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Line x tester analysis for combining ability in bitter gourd (*Momordica charantia* L.)

N. S. TALEKAR[1] , M. A. VADDORIA[2] N. B. PATEL[3] AND L. L. JIVANI[4]

Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh - 362 001(Gujarat)

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ABSTRACT

An experiment was under taken to study the combining ability analysis using seven lines and four testers and their 28 F_1 hybrids of bitter gourd obtained from line x tester analysis for fruit yield and its contributing characters. Analysis of variance indicated that mean squares due to lines x testers were significant for all the characters except fruit girth indicating predominant role of both additive and non-additive gene effects in the inheritance of all these traits. The estimates of σ^2gca were higher than the corresponding σ^2sca for days to open first female flower, days to open first male flower, days to first picking, vine length, number of primary branches per vine, number of fruits per vine, fruit length, fruit girth and fruit yield per vine, while in case of remaining characters *viz.*, number of nodes bearing first female flower, internodal length and average weight of fruit, the magnitude of σ^2sca was higher than σ^2gca. This indicated the preponderance of additive and non-additive component of genetic variance. The estimate of gca effects indicated that among the lines, Preethi and Ujjwala were the good general combiners for fruit yield and some of the yield contributing characters *viz.*, internodal length, vine length, number of fruits per vine, average fruit weight and fruit length, while among testers, HABG-22, CO-4 and HABG-21 were found good general combiners for fruit yield per vine and number of primary branches per vine. These parents were expected to accumulate additive genes that can be used as one of the parents for the development of varieties/hybrids in bitter gourd. The cross combinations *viz.*, Kalyanpur Baramasi x HABG-21, Hirkani x CO-4, Phule Green Gold x Pant Karela-1, Kalyanpur Sona x CO-4 and Priya x HABG-21 were found to be good specific cross combinations for fruit yield per vine. These findings can be further utilized to develop and enhance the best yield potential of bitter gourd cultivars.

Key words : Line x tester, combining ability, yield, bitter gourd

Bitter gourd is an important crop of India. It is a rich source of nutrients and ranks first among all cucurbits for its nutritive value and the plant extracts have been traditionally used to cure diabetic (Dey *et al.*, 2010). Bitter gourd offers much scope of improvement through heterosis breeding among genetically diverse genotypes. Information on combining ability facilitates the choice of suitable parents for hybridization programme to develop promising F_1 hybrids. The line x tester cross help in determining both general and specific combining abilities of parents and hybrid combinations, respectively. Further, it helps in formulating the breeding methodology for crop improvement. The present investigation was thus, conducted to identify the productive parents and its component traits in bitter gourd through combining ability analysis.

MATERIALS AND METHODS

The experimental material comprised of 28 F_1 hybrids developed by crossing of seven lines *viz.*, Phule Green Gold, Hirkani, Kalyanpur Sona, Ujjwala, Kalyanpur Baramasi, Priya, Preethi and four testers *viz.*, CO-4, Pant Karela-1, HABG-21 and HABG-22. Twenty eight hybrids along with 11 parents and a check variety,

[1] P.G. Student, [2] Research Scientist (Garlic-Onion), Vegetable Research Station, [3]Assistant Professor, [4] Associate Research Scientist, Vegetable Research Station

Priya were evaluated during *kharif* 2012 in a randomized block design with three replications at Instructional farm, Department of Agronomy Junagadh Agricultural University, Junagadh. Each genotype consisting a single row of ten plants. The plants were spaced at a distance of 2.0 m between rows and 1.0 m within a row. Three seeds were dibbled in each hill, which were kept single plant per hill when the crop was 20 days old. Thus, the perfect population of ten plants of each genotype was obtained. All need based agronomic practices were followed during the crop growth period to raise a good crop. Observations were recorded on randomly selected five plants in each entry for 12 quantitative traits *viz.*, days to open first female flower, days to open first male flower, number of nodes bearing first female flower, days to first picking, internodal length (cm), vine length (cm), number of primary branches per vine, number of fruits per vine, average weight of fruit (g), fruit length (cm), fruit girth (cm) and fruit yield per vine (kg). The mean values were used for the analysis of variance for experimental design. The combining ability analysis for different traits was worked out as per method suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

Analysis of variance (Table 1) indicated that mean squares due to lines and testers were significant for all the traits, while mean square due to lines x testers was also significant for all the characters except fruit girth indicating predominant role of both additive and non-additive gene effects in the inheritance of all these traits. Similar findings in bitter gourd were also reported by Khattra *et al.* (2000), Sundharaiya and Vekatesan (2007), Yadav *et al.* (2008), Jadhav *et al.* (2010), Dey *et al.* (2010), Kumara *et al.* (2011), Laxuman *et al.* (2012) and Thangamani *et al.* (2012).

The magnitude of gca and sca variances revealed that the gca variances were higher than the corresponding sca variances for days to open first female flower, days to opening of first male flower, days to first picking, vine length, number of primary branches per vine, number of fruits per vine, fruit length, fruit girth and fruit yield per vine, while in case of remaining characters *viz.*, number of nodes bearing first female flower, internodal length and average weight of fruit, the magnitude of sca variances was higher than gca variances. This indicated the importance of non-additive gene action. Similar findings were also reported by Khattra *et al.* (2000) and Thangamani *et al.* (2012) in this crop.

The perusal of the data on general combining ability effects of the lines and testers (Table 2) indicated that among lines, Preethi and Ujjwala were found to be good general combiners for fruit yield per vine, internodal length, vine length, number of fruits per vine, average fruit weight and fruit length, while among testers, HABG-22 was the best general combiner for all the traits studied whereas, CO-4 was good general combiner for fruit yield per vine, vine length, number of primary branches per vine and number of fruits per vine. Either good or average general combining ability effect was also depicted by Phule Green Gold for days to open first female flower, days to open first male flower and days to first picking; Hirkani for number of fruits per vine; Kalyanpur Sona for average weight of fruit and Kalyanpur Baramasi for vine length and fruit length. This would help in construction of a suitable selection index for breeding productive genotypes. High general combining ability effects mostly contribute additive gene effects or additive x additive interaction effects and represent fixable portion of genetic variation. In view of this, HABG-22, HABG-21, CO-4, Preethi and Ujjwala offers the best possibilities of the development of improved lines with enhanced fruit yielding ability in bitter gourd and these lines turned out to be good general combiners and can be used as one of the parents in hybridization programme for fruit yield improvement programme.

The estimate of sca effects revealed (Table 3) that none of the crosses was consistently superior for all the characters. The crosses Kalyanpur Baramasi x HABG-21, Hirkani x CO-4, Phule Green Gold x Pant Karela-1 and Kalyanpur Sona x CO-4 had high sca for fruit yield per vine involved average x good, poor x poor and average good general combiner parents, respectively. This indicated the presence of epistatic gene action and such deviation could be attributed to the genetic diversity in the form of heterozygous loci. This could also be an indication of gene dispersion and genetic interaction between favorable alleles contributed by both the parents. Such combination could be utilized for intermating segregants in F_2 or F_3 generation and simultaneous selection for desirable plant type.

In contrast to general combining ability effects, the specific combining ability effects represent dominance and epistatic components of variation which are non fixable in nature. But if the crosses showing high sca effects involving either both or one good general combiner parents, they could be successfully exploited for varietal improvement and expected to

Table 1 Analysis of variance for combining ability and variance components for different characters in bitter gourd

Source	df	Days to open first female flower	Days to open first male flower	Number of nodes bearing first female flower	Days to first picking	Internodal length	Vine length
Replications	2	0.57	0.15	4.23 **	0.86	0.19 *	570.28 **
Lines	6	59.42 **++	27.59 **++	3.77 **++	68.09 **++	0.54 **++	13274.40 **++
Testers	3	30.74 **+	29.82 **+	2.88 **++	48.89 **++	0.38 **++	34203.33 **++
Lines x Testers	18	6.74 *	7.96 *	1.45 **	6.42 **	0.23 **	3277.69 **
Error	54	3.33	3.59	0.59	2.33	0.04	62.588
Variance components							
σ^2l		4.67 **	1.99 *	0.26	5.48 **	0.04	1100.98 **
σ^2t		1.30 *	1.24 *	0.10	2.21 **	0.01	1625.74 **
σ^2lt		1.13 *	1.45 *	0.28 **	1.36 **	0.06 **	1071.70 **
σ^2gca		2.53 **	1.52 **	0.16 **	3.40 **	0.02 **	1434.92 **
σ^2sca		1.13	1.45	0.28	1.36	0.06	1071.70
σ^2sca/ σ^2gca		0.44	0.95	1.72	0.40	2.52	0.74

Source	df	Number of primary branches per vine	Number of fruits per vine	Average weight of fruit	Fruit length	Fruit girth	Fruit yield per vine
Replications	2	1.21	5.65 *	12.45	5.92 **	0.61	0.28 **
Lines	6	2.32 **++	52.69 **+	198.35 **+	41.74 **++	3.99 **++	0.69 **++
Testers	3	25.07 **++	264.79 **++	729.84 **++	53.71 **++	14.86 **++	4.63 **++
Lines x Testers	18	1.64 **	18.84 **	52.84 **	4.81 **	0.78	0.39 **
Error	54	0.44	1.13	9.29	1.04	1.12	0.01
Variance components							
σ^2l		0.15	4.29 *	15.75 *	3.39 **	0.23 **	0.05
σ^2t		1.17 **	12.55 **	34.31 **	2.50 **	0.65 **	0.21 **
σ^2lt		0.39 **	5.90 **	14.51 **	1.25 **	-0.11	0.12 **
σ^2gca		0.80 **	9.55 **	27.56 **	2.82 **	0.50 **	0.16 **
σ^2sca		0.39	5.90	55.12 **	1.25	-0.11	0.12
σ^2sca/ σ^2gca		0.49	0.61	2.00	0.44	-0.22	0.75

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

+,++ Significant at 5 and 1 per cent levels, respectively against lines x testers interaction

Table 2 Estimate of gca effects of parents for quantitative traits in bitter gourd

Parents	Days to open first female flower	Days to open first male flower	Number of nodes bearing first female flower	Days to first picking	Internodal length (cm)	Vine length (cm)	Number of primary branches per vine	Number of fruits per vine	Average weight of fruit (g)	Fruit length (cm)	Fruit girth (cm)	Fruit yield per vine (kg)
Lines												
Phule Green Gold	-1.07*	-1.34*	0.67**	-1.25**	0.42**	-2.77	-0.21	-1.05**	-6.51**	-2.20**	-0.29	-0.20**
Hirkani	0.17	0.57	-0.16	-0.01	-0.02	0.24	-0.11	0.82**	0.47	-1.06**	-0.08	0.04
Kalyanpur Sona	0.01	-0.26	-0.27	0.55	-0.01	-15.44**	-0.79**	-0.33	2.13*	-0.66*	0.20	0.05
Ujjwala	-0.48	-0.01	-0.17	0.18	-0.11*	25.63**	0.62**	2.34**	4.61**	1.81**	0.55	0.28**
Kalyanpur Baramasi	1.17*	-0.34	-0.38	0.73	-0.02	17.80**	0.16	-0.39	-1.11	2.16**	0.29	-0.01
Priya	3.76**	2.98**	0.90**	3.87**	0.02	-63.19**	0.12	-3.67**	-3.62**	-1.81**	-1.12**	-0.35**
Preethi	-3.57**	-1.59**	-0.58**	-4.07**	-0.27**	37.72**	0.20	2.29**	4.02**	1.77**	0.44	0.29**
Testers												
CO-4	0.07	0.51	0.23	-0.45	0.06	25.24**	0.39**	1.51**	0.77	0.23	0.38	0.12**
Pant Karela-1	1.26**	1.08**	0.30	1.95**	-0.03	-54.93**	-1.59**	-4.87**	-7.67**	-2.31**	-1.19**	-0.65**
HABG-21	0.31	0.08	-0.02	0.20	0.14**	-5.03**	0.32*	-0.06	0.20	0.81**	0.06	0.07*
HABG-22	-1.64**	-1.67**	-0.51*	-1.70**	-0.16**	34.72**	0.88**	3.42**	6.68**	1.26**	0.74**	0.46**

G = Good; A = Average; P = Poor

throw better transgressive segregants carrying fixable gene effects. The most of the cross combinations which were either due to good x poor, poor x good or average x average crosses besides exhibiting favourable and high additive effect of parents and manifest the complementary interaction effects and thus leads to higher sca effects.

In the present study, such cross combinations for fruit yield per vine were Kalyanpur Baramasi x HABG-21 (average x good), Hirkani x CO-4 (average x good), Phule Green Gold x Pant Karela-1 (poor x poor), Kalyanpur Sona x CO-4 (average x good) and Priya x HABG-21 (poor x good). This indicated the presence of both additive and non-additive gene action involved in the expression of fruit yield per vine. Further, some parents with positive and significant general combining ability produced hybrids with negative and significant specific combining ability indicating the role of complementary gene action. The combining ability of parents could not always be judged by the *per se* performance accurately. Therefore, both general combining ability and *per se* performance of breeding lines should be considered together for assessing their breeding potentiality. In the present investigation, none of the cross combination showed simultaneous significant specific combining ability effect favorably for all the characters. This may be due to complementation of favourable genes. The good combiners when crossed did not produce good hybrid. These findings are akin to the findings of Singh *et al.* (2004), Sundharaiya and Vekatesan (2007), Yadav *et al.* (2008), Dey *et al.* (2010) and Jadhav *et al.* (2010).

On the basis of general combining ability effects and specific combining ability effects, a few crosses were identified. These F_1 hybrids were Kalyanpur Baramasi x HABG-21, Hirkani x CO-4, Phule Green Gold x Pant Karela-1 and Kalyanpur Sona x CO-4. These are the potential source for the development of F_1 hybrid varieties in bitter gourd.

From the present study, it was formed that the parents *viz.*, Preethi, Ujjwala, HABG-21, HABG-22 and CO-4 were good general combiners for fruit yield and its attributing characters and could be utilized in future breeding programmes. Among hybrids, Kalyanpur Baramasi x HABG-21, Hirkani x CO-4, Phule Green Gold x Pant Karela-1 and Kalyanpur Sona x CO-4 were the promising hybrid combinations for most of the desirable characters including fruit yield per vine in bitter gourd.

Table 3 Specific combining ability effects for different characters in bitter gourd

Sr. No.	Crosses	Days to open first female flower	Days to opening of first male flower	Number of nodes bearing first female flower	Days to first picking	Internodal length (cm)	Vine length (cm)
1	Phule Green Gold x CO-4	0.59	0.15	0.50	0.71	0.24*	55.25**
2	Phule Green Gold x Pant Karela-1	-0.26	-1.75	-0.60	0.02	-0.28*	7.10
3	Phule Green Gold x HABG-21	-0.30	0.25	0.29	-1.10	0.40**	-44.79**
4	Phule Green Gold x HABG-22	-0.02	1.34	-0.18	0.36	-0.36**	-17.55**
5	Hirkani x CO-4	1.34	2.57*	-1.09*	1.97*	-0.09	10.56*
6	Hirkani x Pant Karela-1	0.48	-0.66	0.10	0.64	-0.01	19.14**
7	Hirkani x HABG-21	0.77	0.66	1.33**	-0.71	-0.05	-32.45**
8	Hirkani x HABG-22	-2.60*	-2.57*	-0.34	-1.91*	0.16	2.75
9	Kalyanpur Sona x CO-4	-1.48	-0.59	-1.11*	-1.29	-0.28*	17.92**
10	Kalyanpur Sona x Pant Karela-1	-1.01	-0.16	0.44	1.48	-0.16	-1.89
11	Kalyanpur Sona x HABG-21	0.60	-0.50	-0.16	-0.36	0.25*	-26.13**
12	Kalyanpur Sona x HABG-22	1.89	1.26	0.83	0.17	0.20	10.11*
13	Ujjwala x CO-4	-1.65	-3.17**	0.65	-1.48	-0.10	-26.16**
14	Ujjwala x Pant Karela-1	-0.17	0.58	0.44	-2.32**	0.26*	-8.31
15	Ujjwala x HABG-21	0.77	0.58	-0.56	3.44**	-0.26*	17.11**
16	Ujjwala x HABG-22	1.06	2.01	-0.53	0.37	0.10	17.36**
17	Kalyanpur Baramasi x CO-4	0.01	0.48	0.49	-0.97	-0.23	-16.99**
18	Kalyanpur Baramasi x Pant Karela-1	0.48	-0.08	-0.24	0.96	0.34**	-30.14**
19	Kalyanpur Baramasi x HABG-21	-1.22	-0.75	-0.65	-0.78	-0.21	46.61**
20	Kalyanpur Baramasi x HABG-22	0.72	0.34	0.40	0.78	0.10	0.52
21	Priya x CO-4	1.76	0.15	0.27	0.25	0.21	-14.33**
22	Priya x Pant Karela-1	-2.09*	1.58	-0.43	-0.57	-0.19	45.85**
23	Priya x HABG-21	0.19	-1.41	0.03	-0.04	-0.17	-2.71
24	Priya x HABG-22	0.14	-0.32	0.12	0.36	0.15	-28.80**
25	Preethi x CO-4	-0.57	0.40	0.29	0.81	0.24*	-26.24**
26	Preethi x Pant Karela-1	2.57*	0.50	0.28	-0.23	0.05	-31.73**
27	Preethi x HABG-21	-0.81	1.16	-0.28	-0.42	0.06	42.36**
28	Preethi x HABG-22	-1.19	-2.07	-0.29	-0.15	-0.36**	15.61**
	SE (S_{ij})	1.05	1.09	0.44	0.88	0.12	4.56

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

Table 3 Contd...

Sr. No.	Crosses	Number of primary branches per vine	Number of fruits per vine	Average weight of fruit (g)	Fruit l ength (cm)	Fruit girth (cm)	Fruit yield per vine (kg)
1	Phule Green Gold x CO-4	-0.91*	-2.10**	-4.56**	-2.40**	-0.29	-0.34**
2	Phule Green Gold x Pant Karela-1	0.50	2.89**	0.07	1.88**	0.19	0.43**
3	Phule Green Gold x HABG-21	0.05	-0.98	-0.33	1.02	-0.35	-0.19*
4	Phule Green Gold x HABG-22	0.36	0.19	4.81**	-0.50	0.45	0.11
5	Hirkani x CO-4	0.82*	2.54**	5.38**	0.74	0.59	0.45**
6	Hirkani x Pant Karela-1	-1.12**	-1.58*	-0.61	-0.19	0.15	-0.13
7	Hirkani x HABG-21	-0.07	-0.93	-4.34*	-0.18	-0.99	-0.37**
8	Hirkani x HABG-22	0.37	-0.22	-0.42	-0.36	0.25	0.05
9	Kalyanpur Sona x CO-4	0.96*	2.11**	3.78*	1.11	0.43	0.41**
10	Kalyanpur Sona x Pant Karela-1	-0.91*	0.03	0.17	-0.85	0.07	0.02
11	Kalyanpur Sona x HABG-21	-0.16	-1.84**	-4.39*	-1.45*	-0.43	-0.38**
12	Kalyanpur Sona x HABG-22	0.11	-0.30	0.43	1.19*	-0.07	-0.05
13	Ujjwala x CO-4	0.18	-0.19	3.45*	0.70	0.13	0.03
14	Ujjwala x Pant Karela-1	-0.19	-0.71	-0.20	-1.33*	-0.16	-0.01
15	Ujjwala x HABG-21	0.05	-0.86	0.24	0.05	0.12	0.01
16	Ujjwala x HABG-22	-0.03	1.76**	-3.49*	0.57	-0.09	0.03
17	Kalyanpur Baramasi x CO-4	0.43	0.28	0.59	0.42	0.08	0.19*
18	Kalyanpur Baramasi x Pant Karela-1	0.09	-3.76**	-5.06**	-0.15	-0.46	-0.58
19	Kalyanpur Baramasi x HABG-21	0.24	4.55**	6.13**	0.20	0.69	0.47**
20	Kalyanpur Baramasi x HABG-22	-0.78*	-1.06	-1.67	-0.47	-0.31	-0.08
21	Priya x CO-4	-0.38	0.22	-7.98**	-1.18*	-0.79	-0.61**
22	Priya x Pant Karela-1	1.27**	3.71**	2.88	1.89**	0.39	0.34**
23	Priya x HABG-21	-0.41	-0.73	2.22	0.43	0.73	0.39**
24	Priya x HABG-22	-0.47	-3.20**	2.87	-1.15*	-0.34	-0.12
25	Preethi x CO-4	-1.10**	-2.87**	-0.67	0.59	-0.15	-0.14
26	Preethi x Pant Karela-1	0.35	-0.58	2.74	-1.23*	-0.20	-0.06
27	Preethi x HABG-21	0.30	0.81	0.46	-0.08	0.23	0.07
28	Preethi x HABG-22	0.44	2.64**	-2.53	0.72	0.12	0.13
	SE (S_{ij})	0.38	0.61	1.76	0.58	0.61	0.08

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

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Effect of physical and chemical mutagens on seed germination and seedling shoot and root development in grain amaranth [*Amaranthus spp.* (L.)]

