fluid of small, medium and large size follicles was 300.68 ± 5.49 , 264.67 ± 7.1 and 235.43 ± 7.28 U/L, respectively which decreased as the follicular size increased. It differences was significantly among the diameter of follicles. The overall mean alkaline phosphatase concentration in follicular fluid was 267.44 ± 7.99 U/L and 259.94 ± 6.73 U/L, respectively for presence and absence of corpus luteum on the ovaries, the difference being non significant. The overall alkaline phosphatase for both the group of ovaries was 262.37 ± 5.22 U/L. The finding of alkaline phosphatase level for both the group of ovaries was significantly with the decreased in follicular diameter increased which was in close proximity with the results of Wise, (1987). Alkaline phosphatases are lysosomal enzymes which catalyze various reactions and involved in the active transport of phosphates across the cell membrane, synthesis of protein and DNA turnover in nucleus (Mishra *et al.* 2003).

The higher alkaline phosphatase activity in the initial stages of follicular development might be due to progesterone and androgen dominant environment that exists in the small follicle, in that a higher

concentration of progesterone and androgen could be conducive to phosphatase activity (Kalmath 2000). The activity of alkaline phosphatase in follicular fluid with the development of the follicle decreased due to the shift in the follicular hormonal milieu from androgen to estrogen dominant follicle.

Lactate dehydrogenase

The mean lactate dehydrogenase concentration in follicular fluid of small, medium and large size follicles with and without corpus luteum on the ovary was 319.04 ± 7.12 , 281.45 ± 7.16 and 227.51 ± 7.31 U/L and 320.64 ± 0.82 , 268.45 ± 6.56 and 235.43 ± 7.63 U/L, respectively. The lactate dehydrogenase concentration of follicular fluid of all the three size of follicles with and without corpus luteum was significantly different and decreased with the increase in the size of follicle. The overall mean values of lactate dehydrogenase in follicular fluid of small, medium and large size follicles was 320.36 ± 6.94 , 272.79 ± 5.08 and 233.32 ± 5.9 U/L, respectively. The lactate dehydrogenase concentration in follicular fluid of all the three size of follicles was significantly different and it decreased with the increase in the size of follicle. The overall mean of lactate dehydrogenase concentration in follicular fluid was 275.83 ± 9.51 U/L and 266.28 ± 7.10 U/L for ovaries in which corpus luteum was presence and absence, the difference being non significant among the group. The lactate dehydrogenase concentration was 269 ± 5.69 U/L.

In present study the lactate dehydrogenase concentrations significantly found to be decreased with the increase in the diameter of follicle such finding correlated well with the study of Wise (1987) and Abd Ellah *et al.* (2010) in buffaloes. The higher serum lactate dehydrogenase activity indicated that there was an inward movement of the lactate dehydrogenase from serum to the follicular fluid as reported by Abd Ellah *et al.* (2010). Increased activity of lactate dehydrogenase (LDH) in follicular fluid in small follicles indicated early follicular degeneration (Wise, 1987). This suggested that as the follicle degenerated, there were distinct biochemical changes that accompanied the degenerative processes. Isoenzyme analysis of lactate dehydrogenase activity in follicular fluid might

increase the accuracy and sensitivity of lactate dehydrogenase for a biological atresia marker in ovine follicles (Nandi *et al.*, 2007).

Follicular fluid Electrolyte

Sodium

The mean sodium concentration in follicular fluid of small, medium and large size follicles was 126.25 ± 2.06 , 130.15 ± 2.07 and 132.65 ± 1.28 mM/L and 126.46 ± 1.7 , 127.85 ± 1.54 and 132.62 ± 0.93 mM/L, respectively for ovaries with and without corpus luteum. The sodium concentration in follicular fluid of all the three size of follicles was not significantly different and it increased as the follicular diameter increased. The overall mean values of sodium in follicular fluid of small, medium and large size follicles was 126.38 ± 1.29 , 128.62 ± 1.23 and 132.62 ± 0.75 mM/L, respectively. The overall mean of sodium concentration in follicular fluid of all the three size of follicles was not significantly different and had showed increasing trend with the increase in the size of follicle. The overall mean of sodium concentration in follicular fluid of follicles was 129.64 ± 1.16 mM/L and 129.77 ± 0.84 mM/L respectively for ovaries with and without CL, the difference being non significant. The overall sodium concentration was 129.73 ± 0.67 mM/L.

The sodium levels non significantly increased as the follicular size increased in present study corroborate well with the study of Arshad *et al.* (2005), Wise, (1987) and Kaur *et al.* (1997). Increased follicular fluid sodium concentrations were related to follicle viability and were linked to the active follicular synthesis of estrogen. A compound with potent sodium retention action, 19-hydroxyandrostenedione, was found in large concentrations in the large follicles (Wise, 1987). Enlargement of the follicle dimension with follicular growth was largely due to the movement of water from blood to antrum, a process that requires an osmotic gradient across the follicular wall. Thus, increased sodium concentration in large follicles could create an osmotic gradient across the follicular wall to facilitate osmosis (Sharma *et al.*, 1995).

Potassium

The mean potassium concentration in follicular fluid

of small, medium and large size follicles was 9.62 ± 0.27 , 8.75 ± 0.40 and 6.47 ± 0.23 mM/L and 9.7 ± 0.27 , 8.65 ± 0.23 and 6.71 ± 0.17 mM/L, respectively for ovaries having corpus luteum and without corpus luteum. The potassium concentration in all the three size of follicles for both the group was significantly different and it decreased with the increased follicular diameter. The overall mean values of potassium in follicular fluid of small, medium and large size follicles was 9.69 ± 0.19 , 8.68 ± 0.20 and 6.65 ± 0.14 mM/L, respectively. The difference being significant and it decreased with the increase in the follicular size. The overall mean of potassium concentration of follicular fluid was 8.24 ± 0.34 mM/L and 8.00 ± 0.23 mM/L for ovaries bearing corpus luteum and without corpus luteum, the difference being non significant. The overall potassium value for both the group was 8.08 ± 0.19 mM/L.

In present study the potassium concentration significantly decreased as the follicular size increased. Similar finding was results of Iwata *et al.* (2004); Leroy *et al.* (2004); and Abd Ellah *et al.* (2010). The decreased concentration of follicular fluid potassium with follicular development could be due to the increased use of glucose by developing follicles, a process that leads to transfer of potassium ions from extracellular to intracellular (Chang *et al.*, 1976). The concentration gradient of potassium between serum and follicular fluid suggests an active inward transport of the cation and is involved in local metabolism (Gosden *et al.*, 1988).