T. A. DESAI[1], S. D. SOLANKI[2], N. N. PRAJAPATI[3] AND H. S. BHADOURIA[4]

Department of Genetics and Plant Breeding ,
C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar-385 506 (Gujarat)

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ABSTRACT

An investigation was undertaken to study the effect of physical (Gamma rays) and chemical mutagens (Ethylmethane Sulphonate and Sodium Azide) on germination per cent, shoot length and root length in grain amaranth [*Amaranthus Spp.* (L.)] cultivated varieties of *viz.,* Gujarat amaranth-1, Gujarat amaranth-2 and Suvarna. The seeds were irradiated with different doses (5, 10, 15, 20, 25 kR) of gamma rays, and for chemical mutagens EMS (0.1, 0.2, 0.3, 0.4, 0.5 %) and SA (0.01, 0.02, 0.03, 0.04, 0.05 %) were used at different concentrations level. The biological parameters like germination, shoot and root length were recorded at 4 days after sowing and at 7 days after sowing, respectively. The studies indicated that germination, shoot length and root length were decreased with the increase of all the mutagen treatments except 15 kR gamma rays. LD-50 value not found for GA-1 and GA-2 varieties but found in Suvarna in this study. LD-50 of the gamma rays for germination was found between 20 and 25 kR in Suvarna, for EMS and SA it was found between 0.3 to 0.4 per cent and 0.03 to 0.04, respectively Suvarna has higher sensitivity to mutagens than other two cultivars and EMS is more effective mutagens than other two mutagens.

Key words : Grain amaranth, mutagens, gamma rays, ethylmethane sulphonate, sodium azide, germination, shoot length, root length.

Grain amaranthus have been cultivated since ancient times in several countries of the world and one of oldest food crops in the new world. Among the three pseudocereals (Buck wheat : *Fagopyrum spp.*, Chenopods : *Chenopodium spp.* and Amaranth : *Amaranthus spp.*) grain amaranth is most important. Amaranth is a potential cereal crop belonging to family Amaranthusaceae. The genus Amaranth includes other species of grain type Amaranth viz., *Amaranthus hypochondriacus* L. (2n=32), *A. cruentus* L. (2n=34), *A. caudatus* L. (2n=32 and occasionally 2n=34 also), *A. adulis* Spegazzini (2n=32) and *A. tricolor* (2n=34). The grain amaranth is thought to be of American origin. Grain amaranthus (Amaranthus spp.) is one of the underutilized crop offering lot of potentiality to be explored as future food crop by virtue of its high quality of protein rich grain and carotene rich leaves. The crop is important and widely spread in India. However, it is mainly grown for grain especially in Uttarakhand, Maharashtra and in some parts of Gujarat. Hybridization is difficult in grain amaranth due to small flower structure, so mutation breeding is a better way to create variability. Mutation induced in self-pollinated crops, is of great value in plant breeding and is recognized as a potential tool for crop improvement by way of creating variability in the population (Hagberg *et al.*1963). Mutagenesis is as effective as hybridization in supplying the genetic variability for selection (Virupakashappa *et al.*1980).

MATERIALS AND METHODS

Pure, healthy and mature seeds of the three varieties of Amaranth *viz.*, Gujarat amaranth-1, Gujarat amaranth-2 and Suvarna were exposed to different doses of gamma rays at Bhabha Atomic Research

[1] P. G. student, [2] Associate Professor, [3] Assistant Research Scientist, Centre for Crop Improvement, [4] Associate Professor.

Centre (BARC), Trombay with gamma rays intensity of 1.8 kR per minute. The doses were given *viz.*, 0, 5, 10, 15, 20, and 25 kR to all the three varieties. For chemical treatments, the solution of Ethylmethane sulphonate (EMS) 0.1, 0.2, 0.3, 0.4, 0.5 % and sodium azide 0.01, 0.02, 0.03, 0.04, 0.05 % concentration were prepared in phosphate buffer at pH 7.0. About 50 gm dry seeds pre-soaked in distilled water for two hours before they were treated with chemical mutagens for each treatment. Pre-soaked seeds were immersed in freshly prepared solutions of chemical mutagens ie., Ethylmethane sulphonate (EMS) for four hours and sodium azide for six hours at room temperature. Seeds of all the treatments were planted in germination paper. In each germination paper, hundred seeds were placed with three replications under control condition at room temperature. Germination was recorded on fourth day and seedling growth was measured on seventh day after sowing.

RESULTS AND DISCUSSION

Effect of physical and chemical mutagen on seed germination, shoot length and root length are presented in Table 1, 2 and 3. All the three varieties exhibited variation due to mutagenic treatments. Germination percent, shoot and root length decreased with the increase in levels of all the mutagenic treatments except 15 kR gamma rays in GA-1 and GA-2. EMS produced more effect on germination, shoot length and root length than gamma rays and SA. LD-50 value not found in GA-1 and GA-2 at these levels of doses of all three mutagens but in Suvarna (0.5 % EMS and 0.05 % SA) doses/concentrations showed LD-50. Higher germination was found with control in all the varieties. The maximum shoot and root length was reported with 15 kR gamma rays in GA-2 and lowest germination, shoot and root length was found in 0.5 per cent EMS treatment in all the three varieties. LD-50 of gamma rays for germination was found at 20 to 25 kR, for EMS 0.3 to 0.4 per cent and in SA 0.03 to 0.04 per cent levels in Suvarna (Table 1, 2 & 3).

Seed germination is the most important parameter used to detect the response of the crops to mutagenic treatments. Physical and chemical mutagens induce physiological damages, in different biological materials during M_1 generation (Gaul, 1970), the increase doses of mutagens caused a progressive increase in the biological damages in term of reduction in germination, shoot and root length in many crops (Kirtane, 2003, Rao, 1988 and Sharma and Sharma 1986). Similar trend was observed in the present study with respect to germination, shoot and root length.

The severe effect of gamma radiation on germination, shoot and root length observed in the present investigation is in accordance with the results observed by Amir and Khavar (2012) in grain amaranth. They also observed significant reduction in all the three characters with increase dose of gamma radiations. Srivastava *et al.*, (2011) reported the effect of sodium azide on wheat that the increase in doses resulted into decrease in germination, shoot and root length. Datir *et al.*, (2007) observed in his study increase the dose of gamma rays and EMS decrease germination per cent.

Table 1 Effect of Gamma radiation on per cent germination, shoot length (cm) and root length (cm) in grain amaranth.

Treatment/ Cultivar kR	GA-1			GA-2			Suvarna		
	Germination (%)	Shoot length (cm)	Root length (cm)	Germination (%)	Shoot length (cm)	Root length (cm)	Germination (%)	Shoot length (cm)	Root length (cm)
Control	87.33	3.93	4.63	89.33	3.97	4.47	84.67	4.13	4.70
5	84.33	3.90	4.37	88.67	3.77	4.33	78.33	4.10	4.60
10	84.00	3.70	4.40	87.67	3.63	4.23	77.67	3.77	4.60
15	87.00	4.07	4.70	89.33	3.60	4.27	65.67	3.43	4.43
20	80.33	3.60	4.23	85.67	4.07	4.57	57.33	3.27	4.50
25	78.33	3.53	4.20	82.33	3.37	4.10	49.00	2.90	3.97

Table 2 Effect of Ethylmethane sulphonate on per cent germination, shoot length (cm) and root length (cm) in grain amaranth.

Treatment / Cultivar	GA-1			GA-2			Suvarna		
	Germination (%)	Shoot length (cm)	Root length (cm)	Germination (%)	Shoot length (cm)	Root length (cm)	Germination (%)	Shoot length (cm)	Root length (cm)
Control	87.33	3.93	4.63	89.33	3.97	4.47	84.67	4.13	4.70
0.1	83.68	3.83	4.43	82.67	3.37	4.23	75.00	3.73	4.50
0.2	78.33	3.57	4.17	79.67	3.47	4.37	68.00	3.73	4.03
0.3	75.33	3.43	4.27	77.33	3.27	3.97	57.00	2.90	3.97
0.4	71.33	3.60	4.07	74.67	3.40	3.97	45.67	2.70	3.50
0.5	65.67	3.10	3.83	68.67	3.07	3.83	37.00	2.57	3.47

Table 3 Effect of Sodium azide on per cent germination, shoot length (cm) and root length (cm) in grain amaranth.

Tretment / Cultivar	GA-1			GA-2			Suvarna		
	Germination (%)	Shoot length (cm)	Root length (cm)	Germination (%)	Shoot length (cm)	Root length (cm)	Germination (%)	Shoot length (cm)	Root length (cm)
Control	87.33	3.93	4.63	89.33	3.97	4.47	84.67	4.13	4.70
0.01	84.67	3.47	4.43	86.67	3.37	4.27	84.33	3.97	4.63
0.02	81.00	3.47	4.27	84.67	3.43	4.13	77.67	3.53	4.47
0.03	80.00	3.53	4.57	87.33	3.57	4.40	59.33	3.17	4.23
0.04	76.67	3.20	4.07	80.67	3.37	4.13	47.33	2.77	3.80
0.05	74.33	3.37	4.13	78.67	3.20	4.03	43.33	2.77	3.63

The effect of mutagenic treatments on the initiation of germination has been attributed to changes in chromosomal organization (Evans and Sparrow, 1961) and different biochemical and physiological processes (Sparrow and Woodwell, 1962). The lowered respiratory quotient in mutagen treated seeds may be cause for inhibition of seed germination (Woodstock and Justice, 1967). The reduction in germination may be due to the enhanced production of the active free radicals, causing lethality (Selima *et al.*, 1974).

CONCLUSION

The overall studies confirmed that EMS could be more useful for inducing the genetic variability in grain amaranth than other two mutagens *viz.*, gamma rays and sodium azide. The cultivar Suvarna has higher sensitivity to mutagens compared to GA-1 and GA-2. LD-50 of gamma rays for germination was found at 20 to 25 kR, for EMS 0.3 to 0.4 per cent and in SA 0.03 to 0.04 per cent levels in Suvarna, which indicates that below these doses or concentrations are suitable for induce mutations in Suvarna. The LD-50 value in respect of germination was not found at any levels of concentrations or doses for present study for the cultivar GA-1 and GA-2.

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Variability studies and multivariate analysis in Indian mustard [*Brassica juncea* (L.) Czern & Coss]

V. B. RATHOD[1], D. R. MEHTA[2], H. V. SOLANKI[3] AND R. B. MADARIYA[4]

Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh-362 001 (Gujarat)

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ABSTRACT

A study on genetic variability and genetic divergence was done with 50 genotypes for 13 quantitative characters in Indian mustard (*Brassica juncea* (L.) Czern and Coss).The analysis of variance indicated the prevalence of sufficient genetic variation among the genotypes for all the 13 traits. The wider phenotypic range, high heritability coupled with high genotypic coefficient of variation (GCV) and high genetic advance as per cent of mean (GA %) were observed for seed yield per plant, biological yield per plant, number of secondary branches per plant, number of siliquae per plant and 1000-seed weight which, indicated that response to selection would be very high for these yield components ultimately leading to seed yield improvement in mustard crop. The genotypes grouped in 9 clusters when grouped using the Tocher's method. Cluster I topped with maximum (33) genotypes followed by cluster II (6) and cluster III and IV (each of 3). While, cluster VII to IX were solitary clusters. Maximum genetic distance (D) was found between cluster II and VI followed by between cluster III and IV. Four clusters *viz.*, II, III, IV and VI were important with respect to construct plant ideotype including seed yield per plant, which could be utilized for breeding p rogramme. Three traits *viz.*, days to 50% flowering, days to maturity and 1000-seed weight also contributed more than 55% towards total genetic divergence.

Key words : Variability, heritability, genetic divergence, multivariate analysis.

Indian mustard [*Brassica juncea* (L.) Czern and Coss, 2n = 36, *Brassicaceae*] popularly known as rai, raya or laha, is one of the most important edible oilseed crops of the country and it occupies considerably large acreage among the *Brassica* group of oilseed crops. India stands first both in acreage and production of rapeseed and mustard in Asia. Globally, India account for 19.29 % and 11.127% of the total acreage and production. In India area, production and productivity of rapeseed-mustard are 6.5 million hectares, 8.79 million tonnes and 1850 kg/ha, respectively during 1912-13 (Anonymous, 2010). Mustard and rapeseed are being grown largely in states like Rajasthan, Uttar Pradesh, Haryana, Gujarat, Punjab, Assam, West Bengal and Madhya Pradesh.

The morphological characterization of germplasm is used to understand the genetic variation since, a wide range of genetic variation among parents is essential for hybridization programmes. Nature and magnitude of genetic variability and heritability in a population as genetic and non-genetic factors are pre-requisites in any successful hybridization programme to get desirable segregants. Arunachalam (1981) stated that multivariate analysis using Mahalanobis' D^2 statistic is a powerful tool to know the clustering pattern to establish the relationship between genetic and geographical divergence and to determine the role of different quantitative characters towards total genetic divergence. Hence, the present experiment was planned on variability analysis along with genetic divergence using 50 genotypes of mustard.

MATERIALS AND METHODS

Fifty genotypes of Indian mustard procured from the Research Scientist (Castor-Mustard), Castor-Mustard Research Station, Sardarkrushinagar Datiwada

[1&3] Ph.D. Students, [2]Associate Professor, [4] Professor and Head

Agricultural University, Sardarkrushinagar were grown in R.B.D. with three replications during *rabi* 2011-12 at Instructional Farm, Junagadh Agricultural University, Junagadh, (Gujarat). Each replication consisted of a single row of 3m length for each entry with row to row and plant to plant spacing being 60 cm and 10 cm, respectively. Recommended agronomic practices and plant protection measures were followed to raise a healthy crop.

Five competitive plants were randomly selected in each entry for recording the observations on plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, number of seeds per siliquae, length of siliquae(cm), 1000-seed weight (g), biological yield per plant, harvest index (%) and oil content (%), while, days to 50% flowering and days to maturity were recorded on plot basis. The genotypic and phenotypic coefficient of variations were estimated as per Burton (1952), while heritability in broad sense and expected genetic advance were estimated as per Allard (1960). Genetic diversity was calculated using Mahalanobis (1936) D^2 statistic and genotypes were grouped into clusters by Tocher's method as described by Rao (1952).

RESULTS AND DISCUSSION

Analysis of variance (Table 1) revealed that variance due to genotypes was highly significant for all the 13 characters indicated the presence of sufficient variability in the genotypes under the study. The experimental materials showed wide range of phenotypic variation for seed yield per plant, number of secondary branches per plant, number of siliquae per plant, biological yield per plant, number of primary branches per plant, harvest index and 1000-seed weight as revealed high values of coefficient of range.

Variability Analysis

The values of phenotypic coefficient of variation (PCV) were higher than genotypic coefficient of variation (GCV), in most of the cases, indicated more influence of environmental factors (Table 2). However, low differences were also observed between PCV and GCV for days to 50% flowering, days to maturity, plant height, number of seeds per siliquae and length of siliquae which revealed that these five traits were comparatively less influenced by the environments. High PCV and GCV were observed for seed yield per plant followed by number of secondary branches per plant, biological yield per plant, number of siliquae

Table 1 Analysis of variance for 13 characters in 50 genotypes of mustard

Source	d.f.	Mean squares												
		Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of secondary branches per plant	No. of siliquae per plant	No. of seeds per siliqua	Length of siliqua (cm)	1000 seed weight (g)	Seed yield per plant (g)	Biological yield per plant (g)	Harvest index (%)	Oil content (%)
Replications	2	13.547**	1.040	146.060*	0.097	13.313	6512.903*	0.090	0.308**	0.091	36.806*	2133.142**	139.249**	0.334
Genotypes	49	37.500**	45.641**	254.691**	1.477**	35.065**	12790.855**	3.914**	0.327**	0.940**	59.866**	273.511**	49.077**	16.303**
Error	98	2.492	1.809	35.647	0.257	4.632	1621.463	0.562	0.044	0.092	10.130	128.356	17.144	5.665

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

Table 2 Phenotypic range, coefficient of range, phenotypic and genotypic coefficient of variation, heritability, genetic advance and genetic advance (as per cent of mean) for various characters in mustard

Characters	Phenotypic range	Coefficient of range (%)	Mean ± S.Em	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability in broad sense (%)	Genetic advance	Genetic advance (percent of mean)
Seed yield/plant	14.24 - 33.01	39.73	20.73 ± 1.838	24.94	19.65	62.1	6.61	31.89
Days to 50% flowering	37.33 - 57.33	21.13	48.23 ± 0.912	7.80	7.08	82.4	6.39	13.24
Days to maturity	95.33 - 109.67	6.99	101.22 ± 0.777	4.05	3.82	89.3	7.53	7.34
Plant height (cm)	134.40 - 187.33	16.45	167.30 ± 3.447	6.23	5.11	67.2	14.43	8.62
No. of primary branches/plant	4.33 - 7.87	28.96	5.98 ± 0.293	13.63	10.67	61.2	1.03	17.20
No. of secondary branches/plant	11.40 - 25.53	38.27	16.80 ± 1.243	22.88	18.96	68.7	5.44	32.36
No. of siliquae/plant	262.80 - 581.27	37.73	410.94 ± 23.245	17.79	14.85	69.7	104.91	25.53
No. of seeds/siliqua	10.80 - 16.67	21.36	13.21 ± 0.433	9.81	8.00	66.5	1.78	13.45
Length of siliqua (cm)	4.40 - 5.90	14.56	5.07 ± 0.122	7.33	6.04	68.0	0.52	10.26
1000 seed weight (g)	3.13 - 5.32	26.02	4.15 ± 0.175	14.74	12.80	75.5	0.95	22.91
Biological yield/plant	48.30 - 97.79	33.88	68.32 ± 6.541	19.46	10.18	27.4	7.50	10.97
Harvest index (%)	21.15 - 37.62	28.04	30.55 ± 2.391	17.25	10.68	38.3	4.16	13.62
Oil content (%)	29.88 - 41.30	16.03	36.92 ± 1.374	8.22	5.10	38.5	2.41	6.52

per plant, harvest index, 1000-seed weight and primary branches per plant indicated the presence of wide variation for these traits to allow selection for individual traits.Similar findings pertaining to presence of high genetic variability were reported by Kumar *et al.*, (2000) and Choudhary *et al.*, (2003). Moderate estimates of GCV and PCV were observed for number of seeds per siliqua, oil content, days to 50% flowering and length of siliquae, while low estimates of GCV and PCV were observed for days to maturity and plant height indicated narrow genetic variability for both characters.

The efficacy of selection not only depends on magnitude of variability present in a trait, but also on the extent of heritability of desirable character. To obtain heritable portion of variability, it was essential to know the heritability estimates for different traits (Burton, 1952). Johnson *et al.*, (1955) suggested that the heritability estimate alongwith genetic advance is more useful than the heritability alone in predicting the resultant effect of selection. In the present study, estimates of high heritability coupled with high genetic advance as per cent of mean was observed for days to 50% flowering, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, 1000-seed weight and seed yield per plant indicated preponderance of additive gene action and selection pressure could profitably be applied on these characters for improving the seed yield (Panse, 1957). On the other hand, moderate to high heritability along with low GCV and low genetic gain were observed for days to maturity, plant height and length of siliqua could be due to preponderance of non-additive (dominant and epistatic) gene actions and/or less genetic variability for these three traits in the materials. For the remaining traits *viz.*, number of seeds per siliquae, biological yield per plant, harvest index and oil content, major variation was environmental, leading to low heritability and low expected genetic advance. Hence, little gain is expected through straight selection.

Multivariate Analysis

Multivariate analysis using Wilk's 'Λ' criterion was carried out to test the differences among 50 genotypes for aggregate of 13 characters. The value of V-statistic (3796.890) which follows x^2 distribution for 637 degrees of freedom showed highly significant differences among the genotypes for aggregate of 13 characters. Thus, one can proceed for further diversity analysis. The D^2-values computed for 1125 pairs ranged from 4.89 (between GDM 4 and PAB 9337) to 309.94

Table 3 Groups of 50 genotypes of mustard in various clusters on the basis of D^2 statistic

Cluster	No. of genotypes	Name of genotypes	Place of origin
I	33	GDM-4, 614-4-4, SKM-9825, GM-3, SKM-9824, SKM-9813, RSK-86, AA-66, 508-4, 5422-2, GM-2, Bharkawada-2	SDAU, Sardarkrushinagar (Gujarat)
		PSR-48, BIO-902, PBN-9501, DIR-437, PusaJaganath, BIO-341-92, PAB-9337, NM-919	IARI (New Delhi)
		UP-11-90, NRCM-8-1, NRCM-421, NRCM-141, JMG-416	NRCRM (Rajasthan)
		R.K.-9501, PRKS-28	CSAUA&T (UP)
		HUM-9901, HUJM-9720	JNKVV (MP)
		TM-1	BARC (Maharashtra)
		DHR-9405	HAU (Haryana)
		B-1328	PORS (West Bengal)
		SAL-6	CSSRI (Haryana)
II	6	B-351, RW-B-94	PORS (West Bengal)
		C-111, SAL-3	CSSRI (Haryana)
		NUDH-YJ-1	Dhara Vegetable Oil and Foods Co. Ltd. (Gujarat)
		PCR-7	NRCRM (Rajasthan)
III	3	DLM-52	PAU (Punjab)
		Aravali (RN 893)	RAU (Rajasthan)
		Ranasan-2	SDAU (Gujarat)
IV	3	NPJ-91, NPJ-95	IARI (New Delhi)
		SKM-9916	SDAU (Gujarat)
V	1	SKM-0287	SDAU (Gujarat)
VI	1	PYM-7	GBPUA & T (Uttarakhand)
VII	1	SKM-9142	SDAU (Gujarat)
VIII	1	SKM-0110	SDAU (Gujarat)
IX	1	IC-355327	NBPGR (New Delhi)

Table 4 Average inter and intra-cluster distance (D= $\sqrt{D^2}$) values in mustard

Characters	I	II	III	IV	V	VI	VII	VIII	IX
I	7.27	8.99	9.72	10.9	9.22	9.42	8.56	9.11	9.57
II		8.58	11.66	12.74	12.53	33.15	10.92	11.74	11.77
III			7.18	15.35	9.86	10.10	11.40	9.95	9.98
IV				7.52	12.35	13.70	8.08	13.25	12.64
V					0.00	9.03	8.96	6.11	9.49
VI						0.00	9.64	10.94	12.27
VII							0.00	9.97	9.08
VIII								0.00	8.31
IX									0.00

(between NPJ 91 and Ranasan 2) indicated the presence of high genetic diversity among genotypes for all the traits.

All fifty genotypes were grouped into nine clusters, using the Tocher's method, in such a way that genotypes within the cluster had smaller D^2 values among themselves than those belonging to different clusters (Table 3). Cluster I was the largest having 33 genotypes from different geographical regions comprising 12 genotypes from SDAU, Sardarkrushinagar (Gujarat); 8 from IARI (New Delhi); 5 from NRCRM, Sewar, Bharatpur (Rajasthan); 2 from CSAUA&T, Kanpur (Uttar Pradesh); 2 from JNKVV (Madhya Pradesh) and one each from BARC, Trombay (Maharashtra); CSSRI, Karnal (Haryana); PORS, Behrampore (West Bengal) and HAU, Hissar (Haryana). Likewise, cluster II comprised of 6 genotypes from different locations of India. While cluster III and VI both possessed three genotypes each. The clusters from V to IX had only single genotype in each cluster. The clustering pattern of genotypes showed that genetic origin was totally independent of their geographical origin. Murty and Arunachalam (1966) also stated that genetic drift and selection in varied environments could be caused for greater diversity than geographic distance. Further, free exchange of seed materials among the different regions consequently causes characters constellations because of the human interference and material may lose its individuality. Singh *et al.* (2007), Singh *et al.* (2009) and Sutariya *et al.*, (2011) also reported that there was no parallelism between geographic distribution and genetic diversity in mustard.

In general, intra- cluster distances were lower than the inter cluster distances (Table 4). Thus, the genotypes included within a cluster tended to diverse less from one another.Intra cluster distance (D) ranged from 7.18 in cluster III to 8.58 in cluster II.The analysis of data revealed that the maximum inter cluster distance (D=33.15) was observed between clusters II and VI followed by that between cluster III and IV (D=15.35) and minimum inter cluster distance (D=6.11) was observed between cluster V and VIII. The genotypes belonging to the clusters separated by high statistical distance could be used in hybridization programme for obtaining a wide spectrum of variation among the segregates. In this context, genotypes from cluster II (B 351, NUDH-YJ 1, C 111, SAL 3, PCR 7, RW-B 94), cluster III (DLM 52, Aravali (RN 893), Ranasan 2), cluster IV (NPJ 91, NPJ 95, SKM 9916) and cluster VI (PYM 7) could be selected as parents in hybridization programme.

Table 5 Cluster means for different characters in mustard

Clusters	Seed yield/ plant (g)	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches/ plant	No. of siliquae/ plant	No. of seeds/ siliqua	Length of siliqua (cm)	1000 seed weight	Biological yield/ plant	Harvest index (%)	Oil content (%)
I	19.71	48.40	101.01	168.07	5.95	17.07	400.46	12.97	5.09	4.28	67.02	29.65	36.69
II	24.34	48.44	99.33	172.03	6.33	20.11	493.02	12.61	4.76	3.63	77.70	31.84	39.42
III	18.43	53.33	108.00	179.40	6.58	13.36	466.60	13.62	5.58	3.70	66.43	27.70	35.39
IV	19.52	38.22	96.44	149.78	5.18	13.87	353.04	13.96	5.05	4.44	60.26	32.54	35.77
V	24.32	50.33	107.67	152.93	5.20	13.33	364.47	14.00	4.94	4.44	65.88	37.45	35.56
VI	14.58	53.33	103.33	163.27	5.53	16.53	398.93	15.07	4.40	3.13	59.80	24.98	38.86
VII	22.17	45.33	99.67	157.00	6.07	13.33	419.80	16.67	5.17	4.00	60.23	37.53	35.02
VIII	32.41	49.67	106.00	158.07	7.07	18.73	388.27	13.20	5.20	4.89	97.79	33.80	38.05
IX	32.35	50.33	101.67	167.53	5.53	12.27	343.67	14.87	5.86	3.68	74.72	43.63	37.65
Mean	20.73	48.23	101.22	167.30	5.98	16.80	410.94	13.21	5.07	4.15	68.32	30.55	36.92
S.Em+	1.838	0.912	0.777	3.447	0.293	1.243	23.245	0.433	0.122	0.175	6.541	2.391	1.374
Per cent Contribution towards total genetic divergence													
	6.61	12.16	32.73	2.69	2.94	4.98	6.69	7.59	7.18	10.29	0.16	0.08	5.88

The clustering pattern could be utilized in selection of parents for crossing and deciding the best cross combinations, which may generate the highest possible variability for various traits. In the present study, the cluster VIII differed from other clusters (Table 5) in respect of seed yield per plant, number of primary branches per plant, 1000-seed weight and biological yield per plant, while, cluster II was the best for number of secondary branches per plant, number of siliquae per plant and oil content. The cluster IV had desirable rating for days to 50% flowering, days to maturity and plant height. The clusters VII, VI and IX were the best for number of seeds per siliquae, length of siliquae and harvest index, respectively.

Contribution of different characters towards total genetic divergence (Table 5) revealed the highest contribution of days to maturity (32.73 %). Three traits contributed more than 55 % of diversity *viz.*days to maturity (32.73 %), days to 50% flowering (12.16 %) and 1000-seed weight (10.29 %).Hence, selection of divergent parents based on these 3 traits would be useful for hybridization programme followed by isolation of desirable transgressive segregants in mustard. Similar findings were also reported by Arha *et al.* (2006) and Budhanwar *et al.* (2010).

Overall, it can be concluded that high heritability along with high GCV and high genetic gain were observed for seed yield per plant, days to 50% flowering, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant and 1000-seed weight which might be attributed to additive gene action in their inheritance and phenotypic selection could be effective. Maximum contribution of days to maturity, followed by days to 50% flowering and 1000-seed weight were observed on total genetic divergence. Hence due consideration should be given to these traits, while imposing selection for amenability in seed yield per plant in mustard.

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Diallel analysis to study combining ability effects in okra [*Abelmoschus esculentus* (L.) Moench]

A. D. GAJERA[1], M. A. VADDORIA[2], N. B. PATEL[3] AND L. L. JIVANI[4]

Department of Genetics and Plant Breeding, College of Agriculture,
Junagadh Agricultural University, Junagadh-362 001 (Gujarat)

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ABSTRACT

The present investigation was undertaken to study the combining ability analysis using eight genotypes crossed in half diallel fashion in okra *[Abelmoschus esculentus* (L.) Moench] for fruit yield and other important traits. Combining ability analysis showed that general and specific combining ability variances were highly significant for all the characters for the expression of fruit yield (g) and its component traits. The parent JOL-09-7 and Arka Anamika were good general combiners for fruit yield and it's components traits. Out of 28 hybrids, 14 showed significant positive sca effects for fruit yield and it's components traits. The crosses GO-2 x GJO-5, GJO-3 x GJO-5 and GO-2 x HRB-108-2 were identified as promising hybrids for their exploitation in breeding programme.

Key words : General combining ability, specific combining ability, okra

Okra *[Abelmoschus esculentus* (L.) Moench], also called as "Lady's finger" is one of the important vegetable crops grown extensively for its green tender fruits in tropical and sub-tropical regions. An improvement in yield of vegetable crops like okra is effected mainly through selection of genotypes with desirable characters from the variation through recombination followed by selection. Heterosis in F_1 generation is of great importance in vegetable crop. Important steps for exploitation of heterosis in any crop are to study the general combining ability of the parents and specific combining ability of hybrids. Combining ability analysis helps to choose suitable parents for hybridization and provides valuable information regarding F_1 crosses to be exploited commercially. Information on the combining abilities of the genotypes will be helpful in the analysis and interpretation of the genetic basis of important traits. Although, some information on gene effects associated with fruit yield and its attributing traits in okra is available but that is scanty. Therefore. the present investigation was carried out to obtain information regarding general and specific combining ability effects for fruit yield and yield attributing traits in okra following a half diallel mating design.

MATERIALS AND METHODS

A set of 28 hybrids were developed using 8 parents (GO-2, GJO-3, GJO-5, Arka Anamika, VRO-6, JOL-09-7, JOL-04-08 and HRB-108-2) of okra through diallel mating design (excluding reciprocals) during *Kharif-2011*. The trial consisting of 28 hybrids and their 8 parents were raised in randomized block design with three replications at Instructional Farm, Junagadh Agricultural University, Junagadh during *summer*-2012. Each entry was sown in 3.0 m long single row plot at 60 x 30 cm spacing. Observations on five randomly selected plants were recorded for days to 50% flowering, days to first picking, plant height, number of branches per plant, number of nodes per plant, internodal length, number of fruits per plant, fruit length, fruit girth, 10-fruit weight and fruit yield per plant. The data generated were utilized to estimate the combining ability by the method II under model I as suggested by Griffing (1956).

[1] P.G. Student, [2] Research Scientist (Garlic-Onion), Vegetable Research Station, [3]Assistant Professor, [4] Associate Research Scientist, Vegetable Research Station.

RESULTS AND DISCUSSION

The analysis of variance for combining ability (Table 1) revealed that general combining ability variances were highly significant for all the characters indicating the involvement of additive type of gene action in the inheritance of all the traits under study. Specific combining ability variances were significant for all the characters indicating the involvement of non-additive gene action in the inheritance of these characters. The significance of variance due to gca and sca for all the characters studied indicated the role of both additive and non-additive gene action. These reflect much scope of improvement in yield through heterosis breeding and recurrent selection.

Consequently it is suggested that these traits could be improved through heterosis breeding rather than selection. Similar results of importance of both additive and non-additive genetic component in the inheritance of various traits were reported by Pal and Sabesan (2009) and Kachhadia *et al.,* (2011) in okra.

The σ^2gca/σ^2sca variance ratio being less than unity (1.0) for all the traits which suggested non additive type of gene action was predominantly involved in the expression of all traits. Thus, it the use of heterosis breeding approach will be fruitful for rapid improvement in the fruit yield governed by non-additive gene action. Role of non additive gene effects was also reported by Bhalekar *et al.,* (2004) and Kumar *et al.,* (2005).

The perusal of data on general combining ability effects of parents (Table 2) revealed that the parents JOL-09-7 and Arka Anamika were the good general combiner for fruit yield, days to 50 % flowering, days to first picking, fruit girth and 10-fruit weight where as, The parent GO-2 was good general combiners for earliness (days to 50 % flowering and days to first picking), number of branches per plant, internodal length and fruit length.For plant height and number of fruits per plant, HR8-108-2 was good general combiner for plant height whereas, GJO-3 was the good general combiner fo fruit girth. On the basis of fruit yield and yield attributing trait JOL-09-7, Arka Anamika, GO-2 and JOL-04-8 appeared desirable parents which could be used in hybridization programme.

Table 1 Analysis of variance for combining ability for various characters in okra

Source of variation	d.f.	Days to 50 % flowering	Days to first picking	Plant height (cm)	No.of branches per plant	No. of nodes per plant	Internodal length (cm)	No. of fruits per plant	Fruit length (cm)	Fruit girth (cm)	10-fruit weight (g)	Fruit yield per plant (g)
GCA	7	28.22**	27.94**	119.28**	0.31**	3.65**	0.23**	3.30**	0.37*	0.39**	162.77**	795.02**
SCA	28	7.87**	8.69**	235.56**	0.33**	5.38**	0.37**	3.77**	0.91**	0.17**	318.27**	1994.63**
Error	70	0.88	2.40	9.90	0.063	0.78	0.03	0.70	0.14	0.03	25.68	175.64
σ^2GCA		2.73	2.55	10.94	0.025	0.29	0.02	0.26	0.02	0.04	13.71	61.94
σ^2SCA		6.99	6.28	225.66	0.27	4.60	0.34	3.07	0.76	0.14	292.58	1818.99
G.P.R. = σ^2 GCA/ σ^2SCA		0.39	0.40	0.05	0.09	0.06	0.06	0.08	0.03	0.26	0.05	0.03

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

Table 2 Estimates of general combining ability effects of parents for different characters in okra

Parents	Days to 50 % flowering	Days to first picking	Plant height (cm)	No.of branches per plant	No. of nodes per plant	Internodal length (cm)	No.of fruits per plant	Fruit length (cm)	Fruit girth (cm)	10-fruit weight (g)	Fruit yield per plant (g)
GO-2	-1.00**	-1.20*	-1.74	0.25**	-0.48	-0.11*	-0.60*	0.31**	-0.28**	-0.91	-7.65
GJO-3	0.37	0.20	-3.66**	0.004	-0.77**	-0.19**	-0.54*	0.20	0.11*	2.46	-3.28
GJO-5	-0.20	0.13	-2.34*	-0.14	-0.35	-0.08	-0.58*	-0.16	0.02	-2.36	-10.69**
Arka Anamika	-2.47**	-2.50**	-0.11	-0.01	-0.06	-0.02	0.34	-0.16	0.30**	5.68**	12.15**
VRO-6	2.64**	2.67**	-2.14*	0.17*	-0.10	-0.05	-0.11	-0.13	-0.07	-0.22	-2.48
JOL-09-7	-1.60**	-1.47**	-0.15	-0.07	0.07	0.01	0.32	-0.05	0.20**	4.87**	12.77**
JOL-04-8	0.67*	0.77	3.39**	0.11	0.60*	0.19**	1.03 **	-0.17	-0.19**	-4.49**	4.86
HRB-108-2	1.60**	1.40	6.74**	-0.31**	1.11**	0.26**	0.14	0.16	-0.09	-5.03**	-5.69
SE(gi)	0.28	0.46	0.93	0.07	0.26	0.05	0.25	0.11	0.04	1.49	3.92
SE(gi-gj)	0.33	0.70	1.41	0.11	0.39	0.08	0.37	0.17	0.07	2.27	5.93

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

In the present study, the parents exhibiting high mean performance also had high general combining ability effects. A close relationship between the mean performance and general combining ability effects was noted by Kumar *et al.*, (2005). Such parallel behavior indicated that selection for good combiners for different characters could also be made on the basis of mean performance.

The estimates of sca effects revealed that 14 out of 36 hybrids showed significant positive sca effects for fruit yield per plant. Ten best specific combiners with mean performance, gca status and their significant response of sca effects to other traits are presented in Table 3. Eight crosses showed significant positive response to ten fruits weight, four crosses for fruit girth and fruit length indicating its direct effect for increasing fruit yield. However, five crosses showed significant response to plant height and number of nodes per plant, six crosses for number of branches per plant and three crosses for internodal length. This may be because of very complex nature of fruit yield and its dependence on its components. Out of ten crosses showing high mean and significant positive sca effects for fruit yield, three *crosses (*GO-2 x GJO-5, GJO-3 x JOL-04-8 *and* GJO-3 x GJO-5*) involved average x poor gca parents, two crosses (*GO-2 x HRB-108-2 and GO-2 x JOL-09-7) with average x good, *two crosses (*JOL-04-8 x HRB-108-2 and GJO-5 x HRB-108-2 *) with poor x* good, one cross (JOL-09-7 x JOL-04-8) with good x poor, one cross (Arka Anamika x JOL-09-7) with good x good, one cross (Arka Anamika x VRO-6) good x average gca parents. Better performance of hybrids involving poor x poor or average x poor general combiners indicated dominance x dominance (epitasis) type of gene action (Jinks, 1955). The crosses showing high sca effects involving one good general combiner indicated additive x dominance type of gene interaction which could produce desirable transgressive segregants in subsequent generations. In a situation where predominance of additive and non-additive gene effect has been observed for most of the traits, it is better to advocate the biparental mating and diallel selective mating to exploit both additive and non-additive type of gene effects.

Table 3 Ten best specific combiners for fruit yield/plant and their performance for other traits in okra

Sr. No	Hybrids	Fruit yield/ plant (g)	Mean fruit yield/ plant (g)	GCA status	Significant response in other traits for SCA effects
1	GO-2 x GJO-5	62.01	234.27	(A x P)	DF, NBP, NFP, FL, TFW
2	GJO-3 x GJO-5	61.42	238.06	(A x P)	PH, NBP, NNP, NFP, FL,FG, TFW
3	GO-2 x HRB-108-2	51.52	228.77	(A x G)	PH, NNP.NFP,FL, FG, TFW
4	JOL-04-8 x HRB-108-2	50.61	240.38	(P x G)	DF, NFP, TFW
5	GO-2 x JOL-09-7	49.62	245.34	(A x G)	PH, NNP, IL, TFW
6	JOL-09-7 x JOL-04-8	43.21	251.44	(G x P)	NFP, FG, TFW,DF, DFP, PH, NNP, IL
7	Arka Anamika x JOL-09-7	38.67	254.19	(G x G)	NFP,NBP
8	Arka Anamika x VRO-6	37.34	237.62	(G x A)	NBP,NFP
9	GJO-5 x HRB-108-2	36.78	211.00	(P x G)	TFW,FG,NNP,NFP,IL, PH, NBP
10	GJO-3 x JOL-04-8	33.19	225.37	(A x P)	TFW, FL, NBP

G = Good; A = Average; P = Poor general combining ability, respectively.