CONCLUSION

Calcium, inorganic phosphorus and sodium non significantly increased in the follicular fluid of small to large follicles in both with and without corpus luteum of ovaries. The concentration of magnesium, acid phosphatase, alkaline phosphatase, lactate dehydrogenase and potassium significantly ($P < 0.05$) decreased in the follicular fluid of small to large follicles in both with and without corpus luteum of ovaries. The result of present study suggested that the oocyte and the granulosa cells of ovarian follicles of buffalo grow and mature in a changing minerals, enzymes and electrolytes from small to large follicles.

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Fishing gears and crafts operated along the Chorward coast, Maliya (hatina), Gujarat along the west coast of India

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ABSTRACT

Rapid development of fishing technology in India during the recent years has paved the way for increased production availability of new synthetic materials, evolution of new designs of fishing crafts and gears and avoidance of ignorant harmful fishing techniques etc. In the state of Gujarat, there are about 7,819 OBM gillnetters in operation in out of these 4,524 OBM gillnetters are active in Junagadh district. Among these, total 1,144 OBM gillnetters are in active fishing in Veraval. The Chorward village is about 25 km far away from the main fishing port of Taulakha place, where the present study was carried out from February 2012 to April 2013.

Key words : Fishing gears, fishing technology, craft

The term 'gillnetting' denotes catching of fish by gilling. Gillnetting is a highly selective fishing gear. It is one of the most suitable fish catching method from conservation and stock regulation point of view because of its selective fishing nature. Gill net is a long wall of webbing kept suspended in water by means of floats on the head rope and sinkers on the foot rope, in which the fish is trapped by its gills or is wedged when it tries to swim through (Markad, 2004). Selectivity of fishing gear is an important tool for effective management of fisheries (Thomas *et al.*, 2002). The importance of selecting the optimum mesh size from the standard point of conservation of resources has been stressed by several investigators. Gujarat is a frontline maritime state of India located in the extreme west of the country (20.1° to 24.7° North and 68.4° to 74.4° East). Gujarat with about 20% (1600 km) of the country's coastline, 33% of the continental shelf area (1,64,000 km²) and over 2,00,000 km² of EEZ ranks first among the maritime states in marine capture fish production. Saurashtra peninsula is the major fishing area of the state. It consists of seven districts namely Amreli,

Bhavnagar, Jamnagar, Surendranagar, Junagadh, Rajkot and Porbandar. Saurashtra region occupies about 50 percent of state's coastline, and accounts for more than 70 percent of fish production of Gujarat state. There are 200 FRP canoes, in the Chorward village, out of which only 150 are active in fishing. Most of the population of this village depend upon fishing activities as the main source of occupation (Anonymus, 2012). The fisherman of Chorward operates only gill nets during the whole year. The details of District wise mechanized and non-mechanised boats of Gujarat state are in Table 1.

MATERIALS AND METHODS

As per the Marine Fishing Regulation Act of Gujarat 2003, the fishing activities remains closed from 10th June to 15th August, due to monsoon and also rough condition of sea. Due to this bad weather, fishermen find it very difficult to navigate their vessels in the monsoon month, so all the fishing activities remain closed. Therefore, barring above described period, data was collected from 1st February 2012 to 30th April 2013. In every week, one day was fixed for sampling i.e. total 30 vessels were taken in to consideration. Periodical purposive random sampling was done to

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Table 1 District wise mechanized and non-mechanised boats of Gujarat state (Anon, 2012)

Sr. No.	District	Trawler	Gill netter	FRP IBM	FRP OBM	Wooden OBM	Dol netters/ Others	Total Mechanized	Mechanized %	Total Non-Mechanized	N.M.%	Total Boats	Percentage
1	VALSAD	550	908	364	0	0	779	2601	11.32	563	4.63	3164	9.00
2	NAVSARI	250	0	125	0	0	319	694	3.02	378	3.11	1072	3.05
3	DANG	0	0	0	0	0	0	0	0.00	0	0.00	0	0.00
4	SURAT	0	10	127	12	0	0	149	0.65	870	7.15	1019	2.90
5	TAPI	0	0	0	0	0	0	0	0.00	2327	19.13	2327	6.62
5	BHARUCH	0	250	422	0	0	0	672	2.92	940	7.73	1612	4.59
6	ANAND	0	0	0	0	0	0	0	0.00	168	1.38	168	0.48
7	KHEDA	0	0	0	0	0	0	0	0.00	40	0.33	40	0.11
8	VADODARA	0	0	4	3	28	0	35	0.15	495	4.07	530	1.51
9	NARMADA	0	0	0	4	0	0	4	0.02	394	3.24	398	1.13
10	PANCHMAHAL	0	0	0	0	1	0	1	0.00	2145	17.63	2146	6.11
11	DAHOD	0	0	0	0	0	0	0	0.00	539	4.43	541	1.54
12	AHMEDABAD	0	0	0	0	0	0	0	0.00	359	2.95	359	1.02
13	GANDHINAGAR	0	0	0	0	0	0	0	0.00	0	0.00	0	0.00
14	SABARKANTHA	0	0	0	0	0	0	0	0.00	509	4.18	509	1.45
15	BANASKANTHA	0	0	0	0	0	0	0	0.00	154	1.27	154	0.44
16	MEHSANAA	0	0	0	0	0	0	0	0.00	0	0.00	0	0.00
17	PATAN	0	0	0	0	0	0	0	0.00	1	0.01	1	0.00
18	RAJKOT	0	0	88	0	0	0	88	0.38	861	7.08	949	2.70
19	KUTCHCH	12	230	850	1	25	173	1291	5.62	162	1.33	1453	4.13
20	JAMNAGAR	216	402	625	985	5	0	2233	9.71	385	3.17	2618	7.45
21	SURENDRANAGAR	0	0	0	0	0	0	0	0.00	464	3.81	464	1.32
22	BHAVNAGAR	0	0	206	0	0	0	206	0.90	20	0.16	226	0.64
23	PORBANDHAR	2313	115	16	2288	0	0	4732	20.59	133	1.09	4865	13.84
24	JUNAGADH	4078	122	332	4524	24	574	9654	42.00	257	2.11	9911	28.20
25	AMRELI	0	30	16	21	0	573	624	2.71	0	0.00	624	1.78
	TOTAL	7419	2067	3180	7819	83	2418	22986	100.00	12164	100	35150	100.00

Source : Anonymous, 2012

collect the required data. The collected data were analyzed as per the standard statistical methods (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Fishing operation

Actual fishing time varies from time to time and season to season, depending on various factors like climate, season and the availability of the fish. In the present study, it was observed that the fishermen of the Chorward coast started fishing at evening time i.e. 4 pm and reported back to the coast next day at 4-5 am early in the morning. Gillnetters which went for fishing at 5 am early in the morning reported back to coast 5 pm in the evening time. Gillnetting was done in the depth range of 20-50 m. Normally two crew members were going for fishing operation, except the owner. The fishing operation was carried out for 6-12 hours. It was found that fishermen were going for fishing for 15-17 days in a month. Depth of operation varied from five to fifteen meters along Tamil Nadu coast (Sathiadhas, 1989) and 20 to 45 m along Chennai, Tuticorin, Gujarat coast (Koya and Vivekanandan, 1992; Luther *et al.*, 1997) and 24-180 m along the Ratnagiri coast (Markad, 2004). It was observed from the reported results that the depth of operation of gill net along the Indian coast ranged from 5.0 to 45 m.