Figure in the parenthesis indicates per se performance for fruit yield per plant

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

DF = Days to 50 % flowering
PH = Plant height
TFW = Ten fruit weight
NBP = Number of branches per plant
FL = fruit length
NNP = Number of nodes per plant
IL = Internodl length
NFP = Number of fruits per plant
DFP = Days to first picking
FG = fruit girth

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G x E interaction and stability analysis in carrot (*Daucus carota* L.)

ASHA PRAJAPATI[1], C. J.TANK[2], R. A. GAMI[3], Y. RAVINDRABABU[4] AND V. H. KANBI[5]

Department of Genetics and Plant Breeding, C. P.College of Agriculture,
S.D. Agricultural University, Sardarkrushinagar-385 506 (Gujarat)

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ABSTRACT

G X E interaction and stability analysis was carriedout in four environments comprised of two different dates of sowing with two different locations for 24 diverse lines of carrot obtained from different sources. The analysis of variance for stability analysis revealed that variance for genotype x environment interactions was significant for weight of root per plant, length of root, plant top height, root laterals and total soluble sugar. The genotypes JDNCT-8, JDNCT-18, JDNCT-36, JDNCT-39, JDNCT-40 and Mehsana local-3 were identified as stable for weight of root per plant. The genotypes JDNCT-24, JDNCT-34 and JDNCT-35 were found better for favorable environments, among these three genotypes JDNCT-34 have the highest average weight of root.

Key words : Carrot, G x E interaction and stability.

Carrot (*Daucus carota* L.), is an important root vegetable root crop worldwide, both economically and as a source of provitamine 'A' carotenes. Carrot is cultivated in India, China, Malaysia, Indonesia, Philippines, European countries, West Africa and north-south America. In India the major carrot growing states are Uttar Pradesh, Assam, Karnataka, Andhra Pradesh, Punjab and Haryana. This plant species originated in Afghanistan (Matskevitzh, 1929) and spread to the Mediterranean region by the tenth to twelfth century and to Europe and China in the fourteenth century. Orange carrots were first known in the seventeenth century in northern Europe. Before that only yellow and purple root carrot types were cultivated. The cultivated types of this species can be readily crossed 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. The only reported interspecific cross with carrot is with *Daucus capillifolius*, where n = 9 for both species (Simon, 1993).

As environment is not static, each organism attempts to cope-up with environmental fluctuations through individual and population buffering (Cook and Johnson, 1968). The stability in productivity of a root crop like carrot over the years and locations is necessary as it is highly sensitive to adaphic factors and environmental fluctuations. Therefore, it is important to isolate genotypes manifesting low genotype x environment interaction in respect to carrot root yield and other important characters.

MATERIALS AND METHODS

The present research was conducted in four environments comprised two different dates of sowing with two different locations *viz.*, at Botanical Garden, Department of Genetics and Plant Breeding, C.P.College of Agriculture, S.D.Agricultural University, Sardarkrushinagar and Main Potato Research Station, S.D.Agricultural University, Sardarkrushinagar Deesa,. during *rabi*.2011-2012. Diverse 24 genotypes were selected from different sources for exprementation. Each genotype was planted with a spacing of 30 cm between rows and

[1] Ex. Junior Research Fellow, Main Potato Researh Station, [2]Associate professor, [3]Assistant Professor, [4] Research Scientist, Center of Excellence for Research on Pulses, [5]Associate professor (Biochemistry), Aspee College of Home Science & Nutrition.

10 cm within row. The experiment was laid out in a Randomized Block Design with three replications. Observations were recorded for the traits *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, â-carotene contents (µg/g) and total soluble sugar. Analysis of variance was performed as per method suggested by Snedecor and Cocharan (1937) and review by Panse and Sukhatme, (1978). The statistical analysis for G x E interaction and stability parameters were carried out according to the Eberhart and Russell (1966).

RESULTS AND DISCUSSION:

The pooled analysis over environments revealed the variance due to was significant for nine characters out of 13 studied., which include number of leaves per plant, petiole length, length of root, weight of root, plant top height, core size, harvest index, β-carotene and total soluble sugar (Table 1.) The value of environmental variance were significant for 11 characters. The value of variance due to G x E interaction was also significant for seven characters (Table 2). These indicated that studied genotypes responded differently to array of environments and environments also showed variation. The mean squares due to G x E interactions were significant for length of root, weight of root, plant top height, root laterals and total soluble sugar while the interactions were non-significant for rest of the traits *viz.*, number of leaves per plant, petiole length, root diameter, core size, harvest index, root index, total biomass and β-carotene. Therefore, stability parameters were estimated for the characters which had significant estimates of G x E interaction.

On the basis of which stability parameters estimates those two genotypes *viz.*, JDNCT-8 and JDNCT-35 registered higher mean length of root, non-significant value of S^2d_i and value of regression coefficient was less than one, there by both were found better for poor environment. One genotype (Pusa Ashita) registered higher length of root, non significant deviation from regression and $b_i>1$. Thus it could be the most adapted for favorable environments only.

The perusal of stability parameters for weight of root per plant revealed that six genotypes

Table 1 Pooled analysis of variance (mean square) over environment for different characters in carrot

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 (µg/g)	Total Soluble sugar
Genotype	23	2.92*	52.69**	7.41*	0.23*	912.51**	141.96**	0.63**	18.97**	186.48**	0.64**	2841.33**	160.0**	7.64**
Environment	3	6.39*	200.84**	67.22*	49.66*	140744.25**	10998.4**	14.65**	651.75**	1225.17**	37.69**	520982.3**	2.59**	2.72**
G x E	69	1.87*	13.00**	5.50*	0.28*	866.50**	60.78**	0.75**	22.21**	143.44**	0.49**	2424.35**	3.27**	0.84**
Pooled error	184	1.63*	10.93**	3.85*	0.24*	162.05**	30.09**	6.64**	2.34**	*80.56***	*0.53***	*644.11***	*0.16***	*0.02***

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

were stable over range of environments. These genotypes registered higher mean weight of root, regression coefficient approaching unity and non-significant deviation from regression (Table 3) and the genotypes were JDNCT-8, JDNCT-18, JDNCT-36, JDNCT-39, JDNCT-40 and Mehsana local-3. Based on unit regression coefficient and least deviation from regression, twelve genotypes *viz.*, JDNCT-11, JDNCT-13, JDNCT-18, JDNCT-27, JDNCT-34, JDNCT-38, JDNCT-39, JDNCT-41, JDNCT-42, Mehsana local-1, Mehsana local-2 and Mehsana local-3 were found stable over wide range of environments for plant top height (Table 3) and also registered higher mean, regression coefficient close to unity and non- significant deviation from regression. The stability parameters showed be marked out for the characters, which had significant value of only G x E (L), otherwise, when both G x E (L) and G X E (NL) are significant. These magnitude should be considered GxE (L) > G x E (NL). In this regards stability parameters should be estimated for the characters length for roots, weight of root, plant top height and total soluble sugars.There is no stand for linear and non linear components of G x E interaction.

For total soluble sugar based on unit regression and least deviation from regression coefficient, three genotypes JDNCT-22, JDNCT-32 and JDNCT-34 were found to be ideally stable over large spectrum of environment for total soluble sugar. Genotypes *viz.*, JDNCT-11, JDNCT-13, JDNCT-14 and JDNCT-18 registered higher mean of total soluble sugar, non-significant S^2d_i and b_i > 1 (Table 3), Therefore, these genotypes could be considered as well adopted to favorable environments. The genotype Mehsana local-1 had higher mean, non-significant S^2d_i and regression coefficient less than one, which revealed that the said genotype would be well adapted to poor environments.

An overall basis of stability parameters (Table 4) revealed that none of the genotypes was stable for all the characters. For weight of root and other component characters, the genotypes JDNCT-8, JDNCT-18, JDNCT-36, JDNCT-39, JDNCT-40 and Mehsana local-3 were stable across environments. The genotypes JDNCT-24, JDNCT-34 and JDNCT-35 were found better for favorable environments.

Table 2 Analysis of Variance (mean squares) for stability for various traits in carrot

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 (µg/g)	Total Soluble sugar
Genotype	23	0.97	17.56**	2.6*	0.079	304.158**	499.17*	1.71	6.32	62.16	0.21	947.12	938818.87**	2.56**
Environment	3	2.13	669.47**	25.17*	16.56**	46914.67**	5900.79*	6.66	217.25**	408.34	12.56**	173660.80**	907562.85**	0.91
G x E	69	0.62	4.34	1.74*	0.92	288.84**	498.73**	2.35**	7.402	47.82	0.16	808.13	10597.57	0.28**
E + (G x E)	72	0.69	32.05**	2.71**	0.78**	2231.58**	723.82**	2.53	16.15**	62.84	0.68**	8010.32**	10534.15	0.31**
Environment (Linear)	1	6.40	2008.47*	75.52	49.67**	140744.37*	17702.95**	19.97	651.75	1225.18	37.69*	520982.53*	27226.942	2.72
Genotype x Environment (Linear)	23	0.72	2.54	2.67*	0.07	418.85*	948.94**	1.84	5.42	39.39	0.20	563.12	31325.927	0.56**
Pooled deviation	48	0.55	5.02	1.22	0.09	114.50	262.22**	2.49	8.04**	49.86	0.14	891.85	22366.11	0.13
Pooled error	184	1.63	10.9	3.85	0.24	162.05	34.95	6.64	2.34	80.56	0.53	2006.13	31252.774	0.02

*, ** Significant against pooled deviation mean square at 5 and 1 per cent level of significance, respectively.

Table 3 Stability parameters of different genotypes for length of root (cm), weight of root (g/plant), plant top height (cm), root laterals and total soluble sugar in carrot

Sr. No.	Genotypes	Length of root (cm)			Weight of root (g/plant)			Plant top height (cm)			Root laterals			Total soluble sugar		
		Mean	b_i	$S^2 d_i$	Mean	b_i	$S^2 d_i$	Mean	b_i	$S^2 d_i$	Mean	b_i	$S^2 d_i$	Mean	b_i	$S^2 d_i$
1.	JDNCT-8	16.88	0.04*	-0.38	94.35	0.80	-310.58	57.47	0.85	-428.71	1.74	4.65**	-1.21	4.09	-0.53*	-0.01
2.	JDNCT-11	15.95	1.12	1.03	87.15	0.88	58.55	66.95	0.70	-505.92	2.44	0.49	-1.68	6.55	2.77*	0.05
3.	JDNCT-13	16.12	0.55	-1.07	89.38	0.74	115.32	65.01	0.76	-501.13	2.52	1.03	-1.81	6.58	2.52*	0.09
4.	JDNCT-14	16.74	1.01	5.93	84.71	0.85	-33.24	58.47	0.77	-518.02	2.38	0.90	-1.34	7.15	4.44*	0.12
5.	JDNCT-18	15.49	2.63**	-0.52	99.55	1.14	53.05	62.43	0.69	-419.59	2.07	0.60	-1.73	6.89	3.11*	0.34
6.	JDNCT-21	14.43	1.53*	-1.07	85.12	1.10	51.26	60.14	3.28**	-501.63	2.87	1.36	-1.58	6.63	0.41*	-0.01
7.	JDNCT-22	15.98	2.20*	-0.47	92.97	1.25	27.20	56.74	0.80	-476.88	1.97	0.29*	-2.05	7.11	1.81	0.08
8.	JDNCT-24	15.18	1.30	-1.21	99.25	1.44*	-262.58	59.28	0.72	-482.46	2.03	0.84	-2.03	5.78	4.29**	0.01
9.	JDNCT-27	16.31	0.87	-1.23	90.70	0.76	-24.21	66.28	0.81	-505.62	2.18	0.13*	-1.80	5.40	0.18*	0.05
10.	JDNCT-32	15.65	0.65	-1.20	84.85	0.91	130.86	61.32	0.67	-508.69	2.58	0.21*	-1.01	7.07	1.02	0.40
11.	JDNCT-34	17.27	0.51	-2.28	125.92	1.59**	-1476.92	64.43	0.63	-525.12	2.06	0.46*	-1.47	6.36	0.87	0.04
12.	JDNCT-35	16.11	0.06*	1.60	98.03	1.46**	-187.51	62.28	0.90	-499.05	2.12	1.13	-1.76	5.67	-0.06*	0.07
13.	JDNCT-36	15.36	2.62**	0.35	94.50	1.00	-28.01	61.30	0.87	-524.40	2.37	0.98	-2.13	5.03	-1.29*	0.01
14.	JDNCT-37	14.57	0.14*	-0.42	83.94	0.50	226.58	59.28	0.45	-436.80	2.28	0.97	-2.11	5.81	-1.62**	0.01
15.	JDNCT-38	15.58	2.21*	-0.76	91.10	1.13	153.26	63.74	0.91	-496.47	2.27	0.82	-1.86	4.77	0.44*	0.02
16.	JDNCT-39	16.45	0.51	-1.15	101.83	0.87	140.81	64.68	0.50	-522.13	2.36	0.05*	-1.44	5.39	0.48*	0.01
17.	JDNCT-40	17.07	0.81	-0.99	99.77	1.24	274.21	61.87	0.78	-519.36	2.20	0.10*	-1.93	5.32	-1.94**	0.22
18.	JDNCT-41	17.76	0.69	-0.63	91.21	0.82	-45.38	68.23	0.61	-519.79	2.10	0.91	-1.42	5.60	7.50**	0.18
19.	JDNCT-42	16.82	0.82	0.19	92.43	0.61	424.92	64.57	0.91	-514.31	2.37	0.97	-2.12	5.00	-0.08*	0.03
20.	Pusa Rudhira	16.20	1.18	0.06	88.53	1.02	124.16	60.90	1.02	-506.81	2.35	0.83	-2.05	5.27	-1.38**	0.02
21.	Pusa Ashita	16.87	2.38*	-0.05	92.81	0.94	-29.22	55.25	0.75	-495.52	2.31	-0.32	-1.91	5.70	0.79	0.61
22.	Mehsana local-1	16.17	0.43	-0.93	87.72	1.10	-30.62	65.71	0.74	-498.91	2.29	1.30	-1.57	5.86	-1.33*	0.13
23.	Mehsana local-2	15.57	1.37	-0.91	88.78	0.79	-48.03	65.07	0.84	-486.52	2.75	0.98	-1.90	5.72	0.67	0.61
24.	Mehsana local-3	15.93	0.87	0.58	98.52	1.05	72.60	64.73	1.03	-486.78	2.45	1.32	-1.71	5.57	0.94	0.02
Mean		16.10			93.46			62.34			2.29			5.84		
S.Em. ±		0.64			8.45			9.34			0.91			0.21		

Table 4 Stable genotypes identified on the basis of high mean for weight of root per plant and stability parameters

Genotypes	Weight of root per plant	Stable for other traits
JDNCT-8	94.35	-
JDNCT-18	99.55	3, 4+
JDNCT-24+	99.25	-
JDNCT-34+	125.92	3+
JDNCT-35+	98.03	-
JDNCT-36	94.50	3
JDNCt-39	101.83	1, 2, 3+
JDNCT-40	99.77	1, 3+
Mehsana local-3	98.52	3

Where,
+ = Better for favorable environments
1 = Length of root
2 = Plant top height
3 = Root laterals
4 = Total soluble sugar

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Genetic analysis in wheat (*Triticum aestivum* L. Em. Thell.)

C. S. DESALE[1] AND D. R. MEHTA[2]

Department of Genetics and Plant Breeding, College of Agriculture,
Junagadh Agricultural University, Junagadh-362 001 (Gujarat)

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ABSTRACT

In bread wheat ten genotypes were crossed in half diallel fashion to estimate gene action involved in the inheritance ofgrain yield and its component traits The non-significance of 't²' values suggested that additive-dominance model was adequate for days to 50% flowering, plant height, number of effective tillers per plant, number of spikelets per main spike, days to maturity, number of grains per main spike, grain weight per main spike, 100 grain weight, grain yield per plant, biological yield per plant, harvest index and protein content. Additive (D) and both the dominance components (H_1, H_2) were significant for all for all the above said characters except 'D' for days to 50% flowering, number of effective tillers per plant, length of main spike, peduncle length of main spike, grain yield per plant, harvest index, total soluble sugar and chlorophyll content. The average degree of dominance $(H_1/D)^{1/2}$ was greater than unity for all the traits indicating over dominance behavior of interacting alleles. Asymmetrical distribution of positive and negative genes in the parental lines was revealed from the estimate, $H_2/4H_1$ for all the characters except days to maturity and grain weight per main spike for which symmetrical distribution was evidenced. Narrow sense heritability estimates were less than 50 per cent for all the traits (except grain weight per main spike) indicating major role of dominance gene effect in the expression of grain yield and its component characters.

Key words : Wheat, gene action, genetic parameters, heritability, grain yield.

Wheat (*Triticum spp.)* 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.Wheat breeding, in its fundamental form had many priorities, of which grain yield potential gain has been given a lot of attention. Progress in this endeavour is dependent on the understanding of the structure of genetic components in the wheat gene pool, and the understanding of the relationship between genotypic and phenotypic variation. A large number of new genetic combinations are, therefore, essential for the construction of high-resolution genetic maps, for implementation of efficient breeding methods and rapid development of superior varieties. The diallel analysis advocated by Hayman (1954) provides reliable method particularly in autogamous crops like wheat to work out the genetic system and gene action involved in the expression of matricate attributes. To understand the mode of expression of genes those are present in the experimental material, geneaction studies is helpful as it aids in selection of parents to be used in hybridization as well as appropriatebreeding procedures for genetic improvement of various polygenic characters. Therefore, this study was undertaken to generate information about nature and magnitude of gene action involved in various characters. Information derived may be effectively exploited in developing and formulating an efficient breeding program for the evaluation of better quality and high yielding varieties.

[1]Assistant Professor, K.K. Wagh College of Agriculture, Panchvati, Nasik (Maharashtra), [2]Associate Professor.

MATERIALS AND METHODS

The experimental material consisted of ten genotypes/ varieties of bread wheat *viz.*, GW-496, GW-322, LOK-1, GW-173, KYZ-300, RAJ-4136, HW-5018, K-604, UAS-281, HI-1544 and GW-366; 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, Gujarat. 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 2.5 m length keeping row-to-row and plant-to-plant distance of 22.5 cm and 10 cm, respectively. Five competitive plants of each parents and hybrids were selected randomly for recording observations for sixteen characters *viz.*, days to 50% flowering, plant height, number of effective tillers per plant, length of main spike, number of spikelets per main spike, peduncle length of main spike, days to maturity, number of grains per main spike, grain weight per main spike, 100-grain weight, grain yield per plant, biological yield per plant, harvest index, total soluble sugar, protein content and chlorophyll content. The genetic components and related parameters were computed according to Hayman (1954). Heritability in narrow sense was worked out following Mather and Jinks (1982).

RESULTS AND DISCUSSION

Knowledge about the magnitude and nature of genetic variation in a specific population is of prime importance for the prediction of the most effective breeding programme (Debnath, 1988). The t^2 test (Hayman, 1954) was employed to test the assumptions of diallel analysis for all the 16 characters. The non-significance of 't^2'values suggested the fulfillment of basic assumptions underlying diallel analysis for all the characters except length of main spike, peduncle length of main spike, total soluble sugar and chlorophyll content which revealed that additive-dominance model was adequate and thereby components analysis was performed for all the characters except stated above.