Vessel and Engine specifications

Among all the OBM gillnetters of Chorward village were Fibre reinforced plastic (FRP) coated. In

Chorward village, there are about 300 OBM gillnetters, out of which only 240 are active in fishing. For the present study, 30 OBM gillnetters were taken in to consideration for collection of data. These all OBM gillnetters were fitted with 2 cylinders, 8 Horse power (HP) engine. Table II shows the vessel and engine specifications for OBM gillnetters operating from Chorward coast, Maliya. The length of OBM gillnetters varied from 7.29 to 9.45 m with an average of 8.28 ± 0.10 , and the breadth of the OBM gillnetters varied from 1.21 to 1.80 m with an average of 1.58 ± 0.04 m. The tonnage of these gillnetters was observed in the range of 1.58 to 3.81 t with an average of 2.25 ± 0.10 t. Most of the gillnetters selected by different researchers for their study were found within the similar range of 6 to 12 m OAL. Silas *et al.* (1984) studied gillnetters along the Cochin coast which ranged from 9.14 to 9.62 m fitted with two cylinder and three cylinder engine whereas other workers have studied gillnetters of sizes 6.7 to 9.8 m with 8.0 HP engine at the Cochra-Nivti in Sindhudurg district of Maharashtra and Dhamlej in Junagadh district of Gujarat (Sehara and Karbhari, 1989), 6 to 16 m along the Kerala coast (Annamalai and Kandoran, 1990), 7.6 and 9.1 m along the Kerala coast (Sathiadhas and Benjamin, 1990), motorised nava with six to seven meters size at selected villages of Kanyakumari district in Tamil Nadu (Annamalai and Kandoran, 1993), 7.62 m OAL at Cochin (Iyer, 1993), 8.5 m mechanised gillnetters with 40 to 45 HP engine at Quilon and Ernakulam districts of Kerala (Panikkar *et al.*, 1993), 12 m motorised crafts with 8 HP engine along Veraval

Table 2 Vessel and engine specifications for OBM gillnetters operating from Chorward coast, Maliya.

Sr.No.	Specification	Minimum	Maximum	Mean ($\pm$ SE)
1	Overall length (m)	7.29	9.45	8.28 (± 0.10)
2	Breadth (m)	1.21	1.80	1.58 (± 0.04)
3	Cylinder	2.00	2.00	2.00 (± 0)
4	Engine power (HP)	8.00	8.00	8.00 (± 0)
5	Tonnage (t)	1.58	3.81	2.25 (± 0.10)
6	Crew number	2.00	2.00	2.00 (± 0)
7	Voyage time (hr)	6.00	12.00	8.93 (± 0.30)
8	Actual fishing time (hr)	16.00	5.00	10.5 (± 0.58)
9	Depth of operation (m)	13	50	30.23 (± 3.47)

coast in Gujarat (Doss *et al.*, 1997), of 10 to 13 m mechanised vessels with 20 HP engine along the Chennai and Tuticorin coast (Luther *et al.*, 1997) and 9.76-12.54 m with 20 HP engine along the Ratnagiri coast (Markad 2004).

Gear specifications

Data on gear specification revealed that the Chorward fishermen were using three different types of gill nets for catching varieties of fishes which are made of monofilament and multifilament. *Dhaker* gill net having mesh size 120-140 mm length of single piece was 130 m long and the numbers of pieces tied together were 10-12. *Chokla* gill net having mesh size 60-81 mm length of single piece was 110-150 m in length and the numbers of pieces together were 10-12. *Jada jal* had mesh size of 180 mm, where the length of single piece was 300 m and the numbers of pieces tied together were 50-100 as mentioned in Table III. Some of the workers have reported these aspects in their study. Silas *et al.* (1984) studied the drift gill nets off Cochin and reported that the mesh size variation was 70 to 130 mm. Mesh sizes reported by other workers ranged between 50 to 130 mm (Sehara and Karbhari, 1989b), 30 to 63 mm (Sathiadhas *et al.*, 1991), 65 to 215 mm (Koya and Vivekanandan, 1992) and 14 to 500 mm (Luther *et al.*, 1997). Total length and height reported by various authors varied from 800 to 1000 m and four

to eight m respectively (Silas *et al.*, 1984), and 100 m to 2500 m and three meter to 15 m respectively (Luther *et al.*, 1997). Authors have reported variations in number of pieces used at a time and were 9 to 12 (Silas *et al.*, 1984), 15 to 70 (Sehara and Karbhari, 1989b), 20 to 40 (Sathiadhas *et al.*, 1991), 30 to 60 (Koya and Vivekanandan, 1992; Luther *et al.*, 1997) and 20-36 (Markad., 2004).

Comparing the mesh size with other coasts it showed that in case of Chorward coast mesh size was found more similarly comparing the total length and total height with other coasts it was also found more in case of Chorward gill nets. The numbers of pieces used in this net were less as compared to the gill net used in the other parts of the country.

Fishing equipments

During the present study it was observed that none of the gillnetters was using the fish finding equipments as well as navigational equipments as the size of the vessel was not large enough to install equipments viz. eco-sounder and Sound navigation and ranging (SONAR). Very high frequency (VHF) set was not found on any of the gillnetters as they were going for one-day fishing trip and fishing grounds were not far away from the landing centre. No fire fighting devices were found on the vessel due to lack of space.

Table 3 Specifications of gill net operated by OBM gillnetters of Chorward coast, Maliya.

Type of net	Species caught	Mesh size (mm)	Length of single piece(m)	Number of pieces	Total weight of net(Kg)	Total length (m)	Total height (m)
Gill net (Dhaker) Monofilament	<i>Pampus argenteus</i> , <i>Parastromateus niger</i> , <i>Hilsa</i> etc.	120-140	130	10-12	75-100	1000-1500	12-14
Gill net (Chokla) Monofilament	<i>Lepturacanthus savala</i> , <i>Rastrelliger kanagurata</i> , <i>Scomberomorus commerson</i> , <i>Carnax para</i> etc.	60-81	110-150	10-12	75-100	1000-1500	12-13
Gill net (Jada jaal) Multifilament	<i>Scomberomorus commerson</i> and <i>Scomberomorus lineolatus</i> .	180	300	50-100	250-500	1500-3000	6-9

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Weed management in *kharif* rice (*Oryza sativa* L.) under System of Rice Intensification (SRI)

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India is the world's second largest rice producer and consumer next to China. Total area under rice in India is 44 million hectares with annual production of 90 million tonnes. It needed to be enhanced from the present 90 million tonnes to about 100 million tonnes by the end of eleventh plan period to meet the growing demand of rapidly increasing population (Kumar *et al.* 2008). The main reasons of low productivity and profitability are vagaries of nature, low water and fertilizer use efficiency and poor crop management practices (poor input use efficiency) including adherence of farmers to the traditional costlier practices, besides low market price of farm produce, especially in the recent past.

A field experiment was conducted during *kharif* season on rice (Cv. GR-12) in the year 2010 at Main Rice Research Station, Anand Agricultural University, Nawagam. The experimental soil was silty clay loam, low in organic carbon (0.36%), medium in available nitrogen (254.34 kg ha⁻¹), phosphorus (35.84 kg ha⁻¹) and high in available potassium (316.35 kg ha⁻¹).

The experiment was laid out in randomized block design with four replications. Ten weed control treatments were studied viz., Weedy check (W₁), Weed free (three HW at 15, 30 & 45 DATP) (W₂), two conoweedings at 10, 20 DATP (W₃), three conoweedings at 10, 20 & 30 DATP (W₄), four conoweedings at 10, 20, 30 & 40 DATP (W₅), Butachlor @ 1.5 kg ha⁻¹ at 5 DATP (W₆), Butachlor @ 1.5 kg ha⁻¹ at 5 DATP + one conoweeding at 30 DATP (W₇), Butachlor @ 1.5 kg ha⁻¹ at 5 DATP + one

HW at 30 DATP (W₈), Pyrazosulfuron @ 25 g ha⁻¹ at 10-12 DATP (W₉), Fenoxaprop-p-ethyl @ 70 g ha⁻¹ at 10-12 DATP (W₁₀). Pre-emergence and post-emergence herbicides were sprayed with Knapsack sprayer fitted with flat fan nozzle using 500 litres of water per hectare as per treatment.

The dominant weed flora found in weedy check plot of field experiment was *Echinochloa crusgalli* L. and *Cynodon dactylon* L. (grassy weeds), *Cyperus rotundus* L. and *Cyperus iria* L. (sedges) and *Eclipta alba* L. and *Amisophacelus cucuttala* L. (broad leaved). At 25 & 50 DATP, significantly the lowest weed dry bio-mass and number of total weed counts were registered under the treatment of three hand weedings carried out at 15, 30 & 45 DATP (W₂) as compared to other weed management treatments. At harvest, results indicated that lower total weed dry bio-mass was registered under treatment of three hand weedings carried out at 15, 30 & 45 DATP (W₂) and it remained at par with treatments of pre-emergence application of Butachlor @ 1.5 kg ha⁻¹ at 5 DATP + one HW at 30 DATP (W₈), four conoweeding at 10, 20, 30 & 40 DATP (W₅). Significantly higher weed dry bio-mass was recorded in weedy check (W₁) at harvest. Similar results were reported by Shekhar and Mankotia (2005).

It is clear from the data that treatment of three hand weedings carried out at 15, 30 & 45 DATP (W₂) recorded higher weed control efficiency (WCE) followed by the treatments of four conoweeding at 10, 20, 30 & 40 DATP (W₅), pre-emergence application of Butachlor @ 1.5 kg ha⁻¹ at 5 DATP + one HW at 30 DATP (W₈), post-emergence application of Pyrazosulfuron @ 25 g ha⁻¹ at 10-12

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Table 1 Effect of weed management treatments on intensity of total weeds, dry bio-mass of total weeds, weed index, weed control efficiency, grain and straw yields at different growth of *Kharif* rice grown under system of rice intensification

Treatments	Intensity of total weeds (no. m ⁻²)		Dry bio-mass of total weeds (gm ²)		WI (%)	WCE (%)	Yield (kg ha ⁻¹)	
	At 25 DATP	At 50 DATP	At 25 DATP	At 50 DATP			Grain	Straw
W ₁ - Weedy check	9.71 ^a (93.75)	13.51 ^a (181.75)	87.60 ^a	145.69 ^a	40.95	0.00	2945 ^c	3473 ^c
W ₂ - Weed free (three HW at 15, 30 & 45 DATP.)	2.17 ^a (3.75)	3.72 ^a (13.00)	5.18 ^a	39.63 ^f	0.00	76.38	4988 ^a	5491 ^a
W ₃ - Two conoweeding at 10 & 20 DATP	6.53 ^b (41.75)	9.97 ^b (98.75)	44.98 ^b	88.17 ^e	14.23	40.92	4278 ^b	4579 ^b
W ₄ - Three conoweeding at 10, 20 & 30 DATP	4.29 ^d (17.50)	7.95 ^c (62.25)	26.86 ^d	70.30 ^c	13.19	53.45	4330 ^b	4818 ^b
W ₅ - Four conoweeding at 10, 20, 30 & 40 DATP	2.82 ^f (7.00)	4.58 ^f (20.25)	9.23 ^e	48.90 ^e	6.68	71.92	4655 ^{bc}	5102 ^{bc}
W ₆ - Butachlor @ 1.5 kg ha ⁻¹ at 5 DATP	5.06 ^c (24.75)	6.57 ^d (42.25)	26.69 ^d	61.40 ^d	12.50	63.50	4364 ^b	4846 ^b
W ₇ - Butachlor @ 1.5 kg ha ⁻¹ at 5 DATP + one conoweeding at 30 DATP	4.60 ^{cd} (20.25)	5.74 ^e (32.00)	24.72 ^d	57.48 ^d	8.36	67.69	4571 ^{bc}	5013 ^{bc}
W ₈ - Butachlor @ 1.5 kg ha ⁻¹ at 5 DATP + one HW at 30 DATP	3.84 ^e (13.75)	4.92 ^f (23.25)	13.68 ^f	47.97 ^e	6.46	71.97	4665 ^{bc}	5123 ^{bc}
W ₉ - Pyrazosulfuron @ 25 g ha ⁻¹ at 10-12 DATP	4.38 ^d (18.25)	6.39 ^{de} (40.00)	20.01 ^e	57.44 ^d	6.87	66.81	4645 ^{bc}	5096 ^{bc}
W ₁₀ - Fenoxaprop-p-ethyl @ 70 g ha ⁻¹ at 10-12 DATP	6.82 ^b (45.75)	8.24 ^c (67.00)	38.30 ^c	61.62 ^d	12.33	56.83	4373 ^b	4888 ^b
S.E.m. ±	0.16	0.23	1.14	2.44	-	-	188.05	175.51
C. D. at 5 %	Sig.	Sig.	Sig.	Sig.	-	-	Sig.	Sig.
C. V. %	6.64	6.40	7.70	7.20	-	-	8.58	7.25

* Figures in parentheses are original values. All figures subjected to transformed values to square root $\sqrt{(X+1)}$. Figures indicating common letters in column do not differ significantly from each other at 5 % level of significance according to Duncan New Multiple Range Test

DATP (W_9), Butachlor @ 1.5 kg ha⁻¹ at 5 DATP + one conoweeding at 30 DATP (W_7) and Butachlor @ 1.5 kg ha⁻¹ at 5 DATP (W_6). Weed control efficiency was varied between 69.5 to 100 % in these treatments.