Both additive (D) and dominance (H_1, H_2) components were significant for all for all the characters except additive gene effect for days to 50% flowering, number of effective tillers per plant, length of main spike, peduncle length of main spike, grain yield per plant, harvest index, total soluble sugar and chlorophyll content (Table 1), for these characters only dominance gene effect was importance, while for the rest of the characters, both additive and dominance components were important in the inheritance of grain yield and its components traits. However, additive component was lower in magnitude than that of dominance components for all the characters which revealed over dominance effect in the expression of all the traits. Similar findings were also reported by Alam *et al.*, (1990), Kathiria and Sharma (1996b) and Khan *et al.* (2010).

The estimates of average degree of dominance $(H_1/D)^{1/2}$ were greater than unity for all the traits (Table 1) indicating over dominance behavior of interacting alleles which suggested that heterosis breeding might be advantageous to get higher gain in bread wheat, however, the flower morphology of the crop and lack of working male sterility would not permit heterosis breeding, therefore segregating generations need to be followed for dilution of dominance and then selection may be applied for development of high yielding varieties. Similar finding was also reported by Sami *et al.*, (2010). The non-significant estimate of 'E'for all the traits except grain weightper main spike, grain yield per plant and biological yield per plant suggested that there was no considerable environment influence likely to modify the ability of genes to express respective characters.

The close to 0.25 $H_2/4H_1$ for days to 50 % flowering, length of main spike, days to maturity and grain weight per main spike and chlorophyll content revealed symmetrical distribution of increasing and decreasing alleles among the parental genotypes, while rest of the characters, an asymmetrical distribution was evidenced. The present findings are in parity with report of Kathiria and Sharma (1996b).

The positive sign of 'F' and more than one ration of K_D/K_R ratio for days to 50% flowering, plant height, number of effective tillers per plant, length of main spike, number of spikelets per main spike, peduncle length of main spike, number of grains per main spike, 100 grain weight, grain yield per plant, biological yield per plant, harvest index, total soluble sugar and protein content suggested an excess of dominant gene in the parents, while negative sign of 'F' and around unity ratio of K_D/K_R for days to maturity and grain weight per main spike indicated an equal proportion of recessive genes and dominant genes with the parents. The number of genes or group of genes exhibiting dominance for a particular character is important for the extent of genetic progress through selection. In the present investigation, the value of h^2/H_2 was very low for most of the characters, which suggested at least one dominant group of genes group could be involved in the inheritance of the studied characters.

High estimates of heritability in narrow sense was observed only for grain weight per main spike, while moderate values were observed for days to 50 % flowering, peduncle length of main spike, days to maturity, number of grains per main spike, 100 grain

Table 1 Estimation of genetic components of variation for different characters in bread wheat

Components/ Parameters	Days to 50% flowering	Plant height	Number of effective tillers per plant	Length of main spike	Number of spikelets per main spike	Peduncle length of main spike	Days to maturity	Number of grains per main spike
D1	1.59 ± 9.64	22.48** ± 4.43	1.16 ± 0.89	0.23 ± 0.34	3.89** ± 0.62	4.13 ± 2.29	15.00* ± 7.48	44.67** ± 10.50
H_1	66.30** ± 20.52	48.24** ± 9.43	6.83** ± 1.89	2.88** ± 0.72	10.26** ± 1.31	16.76** ± 4.86	62.12** ±15.92	133.09** ± 22.35
H_2	55.89** ± 17.44	36.88** ± 8.01	5.70** ± 1.61	2.47** ± 0.61	7.69** ± 1.11	12.24** ± 4.13	56.26** ±13.53	102.75** ± 18.99
h^2	22.15** ± 3.44	8.11 ± 5.36	-0.10 ± 1.08	0.16 ± 0.41	0.05 ± 0.74	-0.02 ± 2.77	2.53** ± 9.05	24.94* ± 12.71
F	6.30 ± 22.25	30.54** ± 10.22	1.44 ± 2.05	0.53 ± 0.78	6.02** ± 1.42	5.36 ± 5.27	0.79 ±17.25	49.58* ± 24.22
E	0.37 ± 2.90	0.88 ± 1.34	0.28 ± 0.27	0.10 ± 0.10	0.18 ± 0.19	0.52 ± 0.69	0.39 ± 2.25	1.55 ± 3.17
$(H_1/D)^{1/2}$	2.39	1.47	2.43	3.52	1.63	2.04	2.04	1.73
$H_2/4H_1$	0.21	0.19	0.21	0.21	0.19	0.18	0.23	0.19
K_D/K_R	1.26	2.73	1.69	1.95	2.82	1.95	1.03	1.95
h^2/H_2	0.40	0.22	-0.02	0.06	0.01	-0.001	0.05	0.24
Heritability (ns) %	35.40	14.10	19.9	7.4	9.4	31.50	41.00	31.80
t^2	2.68	0.45	5.23	7.33*	0.01	11.80*	5.20	0.03

*,** Significant at 0.05 and 0.01probability level, respectively

Table 1 Contd.

Components/ Parameters	Grain weight per main spike	100 grain weight	Grain yield per plant	Biological yield per plant	Harvest index	Total soluble sugar	Protein content	Chlorophyll content
D	0.05* ± 0.02	0.26** ± 0.04	2.21 ± 2.58	123.90** ±45.11	109.18 ± 89.38	285.30 ± 5521.96	0.56** ± 0.11	0.0012 ±0.0036
H_1	0.08** ± 0.03	0.46** ± 0.08	23.97** ± 5.50	785.41** ±96.02	963.02** ±190.25	44178.13** ±11754.01	1.59** ±0.23	0.026** ±0.0077
H_2	0.08** ± 0.03	0.34** ± 0.07	16.16** ± 4.67	568.86** ±81.61	756.35** ±161.69	35998.82** ± 9989.60	1.19** ±0.19	0.023** ±0.0065
h^2	0.009 ± 0.02	-0.002 ± 0.05	2.70 ± 3.13	47.37 ±54.63	-1.14 ±108.23	1042.90 ± 6686.65	0.11 ±0.13	0.0023 ±0.0044
F	-0.0007 ± 0.04	0.32** ± 0.09	7.81 ± 5.96	299.59 ±104.09	235.45 ±206.22	342.18 ±12740.82	0.42 ±0.25	0.0022 ±0.0083
E	0.009 ± 0.005	0.01 ± 0.01	1.61* ± 0.78	1.66** ±13.60	8.60 ± 26.95	68.66 ± 1664.93	0.02 ±0.03	0.0003 ± 0.001
$(H_1/D)^{1/2}$	1.34	1.31	3.29	2.52	2.97	12.44	1.69	4.64
$H_2/4\ H_1$	0.23	0.19	0.17	0.18	0.20	0.20	0.19	0.22
K_D/K_R	0.99	2.74	3.31	2.85	2.14	1.10	1.57	1.49
h^2/H_2	0.11	-0.005	0.17	0.08	-0.002	0.03	0.09	0.09
Heritability (ns) %	50.70	21.20	16.40	12.4	16.90	30.90	46.10	13.70
t^2	3.66	0.31	0.46	2.15	5.17	207.76**	0.93	39.04

*,** Significant at 0.05 and 0.01probability level, respectively

weight, total soluble sugar and protein content. On the other hand, plant height, number of effective tillers, grain yield per plant, biological yield per plant, harvest index per plant, chlorophyll content displayed low heritability. Very low heritability was observed in case of length of main spike and number of spikelets per main spike.In general, narrow sense heritability was found to be less than 50 per cent for all the traits except grain weight per main spike, indicating prime role of dominance gene effect in the expression of grain yield and its attributes. High narrow sense heritability for grain weight per main spike indicated that the major part of phenotypic variability was due to additive component, and possibility of fixing this character by pedigree method of selection.

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Combining ability for yield related characters in fieldpea [*Pisum sativum* (L.) *Var arvense.*]

D. J. JOSHI[1], Y. RAVINDRABABU[2], A. M. PATEL[3] AND S. S.CHAUHAN[4]

Centre of Excellence for Research on Pulses,
S. D. Agricultural University, Sardarkrushinagar - 385 506 (Gujarat)

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ABSTRACT

The combining ability analysis for yield and its contributing traits was performed in fifty five genotypes of fieldpea including ten parents and their forty five F_1's developed through half diallel mating design. Among the parents, DF-1, IPFD 10-13 and GCO-703 were good general combiners for grain yield and important yield contributing traits which can be utilized in hybridization programme. Three crosses DF-1 x HFP-4, HUDP 954 x LFP 477 and LFP 477 x IPFD 10-13 were found to be most promising for grain yield with respect to high and significant *sca* effects to through transgressive segregants in fieldpea.

Key words : Diallel, combining ability, GCA, SCA, fieldpea

Fieldpea [*Pisum sativum* (L.) *var arvense.*] is a highly nutritive *rabi* season legume with high yield levels. It provides protein-rich food for humans. It also aids to soil health and provides quality forage for animals. It belongs to family *Papilionaceae* and is grown all over India and Indian subcontinent. Fieldpea is consumed as green vegetable, chat (spicy-dish), chhola (whole grain), dhal (pulses) and flour and thus contributing significantly to market economy. Combining ability analysis on the basis of diallel mating system is one of the most appropriate methods to identify the best combiners, which can be utilized for hybridization programme. It gives information about nature of gene action and the relative magnitudes of fixable (additive) and non-fixable (non-additive/dominance) genetic variations. The present investigation was, therefore, undertaken to get information on the combining ability of ten cultivars of fieldpea and their forty five hybrids in respect of yield and yield components.

MATERIALS AND METHODS

The experimental material comprised of fifty five fieldpea genotypes including ten parents *viz.*, DF-1, HFP-4, HUDP 954, KPMR 400, HFP 715, Pant P 167, IPFD-1-10, LFP 477,IPFD 10-13, and GCO-703 and their forty five F_1's developed through half diallel mating design. The experimental material was grown in randomized block design with three replications with 45 x 10 cm row to row and plant to plant spacing, respectively during *rabi*, 2012 at Centre of Excellence for Research on Pulses, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. All the management practices were followed as per recommendations to raise the normal crop. The observations were recorded on five randomly taken plants from each genotype in each replication for grain yield and its contributing characters *viz.*, number of pods per plant, number of seeds per pod, number of primary branches, test weight and harvest index in fieldpea. The data were analyzed for combining ability by using Model I and Method II of Griffing (1956).

RESULTS AND DISCUSSION

The analysis of variance for combining ability exhibited that mean squares due to general combining ability and specific combining ability were found significant for all the traits except gca for number of primary branches. This indicated that additive and non-additive genetic component of variation involved in the expression of these attributes. However, the ratio of gca / sca genetic variance indicated that non-additive type of genetic variation was more important in the

[1] P.G. Student, N. M. College of Agriculture, NAU, Navsari
[2] Research Scientist, [3] Assistant Research Scientist, [4] Junior Research Fellow

Table 1 Analysis of variance for combining ability for different characters in fieldpea

Source of variation	d.f	Mean Squares					
		Number of pods per plant	Number of seeds per pod	Number of primary branches	Test weight (g)	Harvest index (%)	Grain yield per plant (g)
General combining ability(gca)	9	83.42**	1.10**	0.07	9.00**	433.12**	10.89**
Specific combining ability (sca)	45	52.87**	0.64**	0.12**	2.87**	176.35**	10.49**
Error	108	0.77	0.20	0.06	0.49	9.53	0.27
σ^2gca		6.88	0.07	0.001	0.70	35.29	0.88
σ^2sca		52.10	0.44	0.057	2.38	166.8	10.21
σ^2gca/σ^2sca		0.13	0.16	0.01	0.29	0.21	0.08

** P=0.001 level

expression of all the characters under study (Table1). On the basis of mean performance of the parents, DF-1, HFP 715 and IPFD 10-13 showed high *per se* performance for grain yield per plant and all the characters. In addition to that IPFD 10-13 also emerged as excellent as it exhibited highest performance for rest of yield contributing characters under study *viz.*, number of seeds per pod, grain yield per plant, test weight and harvest index.

The parental line DF-1 was also found to be good general combiner for grain yield per plant and harvest index. On the other hand, HFP 715 was also found good general combiner for number of primary branches, test weight, and harvest index, whereas, the parent KPMR 400 had good general combining ability effect for number of pods per plant and number of primary branches (Table-2). Three hybrids *viz.*, DF-1 x HFP -4, HFP-4 x IPFD 10-13 and LFP 477 x IPFD 10-13 were found best performing based on their *per se* performance for grain yield per plant. Moreover, these hybrids were also superior in per *se* performance for one and more yield contributing traits studied (Table-2). Similar findings have been reported for one or more characters in fieldpea by Sofi Parvez *et al.* (2006), Sharma *et al.*, (2007), Ercan Ceyhan *et al.*, (2008), Borah (2009), Singh *et al.*, (2010), Punia *et al.*, (2011) and Abbas (2012).

The best cross combinations namely; DF-1 x HFP -4, HFP-4 x IPFD 10-13 and LFP 477 x IPFD 10-13 expressed maximum sca effects along with *per se* performance for grain yield per plant. Further, these hybrids also exhibited significantly higher sca effects for one or more yield contributing characters.

A comparative study of most of the crosses showing high sca effects for different characters which produced maximum yield, had at least one parent as good combiner for grain yield and its contributing traits. An overview of the results suggested that parental lines DF-1, KPMR 400 and IPFD 10-13 were found to be common good general combiners for grain yield and its component traits. These lines can be utilized in future for fieldpea hybrid breeding programmes. Besides this, the parents showing good general combining ability for particular components may be utilized in component breeding for effective improvement in particular components, resulting in the improvement of seed yield itself.

The F_1 hybrids, such as DF-1 x HFP-4, HFP-4 x IPFD 10-13 and LFP 477 x IPFD 10-13 showed potential to produce transgressive segregants in further segregating generation. The non additive gene action was predominately responsible for the inheritance of all the traits; heterosis breeding could be the best breeding method for improvement of grain yield in fieldpea. Since, non-availability of male sterility system at commercial level both additive and non-additive genetic variances are important in fieldpea. To take advantage of both types of gene action, reciprocal recurrent selection or biparental mating followed by modified recurrent selection has been suggested for the improvement of the yield and yield related traits for the development of high yielding stable genotypes of fieldpea.

Table 2 Best performing parents and hybrids with SCA effects in fieldpea

Character	Best Performing Parents (per se performance)	Best combiners	Best Performing hybrids (per se performance)	Hybrids with SCA effects	SCA effects
Number of pods per plant	DF-1 KPMR 400 HUDP 954	DF-1	HFP-4 x HFP715 HFP-4 x IPFD 10-13 HFP-4 x KPMR 400	HFP-4 x HFP 715 IPFD-1-10 x IPFD 10-13 HFP-4 x IPFD 10-13	21.57** 10.37** 9.39**
Number of seeds per pod	GCO-703 HFP 715 IPFD-1-10	IPFD-1-10	HFP 715 x IPFD-1-10 DF-1 x GCO-703 IPFD-1-10 x GCO-703	HFP 715 x IPFD-1-10 DF-1 x GCO-703 Pant P 167 x LFP 477	1.75** 1.40** 1.17**
Number of primary branches	GCO-703 KPMR 400 LFP477	KPMR 400	DF-1 x Pant P 167 KPMR 400 x LFP 477 HFP 715 x IPFD-1-10	DF-1 x Pant P 167 KPMR 400 x LFP 477 HFP-4 x Pant P 167	0.76** 0.49** 0.48**
Test weight (g)	Pant P 167 HFP 715 IPFD 10-13	HFP 715	HUDP 954 x KPMR 400 HFP 715 x GCO-703 Pant P 167 x IPFD-1-10	KPMR 400 x LFP 477 HFP 715 x GCO-703 DF-1 x LFP 477	5.36** 3.26** 2.66**
Harvest index (%)	DF-1 HFP 715 HUDP 954	DF-1 HFP 715	HFP 715 x IPFD 10-13 DF-1 x IPFD-1-10 HFP-4 x IPFD 10-13	HFP 715 x IPFD 10-13 LFP 477 x IPFD 10-13 HUDP 954 x GCO-703	48.39** 20.85** 19.34**
Grain yield per plant (g)	DF-1 HFP 715 IPFD 10-13	DF-1 HFP 715	DF-1 x HFP-4 HFP-4 x IPFD 10-13 LFP 477 x IPFD 10-13	DF-1 x HFP-4 HUDP 954 x LFP 477 LFP 477 x IPFD 10-13	6.21** 5.68** 5.34**

** Significant at 1% level.

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Effect of some organic amendaments on termite infestation in wheat

V. C. GADHIYA[1], P. K. BORAD[2] AND DEB SUSHMA[3]

Department of Entomology, B. A. College of Agriculture,
Anand Agricultural University, Anand - 388 110 (Gujarat)

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ABSTRACT

With a view to know the effect of organic amendments on termite in wheat, an experiment was carried out at Anand Agricultural University, Anand during *rabi* season of 2010-11. Among the tested eleven organic amendments, the soil application of castor cake, vermicompost and neem cake @ 1 tonne/ha at the time of land preparation before sowing were found to be more effective in suppressing the termite population and produced 3516 to 4223 kg/ha grain and 4247 to 5659 kg/ha straw yield. The NICBR of these amendments were 1 : 1.35, 1 : 2.53 and 1 : 1.38, respectively. There was no detrimental effect of evaluated insecticides on the seed germination and number of tillers per plant in wheat.

Key words : Termite, organic amendments, wheat

The successful story of green revolution in India is mainly attributed to increase in wheat production. Among the insect pests which cause damage to wheat crop in field, termite acts as a major insect pest of the crop in India and particularly under rainfed situation. Considerable losses to the extent of ₹ 280/- million in grain crops including wheat were reported by Fletcher and Ghosh (1912). Mehta and Verma (1968) calculated the loss due to termite up to ₹ 230/- million for the Agricultural crops.

The most common species of termites attacking the wheat crop are *Microtermes obesi* Holm) and *Odontotermes obesus* (Rambur). These two species probably account for about 80 per cent of the total loss (Roonwal, 1979). Wheat is second important staple food crop after rice. Its value in human diet, both as a source of carbohydrates and protein, and its baking qualities make it relatively more important crop than other cereal grains. Wheat crop is attacked by 24 species of insect pests (Singh, 1998). Among these, termite is rank first as a pest of wheat not only in India but South Asia too (Geddes and Iles, 1991). About 16 species of termite were found to damage the wheat crop in India, of these two species, *Odontotermes obesus* (Rambur) and *Microtermes obesi* (Holm) were found dominant (Chhillar *et al.*, 2006). The yield losses were recorded 43 to 80 per cent in wheat due to termite damage (Sattar and Salihah, 2001 and Chhillar *et al.*, 2006). Considering the importance of termite, a study was carried out to know the effect of organic amendments on termite infesting wheat crop at Anand Agricultural University, Anand during *rabi* season of 2010-11.

MATERIALS AND METHODS

A field experiment was laid out at Anand Agricultural University, Anand during December, 2010. Wheat variety GW 496 was used. The gross and net plot size were 5 x 4 m and 4 x 3 m, respectively with a row distance of 30 cm. There were 12 treatments including control. The details of respective soil amendments are given in Table 1. Each treatment was applied at the time of land preparation and then the seeds were sown. To know the effect of soil amendments on germination, 2 m area from each treatment were selected 10 days after sowing and germination count were recorded. To see the effect of soil amendments on tillering, 10 plants from each plot were counted after 28 days of germination. The termite infestation was recorded from three, one meter randomly related rows at weekly interval starting from one week after germination till harvest. The grain and straw yield of wheat were also recorded.

[1&3] P.G. Scholer, [2] Professor & Head

RESULTS AND DISCUSSION

Germination

No significant effect on seed germination was observed due to organic amendments. In all the treatments germination ranged between 83 to 91 per cent (Table 1). The lowest (83 %) seed germination was recorded in the plots treated with cotton cake and orgo natural organic manure. The highest (90.97 %) germination was recorded in the treatment of poultry manure followed by *Calotropis gigantea* leaf powder.