Significantly lower weed index was observed under treatment of three hand weedings carried out at 15, 30 & 45 DATP (W_2) followed by treatments of pre-emergence application of Butachlor @ 1.5 kg ha⁻¹ at 5 DATP + one HW at 30 DATP (W_8), four conoweeding at 10, 20, 30 & 40 DATP (W_5), post-

emergence application of Pyrazosulfuron @ 25 g ha⁻¹ at 10-12 DATP (W_9), Butachlor @ 1.5 kg ha⁻¹ at 5 DATP + one conoweeding at 30 DATP (W_7), Fenoxaprop-p-ethyl @ 70 g ha⁻¹ at 10-12 DATP (W_{10}) and Butachlor @ 1.5 kg ha⁻¹ at 5 DATP (W_6). The weedy check (W_1) recorded the maximum weed index. Halder and Patra (2007) also obtained similar results.

Significantly higher yield attributing characters viz., panicle weight, panicle length, test weight and

Table 2. Yield attributing characters of rice influenced by weed management treatments at harvest grown under system of rice intensification

Treatments	Panicle length (cm)	Panicle weight (g)	Number of grains panicle ⁻¹	Test weight (g)
W_1 - Weedy check	18.42 ^c	1.98 ^c	149.75 ^c	14.05 ^c
W_2 - Weed free (three HW at 15, 30 & 45 DATP.)	24.50 ^a	3.38 ^a	239.25 ^a	17.35 ^a
W_3 - Two conoweeding at 10 & 20 DATP	21.00 ^b	2.94 ^b	199.75 ^b	14.90 ^{bc}
W_4 - Three conoweeding at 10, 20 & 30 DATP	22.38 ^{ab}	2.83 ^b	215.75 ^{ab}	15.33 ^{abc}
W_5 - Four conoweeding at 10, 20, 30 & 40 DATP	23.28 ^{ab}	3.15 ^{ab}	226.00 ^a	17.03 ^a
W_6 - Butachlor @ 1.5 kg ha ⁻¹ at 5 DATP	22.53 ^{ab}	3.01 ^{ab}	217.50 ^{ab}	16.95 ^{ab}
W_7 - Butachlor @ 1.5 kg ha ⁻¹ at 5 DATP + one conoweeding at 30 DATP	22.63 ^{ab}	3.19 ^{ab}	219.00 ^{ab}	17.00 ^a
W_8 - Butachlor @ 1.5 kg ha ⁻¹ at 5 DATP + one HW at 30 DATP	23.45 ^{ab}	3.21 ^{ab}	226.75 ^{ab}	17.15 ^a
W_9 - Pyrazosulfuron @ 25 g ha ⁻¹ at 10-12 DATP	23.00 ^{ab}	3.17 ^{ab}	225.00 ^a	17.13 ^a
W_{10} - Fenoxaprop-p-ethyl @ 70 g ha ⁻¹ at 10-12 DATP	21.83 ^b	3.05 ^{ab}	219.00 ^{ab}	16.68 ^{ab}
S.Em. $\pm$	0.78	0.12	7.65	0.64
C. D. at 5 %	Sig.	Sig.	Sig.	Sig.
C. V. %	6.95	8.18	7.16	7.77

* Treatments means with the letters in common are not significant according to Duncan New Multiple Range Test at 5 % level of significance

number of grain per panicle were noted under treatment of three hand weedings carried out at 15, 30 & 45 DATP (W_2), but remained at par with treatment of pre-emergence application of Butachlor @ 1.5 kg ha^{-1} at 5 DATP + one HW at 30 DATP (W_8), four conoweeding at 10, 20, 30 & 40 DATP (W_5), post-emergence application of Pyrazosulfuron @ 25 g ha^{-1} at 10-12 DATP (W_9) and Butachlor @ 1.5 kg ha^{-1} at 5 DATP + one conoweeding at 30 DATP (W_7), (Table 2). This might be due notable increase in uptake of nutrients, growth and development and thereby increase in yield attributes under weed free condition.

Significantly higher grain & straw yield of rice were recorded under treatment of three hand weedings carried out at 15, 30 & 45 DATP (W_2) which was remained at par with treatments of pre-emergence application of Butachlor @ 1.5 kg ha^{-1} at 5 DATP + one HW at 30 DATP (W_8), four conoweedings at 10, 20, 30 & 40 DATP (W_5), post-emergence application of Pyrazosulfuron @ 25 g ha^{-1} at 10-12 DATP (W_9) and Butachlor @ 1.5 kg ha^{-1} at 5 DATP + one conoweeding at 30 DATP (W_7). Significantly the lowest grain yield was recorded under weedy check (W_1) which might be due to higher infestation of weeds in the plot resulted in strong competition of weeds with the crop for moisture, light, nutrients and space. These results are in close association with the findings of Saha *et al.* (1999) and Dixit and Varshney (2008).

In view of the results obtained from this investigation, it could be conducted that higher

profitable yield of *kharif* rice grown under System of Rice Intensification could be obtained by keeping it weed free by three hand weedings carried out at 15, 30 & 45 days after transplanting (DATP). While under labour crises situations, either Pyrazosulfuron @ 25 g ha^{-1} in 500 litres of water at 10-12 DATP or Butachlor @ 1.5 kg ha^{-1} in 500 litres of water at 5 DATP coupled with one hand weeding at 30 DATP may be adopted.

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Non-chemical management of shoot and fruit borer (*Leucinodes orbonalis* Guenee) on brinjal

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Brinjal (*Solanum melongena* Linn.) is an important vegetable crop grown all over the country in different types of soil. Brinjal shoot and fruit borer (*Leucinodes orbonalis* Guen.) is most important, noxious and typical cosmopolitan pest causing serious damage to brinjal cultivation and limits the yield to very low level. The affected growing point is damaged and showed typical drooping symptom, whereas, affected fruits showed holes and fetch less price in the market. The increasing concern for environmental safety and global demand for pesticide residue free food has evoked keen interest in pest control through eco-friendly plant products which are easily biodegradable and do not leave any harmful toxic residues besides conserving natural enemies.

Field experiment was conducted at Horticultural Instructional Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat during *kharif* 2012. The brinjal seedlings of var. GOB-1 were transplanted in the plots of 3m × 3m size at 75cm × 60cm plant spacing. There were eight treatments including control and each treatment was replicated four times. All the crop management practices except the insecticide applications were followed to maintain healthy crop growth. Spraying was done late in the afternoon with high volume knapsack sprayer. Total three sprays were applied at 15 days interval when initial damage of *L. orbonalis* Guen. was started commencing 35 days after transplanting. Observations were recorded on infested shoots and fruits from five randomly selected plants from each treatment plots before as

well as 7 and 14 day after each spray. The fruit damage on number as well as weight basis was observed during each picking by counting the total healthy as well as infested fruits to work out the per cent fruit infestation. The data recorded from the field were subjected to statistical analysis. To find out an effective and economical control of shoot and fruit borer incremental cost benefit ratio was worked out for each treatment. Yield increase over control was calculated by yield of treatment minus yield of control and per cent yield increased over control was calculated by yield of treatment minus yield of control divided by yield of treatment into one hundred.

RESULTS AND DISCUSSION

The data presented in Table 1 shows that the seven days after first application T_3 (11.66%) was found significantly more effective in recording lowest mean percentage of shoot infestation and was at par with T_5 (16.25%). Fourteen days after first application T_5 (10.69%) recorded significantly lower shoot borer infestation and were as effective as T_6 (12.66%), T_3 (13.73%), T_7 (13.98%), T_2 (15.08%) and T_1 (14.88%) in reducing the shoot borer infestation. Control plot recorded significantly highest shoot borer infestation (23.25%).

Seven days after second application of treatment, T_5 (8.69%) recorded significantly lower shoot infestation which was at par with T_1 (10.88%), T_3 (11.00%) and T_6 (11.02%), respectively. Fourteen days after second application of treatment, T_5 recorded significantly the lowest shoot infestation (5.89%) and was at par with T_3 (7.54%). However, control plot recorded significantly highest shoot infestation (16.50%).

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Table 1 Effect of various non-chemical treatments against the infestation of *L. orbonalis* on brinjal

Treatment	Mean per cent damage of shoot											Mean per cent damage of fruit	
	1 DBS	1 st spray			2 nd spray			3 rd spray			Pooled of three spray	Number base	Weight base
		7	14	DAS	7	14	DAS	7	14	DAS			
T ₁ - Green Chilli extract 5%	22.99 (15.25)	27.09 (20.74)	22.69 (14.88)		19.26 (10.88)	17.32 (8.86)		14.82 (6.54)	13.73 (5.63)		19.15 (10.76)	22.73 (14.93)	22.46 (14.60)
T ₂ - Garlic bulb extract 2%	22.97 (15.23)	27.53 (21.36)	22.85 (15.08)		20.64 (12.43)	17.89 (9.44)		15.87 (7.48)	14.72 (6.46)		19.92 (11.61)	25.38 (18.37)	24.91 (17.74)
T ₃ - Infested shoot and fruit pruned at weekly interval	22.33 (14.44)	19.97 (11.66)	21.75 (13.73)		19.37 (11.00)	15.94 (7.54)		13.88 (5.75)	12.34 (4.57)		17.21 (8.75)	21.23 (13.11)	21.30 (13.20)
T ₄ - Tobacco decoction 1.5%	23.16 (15.47)	26.39 (19.76)	25.09 (17.98)		21.86 (13.86)	19.12 (10.73)		16.83 (8.38)	14.73 (6.47)		20.67 (12.46)	23.99 (16.53)	23.25 (15.58)
T ₅ - Neem oil 0.5%	23.21 (15.53)	23.77 (16.25)	19.09 (10.69)		17.14 (8.69)	14.04 (5.89)		12.01 (4.33)	11.08 (3.69)		16.19 (7.77)	18.07 (9.62)	17.70 (9.24)
T ₆ - NSKE 5%	22.03 (14.07)	26.01 (19.23)	20.84 (12.66)		19.39 (11.02)	16.95 (8.50)		14.83 (6.55)	13.52 (5.47)		18.59 (10.16)	22.36 (14.47)	21.95 (13.97)
T ₇ - Bt formulation @ 1.5g/lit water	21.23 (13.11)	25.35 (18.33)	21.96 (13.98)		21.34 (13.24)	19.41 (11.04)		16.61 (8.17)	14.88 (6.59)		19.93 (11.62)	24.10 (16.67)	24.05 (16.61)
T ₈ - Control	23.34 (15.69)	33.24 (30.05)	28.83 (23.25)		25.92 (19.11)	23.97 (16.50)		20.50 (12.26)	18.33 (9.89)		25.13 (18.03)	32.11 (28.25)	31.72 (27.64)
S. Em.±	0.82	1.48	1.48		0.94	0.75		0.73	0.68		0.43	0.94	0.98
C. D. at 5%	N.S.	4.36	4.37		2.76	2.20		2.16	2.00		1.20	2.76	2.89
C. V. %	7.23	11.33	12.97		9.09	8.28		9.37	9.61		10.90	7.91	8.38

Table 2 Effect of various non-chemical treatment on the yield of marketable fruits of brinjal

Treatments	Yield of marketable fruits (Q/ha)	Yield increase over control (Q/ha)	Percent increase over control
T ₁ - Green chilli extract 5%	351.62	75.20	21.39
T ₂ - Garlic bulb extract 2%	321.40	44.98	14.00
T ₃ - Infested shoot and fruit pruned at weekly interval	381.65	105.23	27.57
T ₄ - Tobacco decoction 1.5%	332.52	56.10	16.87
T ₅ - Neem oil 0.5 %	402.80	126.38	31.37
T ₆ - NSKE 5%	364.43	88.01	24.15
T ₇ - Bt formulation @ 1.5g/lit water	339.41	62.99	18.56
T ₈ - Control	276.42	----	----
S. Em.±	13.42	----	----
C. D. at 5%	39.49	----	----
C. V. %	7.75	----	----

Seven days after third application of non-chemical treatments T₅ recorded significantly lowest shoot infestation of 4.33 per cent being at par with T₃ (5.75%). Fourteen days after third application of non-chemical treatments T₅ recorded significantly lowest shoot infestation of 3.69 per cent and was at par with T₃ (4.57%). All other treatments were effective to reduce shoot infestation than control plot (9.89%), respectively.