Tillering

No adverse effect of organic amendments was observed on tillering of wheat (Table 1). The maximum tillering was recorded in FYM (3.57) while minimum was noticed in cotton cake plots (2.97).

Termite damage

The data revealed that the application of castor cake (2.32%) significantly superior in reducing the termite infestation in wheat crop than all other organic amendments except vermicompost (Table 1). The plots treated with neem cake (3.38%) were equally effective as vermicompost and found at par with *C. gigantea* leaf powder (4.11%). In past, Singh and Singh (2003) reported that application of neem cake @ 2 kg/ tree was very effective against termite. Furrow application of neem cake at 700 kg/ha was next to the endosulfan in their effectiveness (Patel *et al.*, 2008). Singh *et al.* (2010) reported that use of dry powder of immature neem kernels and leaves effectively control the termite and increase the yield of wheat with economic return. Jatropha cake, poultry manure and tobacco dust noted 5.18, 5.41 and 5.91 per cent damaged plants, respectively and they were at par with each other but significantly more effective than remaining amendments. Of the evaluated organic amendments, the maximum damaged plants (8.76%) were observed in plots treated with mahua cake and it was at par with FYM (8.29%) and cotton cake (8.68%).

Grain yield

The significantly higher grain yield was obtained from the plots treated with castor cake (4222.22 kg/ha) and it was statistically at par with vermicompost (3833.33 kg/ha) and neem cake (3516.67 kg/ha). Application of neem cake at sowing and 40 days after

Table 1 Effect of organic amendments on termite damage and yield of wheat

Organic amendments	Germination (%)	No. of tillers/ plant	Termite damaged plants (%)	Yield (kg/ha)		NICBR
				Grain	Straw	
FYM @ 10 ton/ha	88.33	3.57	16.73(8.29)	1916.67	2206.67	0.45
Vermicompost @ 1 ton/ha	87.00	3.30	10.10(3.08)	3833.33	4547.22	2.53
Neem cake @ 1 ton/ha	86.67	3.24	10.59(3.38)	3516.67	4247.22	1.38
Castor cake @ 1 ton/ha	88.00	3.17	8.77(2.32)	4222.22	5658.33	1.35
Mahua cake @ 1 ton/ha	87.00	3.00	17.22(8.76)	1802.78	2088.89	-0.25
Cotton cake @ 1 ton/ha	83.00	2.97	17.13(8.68)	1869.44	2185.00	-0.86
Tobacco dust @ 1 ton/ha	86.33	3.17	14.07(5.91)	2080.56	2611.11	1.44
Jatropha cake @ 1 ton/ha	85.33	3.30	13.15(5.18)	3013.89	3505.56	1.19
Poultry manure @ 1 ton/ha	90.97	3.27	13.45(5.41)	2875.00	3298.89	30.42
Calotropis gigantea leaf powder @ 1 ton/ha	89.00	3.17	11.69(4.11)	3061.11	3622.22	6.97
Orgo natural organic manure @ 1 ton/ha	83.00	3.33	14.74(6.47)	1955.56	2430.56	-0.81
Control	88.00	3.13	23.29(15.63)	1033.33	1156.67	-
S. Em. ±	5.18	0.25	0.53	252.91	217.28	
C. D. at 5%	NS	NS	1.48	741.81	637.30	
C. V. %	10.33	13.41	9.51	16.86	12.02	

Figures in parentheses are retransformed values; those outside are arcsine value.

emergence increased groundnut pod yield (Rao *et al.*, 1991). The grain yield was harvested between 2875 and 3061.11 kg/ha from the plots treated with *C. gigantea* leaf powder, jatropha cake and poultry manure (Table 1). Among the evaluated organic amendments, the minimum yield (1802.78 kg/ha) was obtained from the plots treated with mahua cake and it was at par with cotton cake (1869.44 kg/ha), FYM (1916.67 kg/ha), orgo natural organic manure (1955.56 kg/ha) and tobacco dust (2080.56 kg/ha).

Straw yield

The significantly highest straw yield was obtained from the plots treated with castor cake (5658.33 kg/ha) than all the evaluated organic amendments (Table 1). The plots treated with vermicompost and neem cake produced 4547.22 and 4247.22 kg/ha straw, respectively. *Calotropis gigantea* leaf powder, jatropha cake and poultry manure applied plots harvested 3622.22, 3505.56 and 3298 kg/ha straw yield, respectively and they were significantly more than remaining amendments. Among the tested organic amendments, minimum straw yield was recorded in plots treated with mahua cake (2088.89 kg/ha) and it was statistically at par with tobacco dust (2611.11 kg/ha), orgo natural organic manure (2430.56 kg/ha), FYM (2206.67 kg/ha) and cotton cake (2185.00 kg/ha).

Economics

Looking to the NICBR, the highest return was obtained with the treatment of poultry manure (30.42). The NICBR of *C. gigantea* leaf powder and vermicompost was 6.97 and 2.53, respectively (Table 1). The treatments of tobacco dust, neem cake, castor cake and jatropha cake gave 1.19 to 1.44 NICBR. The NICBR was poor (-0.81 to 0.45) in the treatment of FYM, orgo natural organic manure, cotton cake and mahua cake.

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Study on the cropping pattern followed by summer cabbage growers in Sabarkantha district of Gujarat state

J. D. DESAI[1], K. D. SOLANKI[2] AND G. N. PATEL[3]

Department of Extension Education, C. P. College of Agriculture,
S. D. Agricultural University, Sardarkrushinagar - 385 506 (Gujarat)

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ABSTRACT

About 60.00 Per cent of population in the country depends on agriculture for their primary livelihood. A farmer who is a good manager should be able to make as much profit, the aim of the most of the farmer should be to earn profits. Crop should be grown only to earn profit. Thus, market oriented agriculture in the mixed economy of the India need to promote farmers that produce products that local people need. It is managed by the farmers through following various cropping pattern. Among the cole crops only cabbage (*Brassica oleracea* L. *var capitata*) and cauliflower (*Brassica oleracea* L. *var botrytis*) are grown in winter within India and produce good yield between 5^{0}C to 30^0 C day temperature. The highest price during the summer season is the driving force within the farmers of the Sabarkantha district and they are motivated to cultivate the cabbage as a summer crop. This is the transformation of farmer from the traditional to the modern farming method. Considering the highest area & production of cabbage crop Sabarkantha district, was purposively selected for the study. Prantij taluka was also purposively selected, because this taluka have highest cabbage growing area as compared to other talukas. Twelve villages form taluka were selected purposively. Using random sampling techniques, equal number of respondents *i.e.,* Ten from each village were selected. Thus, total 120 respondents were selected. Cropping pattern in this study was defined as a sequence of crops sown by the respondents on a given area. The information about cropping pattern followed by the cabbage growers was collected. Based on the frequency and percentage of the farmers adopting different cropping pattern, each cropping pattern has been assigned rank. Major cropping pattern of Chilli – Chilli – Cabbage (49.17 per cent), Okra – Okra – Cabbage (33.34 per cent), Cauliflower – Cabbage (29.16 per cent), Cotton – Wheat – Pearl millet (27.5 per cent), Bottle guard – Bottle guard – Cabbage (25.00 per cent), Brinjal –Brinjal –Brinjal (24.16 per cent), Cabbage – Cabbage (22.50 per cent) and Tomato – Tomato – Tomato (22.50 per cent) were adopted by the respondents with the first to seventh rank, respectively.

Key words : Cropping pattern, cabbage growers, summer

India is the largest food producer in the world. It produces 150 million tones fruits and vegetable every year (MFPI, 2011). About 60 per cent of population depends on agriculture for their primary livelihood. A farmer who is a good manager should be able to make as much profit from farming as from any other business, if he determine the objectives. In deciding how to use his productive resources, a farmer must be guided by certain objectives. However, the conditions under which farming is carried on are changing fast. To be efficient, farmers must be prepared to learn and use new methods of production and true subsistence farming methods (Upton and Anthonio, 1975). In the present era, the aim of the most of the farmer should be to earn profits. Crop should be grown only to earn profit and therefore, farming as a business means farming for profit, not just some profit but as much profit as a possible. This is the transformation of farmer from the traditional to the modern farming method. Thus, market oriented agriculture in the mixed economy of the India need to promote farmers that produce products that local people

[1] P.G. student, [2] Associate Director of Extension Education, Directorate of Extension Education, [3] Research Scientist (Agronomy), CWMPR & RE.

need also to produce unique products for national and global markets, which should be managed by the farmers through following various cropping pattern.

In vegetables, prime position in the production of cauliflower, second in onion and in third cabbage in the world. The cabbage thrives in a relatively cool moist climate and produce good yield between 5 ºC to 30 ºC day temperature. It is eaten raw as well as cooked. It is normally used in social events and festivals as a " *SALAD*" and therefore, there is a demand of cabbage during round the year. In last one decade cabbage production increased by 2.02 times. Due to availability of potential and high temperature resistant varieties of cabbage, its productivity has increased more than 1.46 times higher as compared to its productivity in 1990 -91 (Singh and Malhotra, 2010). Climate has also best own agro-climatic conditions enabling our country to grow vegetables in temperate and humid tropic and from sea level to snow line. Owing to this, the harvesting season of cabbage has varies in various states of India. Cabbage crop is harvesting during December, January and February as a traditionally in Gujarat. Due to the seasonality of the cabbage production, supply is not uniform through the year, but the user needs are vital in marketing. Considering this facts, the average wholesale price of cabbage was recorded from 9477 Rs/qtl to 12681 Rs/qtl during the period of April to August-2011 at Ahmedabad and in other cities of country (Indian Horticulture Database, 2011). The highest price during the summer season is the driving force within the farmers of the Sabarkantha district and there are motivated to cultivate the cabbage as a summer crop. It is totally unfavourable climate condition for the cabbage crop, however the farmers are cultivated the cabbage during the summer.

The current advances in market oriented summer cabbage cultivation have not recommended and demonstrated for increasing the cabbage production by the agricultural scientists. Raising the efficiency of the growers, it essential for getting desire profit from the summer cabbage cultivation. Understanding that, no detail study has yet carried out in this regards so, to know the cropping pattern of the summer cabbage growers was under taken with specific objectives.

METHODOLOGY

Considering the area and production of cabbage crop Sabarkantha district, was purposively selected for the study. Prantij taluka was also purposively selected, because this taluka have more cabbage growing area as compared to other talukas. Twelve villages form a taluka were selected purposively. Using random sampling techniques, equal number of respondents *i.e.*, Ten from each village were selected. Thus, total 120 respondents were selected. The present study was confined to "*Ex-Post facto*" research design. Cropping pattern were measured with help of structured schedule and receiving response of appropriate questions. Cropping pattern in this study was defined as a sequence of crops sown by the respondents on a given area. The information about cropping pattern followed by the cabbage growers was collected. Based on the frequency and percentage of the farmers adopting different cropping pattern, each cropping pattern has been assigned rank.

RESULTS AND DISCUSSION

Cropping pattern means a sequence of crops sown by the respondents on a specific given area. It ensures the greatest efficiency to land, fertilizer, irrigation water and other inputs. It also offers some alternative plans for the farmers to maximize production and as much profit as possible per unit area and time. The cropping pattern was thus studied. Data with respect to cropping pattern followed by the respondents are presented below in Table 1.

The data in Table 1 revealed that 49.17 per cent of the farmers had adopted Chilli–Chilli–Cabbage cropping pattern with the first rank in all cropping pattern. The cropping pattern of Okra– Okra – Cabbage 33.34 per cent was found with second rank. The Cauli-flower – Cabbage 29.16 per cent was found with third rank. While Cotton – Wheat – Pearl millet 27.5 per cent, Bottle guard – Bottle guard – Cabbage 25.00 per cent and Brinjal – Brinjal – Brinjal 24.16 per cent cropping patterns were adopted by the Cabbage growers and fourth fifth and sixth ranked, respectively. Considering the land holding as well as available irrigation resource the respondents were also adopted Cabbage – Cabbage (22.50 per cent), Tomato-Tomato -Tomato (22.50 per cent), Cluster bean-Wheat – Sorghum (20.00 per cent), Castor-Castor-Pearl millet (16.66 per cent), Bitter guard-Bitter guard – Bitter guard (13.34 per cent), Cotton-Cotton – Cabbage (11.66 per cent), Cluster bean-Mustard - Sorghum (10.84 per cent), Cluster bean-Wheat -Fodder pearl millet (07.50 per cent) and Cotton -Wheat-Sorghum (04.16 per cent) cropping patter on their available land.

Table 1 Distribution of the respondents according to various cropping patterns adopted by them and rank order of the cropping patterns.

(n = 120)

Sr. No.	Cropping pattern	Number of respondents	Per cent	Rank
1.	Chilli – Chilli – Cabbage	59	49.17	I
2.	Okra – Okra – Cabbage	40	33.34	II
3.	Cauli-flower – Cabbage	35	29.16	III
4.	Cotton – Wheat – Pearl millet	33	27.50	IV
5.	Bottle guard – Bottle guard – Cabbage	30	25.00	V
6.	Brinjal – Brinjal – Brinjal	29	24.16	VI
7.	Cabbage – Cabbage	27	22.50	VII
8.	Tomato – Tomato – Tomato	27	22.50	VII
9.	Cluster bean – Wheat – Sorghum	24	20.00	IX
10.	Castor – Castor – Pearl millet	20	16.66	X
11.	Bitter guard – Bitter guard – Bitter guard	16	13.34	XI
12.	Cotton – Cotton – Cabbage	14	11.66	XII
13.	Cluster bean – Mustard – Sorghum	13	10.84	XIII
14.	Cluster bean – Wheat – Fodder pearl millet	09	07.50	XIV
15.	Cotton – Wheat – Sorghum	05	04.16	XV

The probable reason behind this might be the mega cities like, Ahmedabad, Gandhinagar and Himmatnagar are nearest to the study area therefore, the farmers of study area are selecting more vegetable crops for cultivation, secondly the farming community give priorities for food and fodder security for their family members and live-stock, respectively. Majority of the farmers are adopted agriculture and animal husbandry as main occupations and earned their family income. They also had given prioritization to cash crops to earn monetary requirement for maintaining social occasions and entertainment and there by overall development.

CONCLUSION

Major cropping pattern of Chilli - Chilli - Cabbage (49.17 per cent), Okra - Okra - Cabbage (33.34 per cent), Cauliflower - Cabbage (29.16 per cent), Cotton - Wheat - Pearl millet (27.5 per cent), Bottle guard - Bottle guard - Cabbage (25.00 per cent), Brinjal - Brinjal -Brinjal (24.16 per cent), Cabbage - Cabbage (22.50 per cent) and Tomato - Tomato - Tomato (22.50 per cent) were adopted by the respondents with the first to seventh rank, respectively. From this, it can be concluded that majority of the farmers are cultivated vegetable crops during the whole year and they are preferred mono cropping system. However, some of them are emphasized to cash crops with rotation of cereal, oil seeds and fodder crops.

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Resource use efficiency for sugarcane production in Kolhapur district of Maharashtra

A. B. BINDAGE[1] AND R. R. PATEL[2]

Department of Agril. Economics, C. P. College of Agriculture,
S. D. Agricultural University, Sardarkrushinagar - 385 506 (Gujarat)

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ABSTRACT

Farm credit is a strategic input. Kisan Credit Card (KCC) aims at providing timely and adequate credit to the farmers in a cost effective and flexible manner. In addition to credit for crop production, the scheme provides credit for ancillary activities. The scheme is being implemented in the country by all the banks from the year 1998-99. The present study was undertaken with an objective to analyse the resource use efficiency in production of Sugarcane. The study used primary data on all variables like labour, seeds, fertilizer, irrigation ,bullock, machinery and insecticide from randomly selected 60 KCC and 60 non-KCC sample farmers. The data pertained to the crop year 2010-11. The return to scale for KCC and non KCC are 0.941953 and 0.938838, respectively.

Key words : Resources, marginal value product, resource use efficiency, return to scale.

Kisan Credit Card scheme is a landmark in the history of rural credit in India. The mechanism of credit cards has been one of the key products developed to expand the outreach of banks and simplify the credit delivery system. The announcement relating to the introduction of Kisan Credit Card scheme was made by the Union Finance Minister during the budget speech for the year 1998-99. NABARD formulated a Kisan Credit Card scheme for uniform adoption by the banks so that the farmers may use the card to readily purchase agriculture inputs such as seeds, fertilizers, pesticides etc. and draw cash for their production needs. The model scheme was circulated to Commercial Banks, Co-operative Banks and Regional Rural Banks in August 1998. Now, about ten years are over since the introduction of this innovative scheme. It gives the adequate and timely credit for purchasing the all resources needed for the cultivation. The proper use of resources results in the better production of crop which can be studied by resource use efficiency (Anjanikumar *et al.*, 2007). So present study is conducted on the objective of resource use efficiency in production of Sugarcane in study area.

[1] P.G. Student, [2] Assistant Research Scientist (Agril. Economics), AICRP on OFR, Jagudan.

MATERIALS AND METHODS

The Kolhapur district of Maharashtra was purposively selected as the number of KCCs issued in this district was high. The primary data on all costs incurred on labour, seeds, fertilizer, irrigation, bullock, machinery and insecticide. For selection of sample farmers, two branches in Kolhapur district which has made a good progress in implementing Kisan Credit Card scheme was selected. From each branch 10 small farmers (less than 2 ha), 10 medium farmers (2.01 ha to 4 ha) and 10 large farmers (above 4 ha) were randomly selected. The corresponding numbers of farmer borrowers in each of these categories who are not KCC holders were also selected for comparison purpose. Thus, study was based on the information obtained from 60 KCC and 60 non-KCC borrowers spread across one district in Maharashtra. Primary data relating to cost incurred on labour, seeds (cane sets), fertilizer, irrigation, bullock, machinery and insecticide is taken into account for calculating resource use efficiency. Similar type of methodologies was used by Sajane (2011).

Production function analysis

The Cobb-Douglas (CD) production function was used

to study the influence of inputs on yield in the study area. The production function of the following type was specified in the present study.

$$Y = A X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} e^u$$

Where,

Y : Gross income (₹/ha)
X_1 : Expenditure on Seeds (₹/ ha)
X_2 : Expenditure on Fertilizers and Manures (₹/ha)
X_3 : Expenditure on Irrigation (₹/ha)
X_4 : Expenditure on Labour (₹/ha)
A : Constant
b_i : Production elasicities
u : Random error.

The above function was converted into the linear form through logarithmic transformation of all variables and is written as

$$\log Y = \log A + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + b_4 \log X_4 + \log u.$$

The marginal value products for each input was calculated at the geometric mean levels of the respective resources by using formula,

Marginal value product of $X_i = b_i \frac{\overline{Y}}{\overline{X}_i}$

Where,

$\overline{Y}$ = geometric mean of gross income
$\overline{X}_i$ = geometric mean of i^{th} resource
b_i = production elasticity of i^{th} resource

The marginal value product was compared with the respective marginal factor cost to arrive at resource use efficiency.

RESULTS AND DISCUSSION

It is difficult to estimate efficiency of farms without knowledge of the condition under which the production is performed. Comparison of output in relation to level of input used will reveal the true picture of efficiency. The studies on efficiency have shown that it is possible to raise the productivity of crop without actually raising the input application. The corrective steps undertaken to mitigate the reasons for low efficiency of the farmers will help in long run to achieve higher productivity. As such the production function approach was used to find out the productivity of resources used for Sugarcane production. For this purpose, the cob-Douglas form of production was estimated taking gross income as dependent variable. Whereas, labour, bullock labour, machinery, cost of fertilizers, manures, seed (cane sets) , irrigation, and insecticide/pesticides as independent variables. The productivity of resources used for Sugarcane production obtained by the production (intercept, co-efficient of multiple determination and returns to scale) for sample farms are depicted in Table 1 and Table 2

It is seen from the Table 1 that in case of KCC holder the elasticity of the production was positive as well as negative. It is inferred that among the explanatory variables labour and seed was positive and significant at 5% level of significance. while in case of irrigation, and machinery charges elasticity were negative with 5% level of significance and bullock charges was highly significant at 1% level of significance with negative elasticity. This negative elasticity at 5% level of significance shows negative impact on gross income of Sugarcane. The value of elasticity ranges from -0.10909 (Bullock labour) to 9.1322 (fertilizer and manure). The cost of labour, seed, fertilizer and manure and insecticide were 0.06042, 0.04820, 9.1322 and 1.9852 adding to the level of gross income by 2.01248 per cent ,respectively. The cost of irrigation (X_4) (-8.4702), bullock (X_5)(-0.10909) and machinery (X_6) (-1.70482) shows negative elasticity. It was statistically non significant. The elasticity of irrigation, bullock and machinery did not contribute to gross income as they are statistically non significant, indicating that at the current level they were applied at optimum level. The value of coefficient of determination (R^2) was 0.9051 indicating that 90 per cent of total variations in the gross income from Sugarcane cultivation was explained by independent variables in the function. The sum of regression coefficient (Σbi's) was 0.9419 indicating increasing return to scale. Similar observation was also made by Rangrajan (1994). Looking to the elasticity, coefficient of multiple determination and return to scale it can be concluded that gross income from Sugarcane crop increased proportionality with an increase in variables factors. Similar findings were reoported by Bista (2012).

In case of non KCC it can be seen from the Table 2 that elasticity of production was positive as well as negative. It is inferred that among the explanatory variables, labour, fertilizer and manure were positive elasticity of production and highly significant at 1 % level of significance while, in case of labour charges was positive and 5 % level of significance while showing positive impact on gross income of Sugarcane. The cost of bullock, insecticide shows negative impact on gross income. The value of

Table 1 Cobb-Douglas production function estimates for Sugarcane for with KCC farmers

Variables	With KCC		
	Production Elasticity	P value	Standard Error
X_1 Cost of Labour (₹)	0.060426*	0.0483	0.21941
X_2 Cost of Seeds(₹)	0.048201*	0.0359	0.15777
X_3 Cost of Fertilizer and manure (₹)	9.1322	0.139954	6.092742
X_4 Cost of Irrigation (₹)	-8.47023*	0.0410	12.17399
X_5 Cost of Bullock (₹)	-0.10909**	0.00894	0.166058
X_6 Cost of Machinery (₹)	-1.70482	0.460771	2.29922
X_7 Cost of Insecticide (₹)	1.985246	0.836365	9.663588
Intercept	2.012481	0.721852	5.622702
R^2 Coeff. of multiple determination	0.905121		
Multiple R 0.951378			
Adjusted R	0.892348		
Σbi Return to scale	0.941953		

*denotes significance at 5% , ** denotes significance at1%

elasticity ranges from -0.00501(bullock) to 3.5127 9(irrigation). The cost of labour, seeds, fertilizer, irrigation, bullock, machinery and insecticide are 0.0123, 0.003785, 0.1042,3.5175, -0.00501,0.8145 and -3.5037, respectively. The cost of bullock (X_4) (-0.00501) and cost of insecticide(X_7)(-3.50378) shows negative elasticity. It was statistically non significant indicating that at the current level they were applied at optimum level. The value of coefficient of determination (R^2) was 0.9586 indicating that 95 per cent of total variations in the gross income from sugarcane cultivation were explained by the independent variable included in the function. The sum of regression coefficient (Σ bi's) was 0.9388 indicating

Table 2 Cobb-Douglas production function estimates for Sugarcane for without KCC farmers

Variables	Without KCC		
	Production Elasticity	P value	Standard Error
X_1 Cost of Labour (₹)	0.012312*	0.04644	0.639268
X_2 Cost of Seeds (₹)	0.003785	0.951875	0.062408
X_3 Cost of Fertilizer and manure (₹)	0.104218**	0.00434	0.332407
X_4 Cost of Irrigation (₹)	3.512753	0.610121	6.847409
X_5 Cost of Bullock (₹)	-0.00501	0.695332	0.012732
X_6 Cost of Machinery (₹)	0.814561**	0.00531	6.15076
X_7 Cost of Insecticide (₹)	-3.50378	0.401459	4.141847
Intercept	0.26598	0.950969	4.304712
R^2 Coeff. of multiple determination	0.958616		
Multiple R	0.979089		
Adjusted R	0.953045		
Σbi Return to scale	0.938838		

*denotes significance at 5%, ** denotes significance at1%

Table 3 Marginal value product, factor cost and their ratio of KCC holder

Variables	Marginal value Product(MVP)	Factor cost	Ratio of MVP to Factor Cost
X_1 Cost of Labour (₹)	0.007793	1	1: 0.007793
X_2 Cost of Seeds (₹)	0.03599	1	1: 0.03599
X_3 Cost of Fertilizer/Manure (₹)	9.55598	1	1: 9.55598
X_4 Cost of Irrigation (₹)	8.1931	1	1: 8.1931
X_5 Cost of Bullock Labour (₹)	-0.23442	1	1: -0.23442
X_6 Cost of Machinery (₹)	2.49183	1	1: 2.49183
X_7 Cost of Insecticide/ pesticide (₹)	3.968	1	1: 3.968

increasing return to scale. Similar observation was also made by Rangrajan (1994). It can be concluded that gross income from Sugarcane crop increased proportionately with an increase in the variable factor. The result of the study of is in colloboration with the earlier findings of Sajane (2011).

Marginal value product for KCC

The marginal value product (MVP) of particular resource represents the expected addition of one unit of resource, while other inputs are held constant. For evaluating the efficiency of resources use, the ratio of marginal value products for different factors to their respective factors costs was estimated for Sugarcane. Allocative efficiency (MVP/FC ratio) more than 1 (one) indicates under utilization of particular resource and scope to increase its application till the ratio reaches to one. The estimated marginal value products (MVP), factor costs and their ratio for Sugarcane in case of KCC holder were computed and the results are given in the Table 3.

The data furnished in Table 3 reveal that the MVP/FC ratio was more than one and it was highest in case of fertilizer and manure (9.55598), irrigation (8.1931) and insecticide and pesticide (3.968).This indicates that an addition of one rupee in fertilizer and manure would yield return of ₹ 9.55598 through the elasticity of fertilizer was very low and non significant; the MVP - factor Cost Ratio was high. This was due to the lack of knowledge and importance about application of these inputs among Sugarcane cultivators. The cost of irrigation has an MVP-factor cost ratio of 8.1931indicates that farmers would get net gain of ₹ 8.193 if they apply additional unit of irrigation worth ₹.1. The production function analysis gave statistically non-significant and negative value to the cost of bullock labour. But the MVP- factor Cost ratio indicated that additional expenditure of one rupee on bullock labour would reduce revenue from Sugarcane by ₹ 0.234. Hence, to be economically efficient farmers have to reduce the expenditure on bullock labour.

The data furnished in Table 4 reveal that the MVP/FC ratio was more than one and it was highest in case of fertilizer and manure (3.0049), irrigation (9.7523) and machinery (3.304).This indicates that an addition of one rupee in fertilizer and manure would yield return of ₹ 3.0049 through the elasticity of fertilizer and manure was very low and non significant; the MVP

Table 4 Marginal value product, factor cost and their ratio of non KCC holder

Variables	Marginal value Product(MVP)	Factor cost	Ratio of MVP to Factor Cost
X_1 Cost of Labour (₹)	0.02217	1	1: 02217
X_2 Cost of Seeds (₹)	0.02418	1	1:0.02418
X_3 Cost of Fertilizer/Manure (₹)	3.0049	1	1:3.0049
X_4 Cost of Irrigation (₹)	9.7523	1	1:9.7523
X_5 Cost of Bullock Labour (₹)	-0.000823	1	1:-0.000823
X_6 Cost of Machinery (₹)	3.304	1	1:3.304
X_7 Cost of Insecticide/ pesticide (₹)	-6.21867	1	1:-6.21867

- factor Cost Ratio was high. This was due to the knowledge and importance about application of these inputs among Sugarcane cultivators. The cost of irrigation has an MVP- factor cost ratio of 9.7523indicates that farmers would get net gain of ₹ 9.7523 if they apply additional unit of irrigation worth ₹ 1. The production function analysis gave statistically non- significant and negative value to the cost of bullock labour and insecticide. But the MVP- factor Cost ratio indicated that additional expenditure of one rupee on bullock labour and insecticide and pesticide would reduce revenue from Sugarcane by -0.000823 and-6.21867.Hence, to be economically efficient farmers have to reduce the expenditure on bullock labour and insecticide and pesticide.

The negative ratio of bullock labour (X_5) and insecticide and pesticide(X_7) indicates excessive use of this resource. Sugarcane growers can increase gross returns by reducing bullock labour cost. The ratio of inputs such as irrigation and machinery explained utilization of inputs. As such gross returns from Sugarcane cultivation can be increased using more of these inputs.

CONCLUSION

In case of KCC insecticide, fertilizers and manures were having positive elasticity co-efficient in the sugarcane but in case of bullock labour the co-efficient were negative. In non KCC category, elasticity co-efficient of irrigation, Machinery, fertilizers and manures were positive but for insecticide it was negative. From Table 1 & 2 it can be observed that the return to scale is maximum for KCC holder farmers than non KCC farmers. Means the resources were efficiently used by KCC holder farmer than Non KCC farmers The results were more accorded to the resum of work done by Patel (1999).

Marginal value product to marginal factor cost

In case of KCC the labour and seeds were used below optimum level and bullock labour used above optimum level. In case of non KCC the seeds and labour used below optimum level and bullock labour used at above optimum level.

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Knowledge level and decision-making of dairy farm women in animal husbandry practices

P. M. PRAJAPATI[1], A. S SHEIKH[2] AND H.K. DESAI[3]

Department of Veterinary and A.H. Extension Education,
College of Veterinary Science & Animal Husbandry
S. D. Agricultural University, Sardarkrushinagar - 385 506 (Gujarat)

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ABSTRACT

In India, women's involvement in livestock management is a long standing tradition and livestock rearing has been as integral part of homestead farming system. Animal husbandry practices is an important tasks in animal husbandry activities and performed by dairy farm women besides fulfilling their responsibilities as home makers. Moreover, the knowledge and skill of the dairy farm women and their participation in decision-making certainly affects effectively in their work. The study was conducted in Vijapur and Mehsana *talukas* of Mehsana district, where production of milk was highest as compared to other talukas. Ten villages having the larger number of female in milk producer' co- operative societies were selected purposively. The dairy farm women were selected by multistage sampling method. Thus, the sample consisted of 120 respondents for the study. A large majority that (63.33 per cent) of the dairy farm women had medium level of knowledge regarding recommended practices of animal husbandry. The participation of dairy farm women was observed more in aspects of milking and preparing milk product (rank I), followed by feeding of milch animals (rank II), health care and management of milch animals (rank III) and breeding of milch animal (rank IV). The less participation of dairy farm women was observed in general aspects of animal husbandry practices (rank V). A great majority (88.33 per cent) of the dairy farm women had medium to high level of participation in decision-making about animal husbandry practices.

Key words : Feeding, breeding, management, knowledge level

Women's contribution to national development is crucial. Emancipation of women is in essential pre-requisite for economic development and social progress of the action. Women play an important and vital role in animal husbandry practices as manager, decision makers and skilled workers. The contribution of dairy farm women in terms of time and effort is not low or less than men. In India, women's involvement in livestock management is a long standing tradition and livestock rearing has been as integral part of homestead farming system. Animal husbandry practices is important tasks in animal husbandry activities are performed by dairy farm women besides fulfilling their responsibilities as home makers. Moreover, the knowledge and skill of the dairy farm women and their participation in decision-making certainly affects effectively in their work. Looking to these facts, the present investigation was planned with following objectives.

[1] To measure the knowledge level of dairy farm women regarding recommended animal husbandry practices.

[2] To study the participation of dairy farm women in decision-making about animal husbandry practices.

METHODOLOGY

The present investigation was purposively carried out in Vijapur and Mehsana talukas of Mehsana district, where production of milk was highest as compared to other talukas. Ten villages having the larger

[1 & 3] P.G. Students , [2] Associate Professor & Head

number of female members in milk producer' co-operative societies were selected purposively. The dairy farm women were selected by multistage random sampling method. Thus, the sample consisted of 120 respondents for the study. The data were collected by personal contact method with the help of structured interview schedule. The collected data were coded, classified, tabulated and analyzed in order to make the findings meaningful in light of objectives for drawing meaningful interpretation.

RESULTS AND DISCUSSION

Knowledge level of dairy farm women regarding recommended animal husbandry practices

In the present study, knowledge refers to know-how about recommended animal husbandry practices possessed by the dairy farm women. Adequate knowledge of recommended animal husbandry practices is essential to dairy farm women for managing successfully and making profit in animal husbandry practices. It was, therefore, thought necessary to obtain information from the dairy farm women about the knowledge they possessed regarding recommended animal husbandry practices. The data regarding level of knowledge are given in Table 1.

Revealing the data in Table,1 that nearly two-fourth (63.33 per cent) of the dairy farm women had medium level of knowledge regarding recommended practices of animal husbandry, followed by high (20.00 per cent) and low (16.66 per cent) level of knowledge. On the basis of the above result, it can be concluded that a great majority (83.33 per cent) of the respondents were found with medium to high level of knowledge regarding recommended animal husbandry practices. The probable reason for above finding may be due to their higher education, medium to high level of experience in animal husbandry practices, better extension contact and medium to high level of mass media exposure. This finding is similar to the finding of Toppo (2005), Khokhar (2007) and Upadhyay (2010).

Table 1 Distribution of dairy farm women according to their level of knowledge regarding recommended animal husbandry practices.

n = 120

Sr. No.	Category	Frequency	Per cent
1.	Low (below 25.86 score)	20	16.66
2.	Medium (in between 25.86 to 55.63 score)	76	63.33
3.	High (above 55.63 score)	24	20.00
	Total	120	100.00

Mean= 40.75 S.D. = 14.882

Aspects-Wise Participation of Dairy Farm Women in Animal Husbandry Practices

From the data in Table 2, It can be concluded that the participation of dairy farm women was observed to be more in aspects of milking and preparing milk product (rank I),followed by feeding of milch animal (rank II), health care and management of milch animal (rank III) and breeding of milch animal (rank IV), respectively. The less participation of dairy farm women was observed in general aspects of animal husbandry practices (rank V). There might be due to fact that

Table 2 Distribution of dairy farm women according to their aspect-wise participation in animal husbandry practices

n = 120

Sr. No.	Aspects	Regularly	Often	Some times	Occasionally	Never	Mean score	Rank
1.	General aspects	30(25.00)	28(23.34)	25(20.83)	21(17.50)	16(13.33)	02.29	V
2.	Feeding of milch animals	56(46.67)	21(17.50)	19(15.83)	18(15.00)	06(05.00)	02.85	II
3.	Breeding of milch animal	44(36.67)	26(21.66)	24(20.00)	14(11.67)	12(10.00)	02.63	IV
4.	Health care and management of milch animals	52(43.34)	23(19.16)	19(15.83)	16(13.33)	10(08.34)	02.75	III
5.	Milking and preparing milk products	62(51.67)	23(19.16)	20(16.67)	12(10.00)	03(02.50)	03.07	I

the males are mostly engaged in the field oriented/ outside work. Hence, the women are responsible for the care and management of animals.This finding are supported by the findings of Toppo (2005), Narmatha *et al.*, (2009).

Participation of dairy farm women in decision- making about animal husbandry practices

In order to know the level of participation of dairy farm women in decision-making about animal husbandry practices, they were grouped on the basis of mean and standard deviation. The data in this regard are presented in Table 3. It can be concluded that a vast majority (88.33 per cent) of the dairy farm women had medium to high level of participation in decision-making about animal husbandry. This might be due to the reason that in the study area dairy farm women might be involved in management of livestock sector dominantly and guidance provided by *Dudhsagar dairy* and village milk producer's dairy co-operative societies. might have encouraged them for better participation in decision-making about animal husbandry practices. The finding is in the line with the findings reported by Chauhan *et al.*, (2005), Toppo (2005), Upadhyay (2010) and Ram *et al.*, (2013).

Table 3 Distribution of dairy farm women according to their level of participating in decision-making

n =120

Sr. No.	Category	Frequency	Per cent
1.	Low (Less than 54.68 score)	14	11.66
2.	Medium (in between 54.68 to 76.81 score)	85	70.83
3.	High(above 76.81 score)	21	17.50
	Total	120	100.00

Mean = 65.741 S.D. = 11.072

CONCLUSION

A large majority that (63.33 per cent) of the dairy farm women had medium level of knowledge regarding recommended practices of animal husbandry. The participation of dairy farm women was observed more in aspects of milking and preparing milk product (rank I), followed by feeding of milch animals (rank II), health care and management of milch animals (rank III) and breeding of milch animal (rank IV). The less participation of dairy farm women was observed in general aspects of animal husbandry practices (rank V). A great majority (88.33 per cent) of the dairy farm women had medium to high level of participation in decision-making about animal husbandry practices.

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Constraints faced and suggested solutions by the farmers of Gujarat in adoption and operation of micro irrigation system

SARVEJIT AHUJA[1] AND K.P.THAKAR [2]

College of Agribuisness Management
S. D. Agricultural University, Sardarkrushinagar - 385 506 (Gujarat)

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ABSTRACT

Micro irrigation technologies are aggressively promoted in India by the central government, state governments and many Nongovernmental Organizations (NGOs), both local and International, by providing different kinds of financial, institutional and technical support systems. GGRC (Gujarat Green Revolution Company LTD) is the only one of its type of company or we can say, service provider, which disburse government subsidy to farmers, for easy adoption and installation of MIS throughout Gujarat state. While studying the level of adoption of Micro Irrigation System by the farmers of Patan district, we came to know about the constraints faced by users while adopting and operating the system. With suggestions to overcome those constraints. Every technology has its own positive and negative points, hence, there are few constraints or problems occurred with the use of MIS. Majority of respondents, complained about the clogging of drippers due to saline substances and water quality, breaking of online small length drippers and improper and irregular services provided by the company dealers. Few respondents mentioned about the problems such as, difficult to make equal distribution of water, and difficulty in interculturing. These constrains directly affect the adoption level of MIS by the farmers. Owners or adopters of these technologies were asked to express their problems which they frequently face during adoption or operation or maintaining the system. Few suggestions were given by the farmers or system owners themselves. Owners and adopters were asked to freely mention their suggestions to overcome these problems or constraints. Majority of farmers suggested proper and required water analysis before installation, to disburse Knowledge about suitable acid treatment for clogging, and local cooperative banks should provide facility for loan of entire system installation. Suggestions or the ways to solve these problems also play important role in extent of adoption of MIS.

Key words : Micro irrigation, socio-economic, adoption, constraints

Gujarat state receives annual rainfall of 828 mm in 35 rainy days with coefficient of variation of 50 %. There is large spatial and temporal variation in rainfall of the state. The low rainfall areas receiving less than 500 mm rainfall are comprised of Kutch district and western parts of Banaskantha and Patan district and parts of Jamnagar, Rajkot and Surendranagar districts. These are also characterized by arid climate. State has achieved agricultural growth rate at 9.6% and have carved a niche in the field of agricultural development in India. Many villages in Gujarat have adopted 100% drip and sprinkler irrigation systems to water crops. In June 2009, more than 93,000 farmers have adopted drip irrigation for their total 1.51 lakh hectare land. Drip Irrigation system and inter-linking of 21 rivers of the state for conservation of water has made it possible for record sugarcane cultivation in the state.