The data on shoot damage pooled over three spray presented in Table 1 revealed that all non-chemical treatments recorded significantly lower damage (7.77% to 12.46%) than control (18.03%). The non-chemical treatment T₅ recorded significantly lowest shoot infestation (7.77%) which was at par with T₃ (8.75%). All other treatments were effective to reduce shoot infestation than control plot (18.03%) where highest shoot infestation observed. Similar results have been shown by Murugesan and Murugesh (2009) and Mathur *et al.*, (2012).

The data presented in Table 1 revealed that treatment T₅ was significantly superior to other treatments which recorded lowest percentage (9.62%) of fruit infestation. Among the other treatments T₃ (13.11%) was found more effective in reducing fruit infestation on number basis being at par with T₆ (14.47%), T₁ (14.93%), T₄ (16.53%), whereas control plot recorded lowest percentage

fruit damage of (28.25%), respectively.

The data on damaged fruits on weight basis in different treatments (Table 1) indicated that the treatment T₅ was recorded the lowest infestation (9.24%) and proved significantly superior to the rest of the treatments. The next effective treatments were T₃ (13.20%), T₆ (13.97%), T₁ (14.60%) and T₄ (15.58%) which were at par with one another. However, control plot recorded significantly highest per cent fruit infestation (27.64%) on weight basis. Similar results have been reported by Sasikala *et al.*, (1999) and Kardale *et al.*, (2010).

The data on fruit yield harvested from the different treatments presented in Table 2 revealed that the highest (402.80 Q/ha) fruit yield was harvested in T₅ and was at par with T₃ (381.65 Q/ha) and T₆ (364.43 Q/ha). However control plot recorded significantly lowest fruit yield 276.42 Q/ha, respectively.

The increase in fruit yield over control was also worked out and presented in Table 2 revealed that the maximum yield increased over control was recorded in the plots treated with neem oil 0.5 per cent (126.38 Q/ha) while minimum in plot treated with garlic bulb extract 2 per cent (44.98 Q/ha), respectively. Maximum increase in yield over control was recorded in neem oil 0.5 per cent, while minimum in garlic bulb extract 2 per cent. Similar

Table 3 Economics of various non-chemical treatments used for control of *L. orbonalis* infesting brinjal

Treatments	Quantity of insecticides for three applications (lit or kg/ha)	Cost of applied treatments (₹/ha)	Cost of labour (₹/ha)	Total cost of plant protection for three applications (₹/ha)	Yield (q/ha)	Gross realization (₹/ha)	Net realization over control (₹/ha)	Net profit (₹/ha)	ICBR
1	2	3	4	5	6	7	8	9	10
T ₁ - Green chilli extract 5%	75 kg	2250	1080	3330	351.62	421944	90240	88020	1:26.43
T ₂ - Garlic bulb extract 2%	30 kg	1050	1080	2130	319.19	383028	51324	49854	1:23.41
T ₃ - Infested shoot and fruit pruned at weekly interval	----	----	4320	4320	381.65	457980	126276	124116	1:28.73
T ₄ - Tobacco decoction 1.5%	22.5 kg	1237	1080	2317	332.52	399024	67320	66150	1:28.54
T ₅ - Neem oil 0.5%	7.5 lit	3450	720	4170	402.80	483360	151656	149286	1:35.80
T ₆ - NSKE 5%	75 kg	2250	1080	3330	364.43	437316	105612	104517	1:31.39
T ₇ - Bt formulation @ 1.5	2.25 kg	2673	720	3339	339.41	407292	75588	74200	1:22.28
T ₈ - Control	----	----	----	----	276.42	331704			

Note: - Labour charge: ₹ 120.00/labour/day (Two labours per hectare required for one spray and one labour required for preparation of material before each spray)

Market price of fruit yield: ₹ 1200/quintal

1. Chilli: ₹ 30.00/kg.
2. Garlic: ₹ 35.00/kg
3. Tobacco leaf powder: 55.00/kg
4. Neem oil: 460.00/lit
5. Dry Neem seed: ₹ 30.00/kg
6. Halt: ₹ 297.00/ 250 gm
7. Labour required for infested shoot pruning: 6 no. /week

results have been reported by Adiroubane and Raghuraman (2008) and Kardale *et al.* (2010).

The data presented in Table 3 concluded that the highest incremental cost benefit ratio (ICBR) was in the treatment T_5 (1:35.80) followed by T_6 (1:31.39), T_3 (1:28.73), T_4 (1:28.54), T_1 (1:26.43), T_2 (1:23.41) and T_7 (1:22.28), respectively. The similar results have reported by Kardale *et al.*, (2010) and Mathur *et al.*, (2012).

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Powdery mildew incidence and conidial variability of *E. polygoni* in the samples collected from major fenugreek growing areas of North Gujarat

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Fenugreek (*Trigonella foenum graecum* L.) is an important spice crop. Powdery mildew caused by *Erysiphe polygoni* DC. is an important yield limiting factor and widely distributed disease of fenugreek. The disease has been observed to occur at flowering and pod formation stages (Dhruj *et al.*, 2000) and damages all parts of the plant. The yield losses due to powdery mildew disease in fenugreek were estimated to the tune of 27-33 per cent in Haryana (SomPrakash and Saharan, 2002). Hence, attempts were made to know the occurrence of disease in major fenugreek growing areas of North Gujarat as well as variability in the pathogen, if any.

Survey of powdery mildew disease of fenugreek was carried out in fenugreek growing areas of North Gujarat viz., Banaskantha and Patan during 2011-12. Three talukas of each of Banaskantha (Tharad, Dhanera and Vav) and Patan (Patan, Chanasma and Siddhpur) districts were surveyed to assess the extent of powdery mildew disease of fenugreek. The crop was critically observed thrice during crop growth periods viz., (i) vegetative stage (ii) pod formation stage (iii) maturity stage. Three villages in each Taluka and five fields in each village were observed. The incidence of powdery mildew was assessed from 15 spots per district by visual observation of diseased area and percent disease incidence was calculated as follows:

$$\text{Per cent Disease incidence} = \frac{\text{No. of fields infected}}{\text{No. of fields observed}} \times 100$$

The intensity of powdery mildew was worked out by randomly observing twenty five plants in each field. The plants were graded by using 0-5 scale at three crop growth stages as mentioned above.

Grade	Description
0	Healthy / No incidence
1	Nearly 50 per cent leaves covered with whitish growth
2	> 50 per cent leaves covered with whitish growth
3	> 50 per cent leaves, stems/branches covered with whitish growth
4	> 50 per cent leaves, stems/branches and pods covered with whitish growth
5	Plant completely covered with whitish growth

The per cent disease intensity was worked out by using following formula (Mckinney, 1923).

$$\text{Percent Disease Intensity (PDI)} = \frac{\text{Sum of all numerical rating}}{\text{Total number of plants examined} \times \text{Maximum rating}} \times 100$$

Fenugreek plants sowing typical powdery mildew symptoms were collected from each infected spot and brought to the laboratory for the purpose of examination. The length (L) and breadth (B) of conidia were measured by Ocular Micrometer and their L/B index was calculated. In each case, 200 conidia stained in cotton blue and mounted in lactophenol were measured. The differences in the

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size of conidia were statistically analysed to find out the morphological difference, L/B (Length and Breadth in μm) ratio was also determined by dividing length of conidium with its Breadth.

RESULTS AND DISCUSSION

The data (Table 1) indicated that powdery mildew of fenugreek was prevalent in both the fenugreek growing districts. The disease was higher (75.55 %) in Banaskantha as compared to patan (66.66 %) district. Among different talukas, maximum disease incidence (86.66 %) was observed in Vav followed by Tharad (80.00 %) and least was in Dhanera (60.00 %) taluka of Banaskantha district. Similarly, maximum disease incidence (73.33 %) was observed in Patan followed by Chanasma (66.66 %) and least was in Siddhpur (60.00 %) taluka of Patan district.

As regards to per cent disease intensity, the disease was not recorded at any of the location surveyed at vegetative stage of the crop. At pod formation stage,

higher average intensity of (46.96 %) was recorded in Vav followed by Tharad (42.04 %) and least was in Dhanera (27.68 %) taluka of Banaskantha district. Similarly in Patan district also, higher average intensity of (36.00 %) was recorded in Patan followed by Chansma (33.36 %) and least was in Siddhpur (28.72 %). The powdery mildew intensity progressively increased towards maturity stage of crop wherein maximum average intensity of (68.48 %) was recorded again in Vav taluka, while, minimum (47.52 %) was in Dhanera taluka of Banaskantha district. In case of Patan district, average powdery mildew intensity was maximum (57.60 %) in Patan taluka, while, minimum (49.92 %) was in Siddhpur at maturity stage.

The average disease intensity varied in different talukas in different districts owing to varied agro-climatic conditions, inoculum potential and varieties cultivated with different genetic makeup. It was observed that disease progress in natural condition was from pod formation stage to maturity stage.

The results obtained in present investigations are in agreement with powdery mildew of different crops

Table 1 Taluka and district-wise per cent disease incidence and intensity of powdery mildew of fenugreek

Sr. No.	District	Taluka	* Disease Incidence (%)	Percent Disease Intensity (PDI)				
				Vegetative stage	Pod formation stage		Maturity stage	
					Range	Average	Range	Average
1	Banaskantha	Tharad	80.00	00.00	0.00-54.43	42.04	15.84-83.23	64.32
		Dhanera	60.00	00.00	0.00-41.60	27.68	7.45-59.43	47.52
		Vav	86.66	00.00	0.00-57.78	46.96	13.45-76.80	68.48
		Average	75.55	0.00	0.00-51.27	38.89	12.24-73.15	60.90
2	Patan	Patan	73.33	00.00	0.00-45.69	36.00	9.54-67.91	57.60
		Chanasma	66.66	00.00	0.00-48.12	33.36	14.58-67.32	52.64
		Siddhpur	60.00	00.00	0.00-39.03	28.72	5.88-60.38	49.92
		Average	66.66	0.00	0.00-44.28	32.69	10.00-65.20	52.58

* Mean of 15 fields observed

Table 2 Conidial size of *E. polygoni* of fenugreek recorded from different talukas of North Gujarat

Sr. No.	Taluka	Conidial size (L X B) (μm)		
		Maximum	Minimum	Average
1	Tharad	$38.80 \pm 2.73 \times 21.20 \pm 1.81$	$29.30 \pm 2.73 \times 15.80 \pm 1.81$	$33.52 \pm 2.73 \times 18.55 \pm 1.81$
2	Dhanera	$36.20 \pm 3.17 \times 21.60 \pm 1.35$	$25.30 \pm 3.17 \times 16.30 \pm 1.35$	$29.61 \pm 3.17 \times 18.37 \pm 1.35$
3	Vav	$40.40 \pm 2.51 \times 19.90 \pm 1.21$	$31.50 \pm 2.51 \times 16.40 \pm 1.21$	$35.44 \pm 2.51 \times 18.20 \pm 1.21$
4	Patan	$39.30 \pm 3.08 \times 22.60 \pm 2.22$	$28.40 \pm 3.08 \times 16.20 \pm 2.22$	$34.34 \pm 3.08 \times 18.55 \pm 2.22$
5	Chanasma	$34.50 \pm 2.30 \times 20.90 \pm 1.82$	$26.00 \pm 2.30 \times 15.80 \pm 1.82$	$30.98 \pm 2.30 \times 18.50 \pm 1.82$
6	Siddhpur	$39.30 \pm 2.71 \times 22.50 \pm 2.27$	$29.80 \pm 2.71 \times 15.70 \pm 2.27$	$34.25 \pm 2.71 \times 19.13 \pm 2.27$

reported earlier (Kansara, 2007; Patel, 2011 and Akhileshwari *et al.*, 2012).

During survey of the year 2011-12, the samples were collected from different talukas of Banaskantha and Patan districts and observed for morphological characters (Table 2). The length of conidia was observed maximum ($40.40 \pm 2.51 \mu\text{m}$) in the sample collected from Vav taluka, while it was minimum ($25.30 \pm 3.17 \mu\text{m}$) in the sample collected from Dhanera taluka. As regards to breadth of conidia, it was observed maximum ($22.60 \pm 2.22 \mu\text{m}$) in Patan

taluka and minimum ($15.70 \pm 2.27 \mu\text{m}$) in Siddhpur taluka. The average length and breadth of conidia was higher in Vav taluka ($35.44 \pm 2.51 \mu\text{m}$) and Siddhpur taluka ($19.13 \pm 2.27 \mu\text{m}$), respectively. This was also evident from length/breadth index of *E. polygoni*. The average length/breadth index (Table 3) was maximum (1.87) in Vav taluka followed by Patan taluka (1.85) among the samples collected. The results obtained in the present study supports the findings of Chattopadhyay and Maiti (1990) who reported that conidia of *E. polygoni* was measuring $29.0-45.0 \mu\text{m} \times 17.0-19.9 \mu\text{m}$.

Table 3 Length/Breadth index of *E. polygoni* of fenugreek recorded from different talukas of North Gujarat

Sr. No.	Taluka	Length (L) / Breadth (B) index			
		Maximum	Minimum	Average	Std. Dev.
1	Tharad	2.44	1.44	1.80	0.27
2	Dhanera	2.08	1.33	1.71	0.22
3	Vav	2.27	1.40	1.87	0.24
4	Patan	2.24	1.43	1.85	0.26
5	Chanasma	2.04	1.24	1.71	0.22
6	Siddhpur	2.23	1.35	1.81	0.27

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