Patan district from north region of Gujarat state was selected purposively for the study, due to considerable amount of adoption of micro irrigation systems found in this area. Three talukas, namely Patan, Sami and Sidhpur were selected to carry out the research work. From the study it is known that majority of farmers in Patan district, about 61% have opted for sprinkler irrigation system, followed by drip irrigation system

[1] P.G. Student, [2] Assistant Professor, Department of Agril. Economics, C. P. College of Agriculture

adopted by 29 % of farmers and mini sprinkler system by 10 % of farmers.

Sami taluka stands on first place for highest area with 272.2 ha, land under MIS adoption in the district, followed by Patan taluka and Harij with second and third place, with area, 146.04 ha and 100.31 ha respectively. Out of the adopters of MIS only few cases were found where, loan was taken for the installation of MIS. Source of application, through which channel did the farmer reached GGRC is also studied, out of 120 respondents, 65 percent applications were reached through suppliers, 17 percent through GUVNL, hence 17 cases of FPA(Four Party Agreement) took place, and 30 percent of applications reached through GWRDC [Gujarat Water Resource Development Corporation].

METHODOLOGY

A systematic plan or programme adopted to carry out the research work or to proceed with the investigation as per the decided objectives, is known as research methodology. An appropriate sampling design so as to focus the importance of objective is also necessary. It was proposed at the outset to study the area under micro irrigation in primary stage. For this purpose the secondary source data from internet and other publications was used. A multistage random sampling was adopted as appropriate sampling procedure for the study.

After the selection of area for study, that is Patan district further it is proposed to select three talukas of Patan district having good records of such tri party agreements. Hence Patan, Sami and Sidhpur talukas selected as per the convenience for the survey. In the third stage, six villages from each taluka were randomly selected, where different numbers of farmers were randomly selected to obtain information on different aspects of the study. Keeping in view the objectives of the study, relevant variables for the study were selected on the basis of reviewed literature on the subject by consulting the experts and extension personnel.

Different variables of the study which include personal (age and education), socio-economic (land holding, annual income and irrigation facility) communication (extension contact) and psychological characteristics (economic motivation, scientific orientation, innovativeness and knowledge level) their problems and suggestions to solve those problems also have been studied.

The schedule was prepared for the adaptors of micro irrigation system to know their personal, socio- economic, communication and psychological characteristics. By the personal interviews schedule were filled and analyzed for different parameters using Excel programme.

RESULTS AND DISCUSSION

Very often, it is observed that all farmers residing in the same community do not adopt improved or modern agricultural technologies to the same extent. This happens due to the influence of specific characteristics which may be personal, socio-economic characteristics of the farmers. Other than personal characteristics, constraints and problems faced by farmers who adopted the micro irrigation system in their fields were also studied to check out the reason behind moderate adoption of micro irrigation system in the study area. Further the farmers were asked for suggestions, where we came to know about their knowledge level regarding the solution of those problems.

Farmers face the problem of clogging of pipes due to saline substances, with higher percentage. This is found to be quite common problem as Timbadia (2001) observed the major constraints were frequent clogging of dripper due to saline substances and other reasons. During the research work we came to know that saline substances are found in this area, hence farmers demand for the proper testing and water analysis before the installation of irrigation system.

They further seek for appropriate treatment of water whenever required. Problem regarding breakage of online dripper leads to the choice of inline drippers for the system installation. Improper services and assistance of irrigation company dealers is also another major problem faced by the farmers, as they lack some technical aspects of the system. Hence they suggested for proper and timely monitoring of company dealers.

Farmers find that the maintenance cost was quite higher if compared to the traditional irrigation systems, agronomic tests also take quite longer time, which is previously studied by Desai *et al.,* (1999) who revealed that the most important constraint faced by the mango orchard growers in adoption of drip irrigation set was high cost of spare parts, heavy installation expenses, lack of capital for covering entire area under drip irrigation system, he also referred to major

Table 1 Distribution of MIS owners according to constraints experienced by them in the study area.

Sr. No.	Constraints	Frequency	Percentage	Rank
1	Clogging of drippers due to saline substances and water quality.	110	91.67	I
2	Breaking of online drippers.	105	87.50	II
3	Improper and irregular services provided by the company dealers.	97	80.83	III
4	Damage caused by rats to the pipes.	89	74.16	IV
5	Lack of technical knowhow about the system.	70	58.33	V
6	High maintenance cost.	55	45.83	VI
7	Time consuming agronomic tests.	46	38.33	VII
8	Lengthy process of getting subsidy.	39	32.50	VIII
9	Difficult to make equal distribution of water.	31	25.83	IX
10	Initially requires large investment for installation.	28	23.33	X
11	Difficulty in interculturing.	27	22.50	XI

Table 2 Distribution of MIS owners according to their given suggestions for overcoming the problem or constraints:

Sr. No.	Suggestions	Frequency	Percentage	Rank
1	Proper and required water analysis before installation.	93	77.5	I
2	Knowledge about suitable acid treatment for clogging.	89	74.16	II
3	Local cooperative banks should provide facility for loan of entire system installation.	84	70.00	III
4	Appropriate training should be provided to farmers.	80	66.67	IV
5	Live demonstrations should be arranged at the field of farmer.	78	65.00	V
6	Quality of products or material should be improved.	71	59.17	VI
7	Paper work for getting subsidy should be reduced.	60	50.00	VII
8	Company dealers should be regularly monitored.	59	49.17	VIII
9	Availability of spare parts in local market with reasonable rate.	27	22.5	IX
10	Design should be developed for equal distribution of water, according to crop.	19	15.83	X

technological constraints which were frequent clogging and lack of technical knowhow.

Process for getting subsidy is also lengthy as per their requirement and another problem is initial investment, which is also higher. Thus it was suggested that local cooperative banks should provide facility for loan of entire system installation, so that such cost burden could be lightened. Further they want that appropriate training should be provided to farmers. Live demonstrations should be arranged at the field of the farmesr so the dependence for maintenance be reduce.

Kalsariya *at al.*, (2003) reported that the higher initial cost of installation of drip irrigation set, uneven distribution of water due to insufficient pressure, drip irrigation is not suitable for all the crops, difficulties in interculturing, maintenance of drip irrigation sets were the major constraints faced by the farmers. Design should be developed for equal distribution of water, according to crop, so that the problem to make equal distribution of water could be solved. It could also be help in interculturing, which is also one of the constraints faced by the farmers who go for micro irrigation systems. Hence the concerned efficiencies should take the note of the same and policy/programme should be modified accordingly, so that the farmers will be motivated towards to adoption further.

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Optimum plot size, shape and number of replications for field experiment on wheat (*Triticum aestivum* L.)

C. M. NALIYADARA[1]

Department of Agricultural Statistics, College of Agriculture,
Junagadh Agricultural University, Junagadh - 362 001 (Gujarat)

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ABSTRACT

Field experiment on wheat crop was conducted during *rabi*-2012 at Junagadh. The crop yield data of 1296 basic units (Basic unit = 0.90 m x 1.00 m) were recorded and analyzed to work out optimum size, shape and number of replications of the plot using Fairfield Smith's, maximum curvature methods and Cochran & Cox equation respectively. The per unit decrease in C.V.% for different plot sizes estimated from the differences between C.V.% of consecutive points indicated that the effective decrease in C.V.% due to increase in plot size was up to 12 units sized plot. The graphical presentation of C.V.% also revealed similar trend, therefore, 12 units size i.e. 10.80 sq. m. size could be considered as optimum plot size. The Smith's model was considered as a measure of correlation between adjacent units with "b" = 0 indicating perfect correlation between adjacent plots. The medium range of "b" obtained in this study indicated the use of smaller plots in field experiments. The equation obtained was, $Y = 11.08 X^{-0.0384}$. The coefficient of determination (R^2) between plot size and C.V.% was computed as 0.36. The results revealed that the smaller plots with fairly large number of replications were observed to achieve 5 per cent accuracy in any of the block size. The increase in plot size from 0.90 m^2 to 10.80 m^2 resulted in reduction of 14 to 2 or 3 to 2 replications, respectively, to obtain the same precision. For controlling soil variation, a block of 3 x 3 plots was required with minimum 2 replications to a chive 5 per cent accuracy for field experiments in wheat crop in Saurashtra region.

Key words : Optimum plot size, replication, wheat.

Each experimental material has inherent variation, which could be accessed through uniformity trial. Uniformity trial helps in proper selection in size, shape and number of replications for field experiments. Field experimentation is one of the powerful tools in research for agricultural science. The experiments were conducted on various crops in irrigation condition at saurashtra region. Wheat is a major cereal growing crop of this region, relatively high variability (>50 %) in this crop.

MATERIALS AND METHODS

Uniformity trial was conducted during *Rabi* - 2012 at Wheat Research Station, JAU, Junagadh. The crop was sown in east to west direction with inter row spacing of 22.5 cm. The crop was harvested in continuous basic unit, each of 0.90 m x 1.00 m consisting of a four rows of 1.00 m length. Fairfield Smith's (1938) variance law and maximum curvature Federer (1955) methods were used for determining optimum plot size and shape on the basis of uniformity trial. Smith's law is as follows,

$$V_x = \frac{V_1}{X^b}$$

Where :

V_x = the variance of mean per plot of X units,
X = the number of basic units in a plot,
V_1 = the variance of mean per plot of one unit,
b = the regression coefficient.

This equation can be written as,

$$\log V_x = \log V_1 - b \log X$$

[1] Assistant Professor

Maximum Curvature method Federer (1955). A curve is plotted by taking the plot size (in terms of basic units) on the X–axis and the C. V. values on the Y- axis of a graph (Fig. 1). The point at which the curve taken a turn, that is the point of maximum curvature. The value corresponding to the point of maximum curvature will be the optimum plot size. Coefficient of variation (C.V.%) per unit area was estimated for various sized plots as under.

$$C.V.\% = \frac{\text{Standard deviation per unit}}{\text{General mean}} \times 100$$

The number of replications required varies with the number of treatments, variation of the character measured, the confidence probability of significant difference and assurance of detecting the difference. The Statisticians Hatheway, Cochran & Cox (1957) equation for estimating the minimum detectable difference between two treatments as a per cent of the mean can be estimated using following relation.

$$d^2 = \frac{2 (t_1 + t_2)^2 (C. V.)^2}{r x^b}$$

Where,

- d = true difference which can be detected at a specified level of significance
- t_1 = significant value of t in the test of significance.
- t_2 = table value of t corresponding to 2(1-p), where p is the probability of obtaining a significant result.
- r = required replications number
- c.v. = coefficient of variation per basic unit area, expressed as a percent of the mean, for the plot size and shape used
- x = number of basic units in the combined plot size
- b = soil heterogeneity index (linear regression coefficient)

RESULTS AND DISCUSSION

The comparisons were made among different sizes and shape of plots using coefficient of variation per units area, C. V. % estimated from Wheat yield.The results are presented in Table-1 indicate that maximum C.V.% (24.42) was observed in the smallest sized plot *i.e.,* one unit (0.90 sq.m.). C.V. % decreased with the increase in plot size up to 72 units size (5.07%). The decrease in C.V.% was not proportional when the plot size is increased beyond 9 units plot. Therefore 9 units size could be taken as point of maximum curvature (Fig. 1). Beyond this point, the decrease in C. V. % was not proportional to the amount of land used. The optimum plot size is one just beyond the point of maximum curvature. Therefore 12 units sized plot was considered as optimum plot size Fairfield Smith's (1938) and Federer (1955). The graphical presentation of C.V. % against plot size (Fig.1) also revealed similar trend. The rate of reduction in C.V.% was more with the increase in length of the plot than that with the increase in width (*i.e.,* number of rows) of plot (Table 1).

The per unit decrease in C.V.% (Table 1) for different plot sizes estimated from the differences between C.V.% of consecutive points indicated that the effective decrease in C.V.% due to increase in plot size was up to 12 units sized plot. The graphical presentation of C.V.% (Fig. 1) also revealed similar trend, therefore, 12 units size *i.e.,* 10.80 sq. m. size could be considered as optimum plot size. These results are in agreement with those reported by Khokhar *et al.,* (1997) in brinjal, Naliyadara *et al.,* (2010) in tomato, Prajapati *et al.,* in mustard (2013) and Naliyadara *et* al., in groundnut (2013)

Among all combinations of 12 units plot (6 x 2), a plot of 6 m. x 1.8 m. had minimum C.V. % per units area (8.06 %) therefore, it can be concluded that a plot of 6 m. x 2.0 m. (8 rows each of 6.00 meter length) could be taken as optimum plot size.

Keeping in view the above results as well as practical difficulties for caring out the agricultural operations, the plot of 4 x 3 having dimensions 4.0 m. x 2.7 m. *i.e.,* 12 rows each of 4.0 meter length could be used instead of plot having dimension of 6.0 m x 2.0 m. This shape has little higher C.V.% (8.16) as compare to 12 units plot (6 x 2) a plot of 6.0 m X 1.80 m had C.V.% per unit area (8.06).

The Smith's Law was considered as a measure of correlation between adjacent units with "b" = 0 indicate perfect correlation and "b" = 1 indicate heterogeneity between adjacent plots. The range of "b" 0.860 to 0.724 was obtained in this study, It was indicated the use of smaller plots in field experiments. The equation obtained was as under.

$$Y = 11.08X^{-0.0384}$$

The coefficient of determination (R^2) between plot size and C.V.% was computed as 0.40. The trend of C.

Table 1 Coefficient of variation (c.v.) in percentage, Different in c.v. and Soil heterogeneity index for different sizes and shapes of plots for Wheat yield, *rabi*-2012-13.

Plot Size	Shape in Basic Unit (L x W)	Variance Between the Plot V(x)	Variance per unit area Vx	C.V. %		Difference in C.V.%	Per unit decrease in C.V. %	Soil heterogeneity (b)
				Plot	Mean			
1	1x1	12048.65	12048.65	24.42	24.42	0.00	0.00	0.00
2	2x1	24112.64	6028.16	17.27	18.10	6.32	6.32	0.860
	1x2	28990.67	7247.67	18.93				
3	3x1	38188.00	4243.11	14.49	15.51	2.59	3.73	0.822
	1x3	49684.12	5520.46	16.52				
4	4x1	50451.36	3153.21	12.49	13.76	1.75	0.84	0.821
	2x2	57612.45	3600.78	13.34				
	1x4	77118.22	4819.89	15.44				
6	6x1	80264.00	2229.56	10.50	11.75	2.01	-0.26	0.811
	3x2	91518.68	2542.19	11.21				
	2x3	101067.10	2807.42	11.78				
	1x6	132744.00	3687.33	13.50				
8	4x2	121142.5	1892.85	9.67	10.32	1.43	0.58	0.826
	2x4	155473.4	2429.27	10.96				
9	9x1	132539.0	1636.28	8.99	10.30	0.02	1.41	0.779
	3x3	161349.0	1991.96	9.92				
	1x9	235159.0	2903.20	11.98				
12	12x1	158641.8	1101.68	7.38	9.08	1.22	-1.20	0.787
	6x2	189285.3	1314.48	8.06				
	4x3	194199.1	1348.61	8.16				
	3x4	259139.6	1799.58	9.43				
	2x6	279836.5	1943.31	9.80				
	1x12	392231.1	2723.83	11.60				
16	4x4	336352.4	1313.88	8.06	8.06	1.02	0.20	0.799
18	18x1	271516.0	838.01	6.43	7.95	0.11	0.91	0.768
	9x2	321104.0	991.06	7.00				
	6x3	323144.0	997.36	7.02				
	3x6	480136.0	1481.90	8.56				
	2x9	496412.0	1532.14	8.70				
	1x18	650324.0	2007.17	9.96				
24	12x2	368931.6	640.51	5.62	7.05	0.90	-079	0.775
	6x4	540174.3	937.80	6.81				
	4x6	627057.8	1088.64	7.33				
	2x12	827000.9	1435.77	8.42				
27	9x3	536940.0	736.54	6.03	6.80	0.25	0.65	0.772
	3x9	843876.0	1157.58	7.56				

36	36x1	540192.0	416.81	4.54				
	18x2	711536.0	549.02	5.21				
	12x3	579136.0	446.86	4.70				
	9x4	930128.0	717.69	5.95				
	6x6	1025792.0	791.51	6.25	6.32	0.48	-0.23	0.743
	4x9	1189520.0	917.84	6.73				
	3x12	1547184.0	1193.82	7.68				
	2x18	1485632.0	1146.32	7.53				
	1x36	1783872.0	1376.45	8.25				
48	12x4	990919.1	430.09	4.61	5.72	0.60	-0.12	0.740
	4x12	2172473.0	942.91	6.83				
54	18x3	1078776.0	369.95	4.27				
	9x6	1899648.0	651.46	5.67	5.58	0.14	0.46	0.734
	6x9	2082132.0	714.04	5.94				
	3x18	2445588.0	838.68	6.44				
72	36x2	1215488.0	234.47	3.40				
	18x4	1993024.0	384.46	4.36				
	12x6	2000448.0	385.89	4.36	5.07	0.51	-0.37	0.724
	6x12	3538944.0	682.67	5.81				
	4x18	3691200.0	712.04	5.93				
	2x36	4482752.0	864.73	6.54				

Fig. 1 : Average Coefficient of variation for different sized plot in Wheat

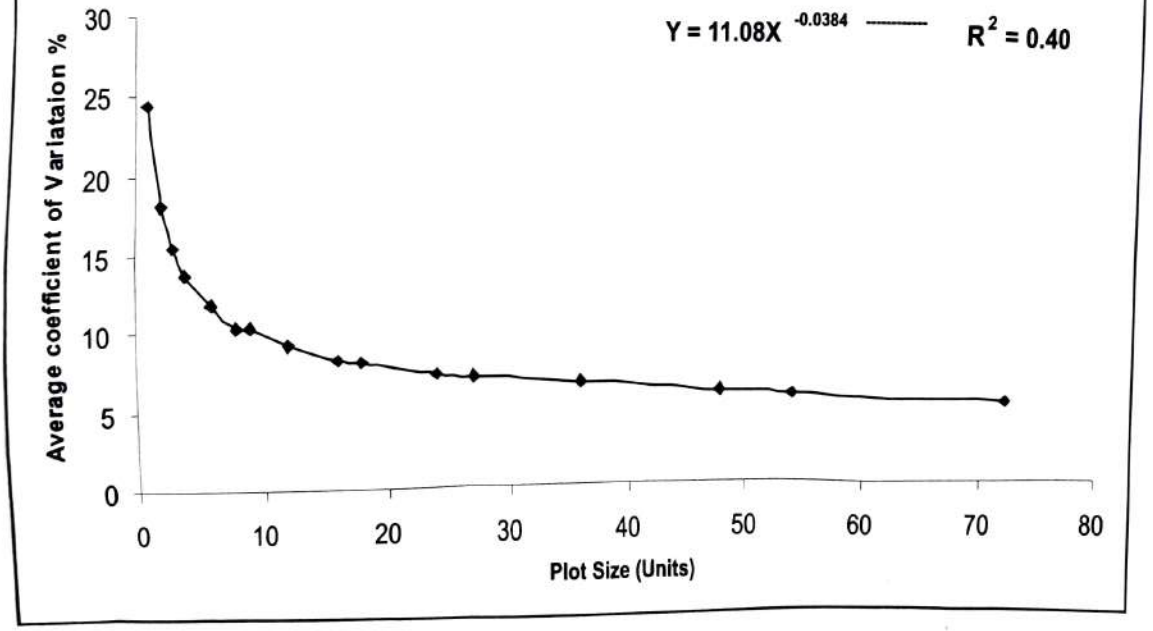

Table 2. Effective number of replications for 5 % standard error and total area required per treatment with different plot sizes.

Plot size			Number of replications								Total area required per treatment (m^2)							
			Block Shape								Block Shape							
Length (Unit)	Width (Unit)	Area (m^2)	1x2	1x3	1x4	1x6	2x4	3x3	3x4	4x4	1x2	1x3	1x4	1x6	2x4	3x3	3x4	4x4
1	1	0.90	14	10	8	6	5	3	3	2	12.60	9.00	7.20	5.40	4.50	2.70	2.70	1.80
1	2	1.80	8	6	5	3	3	3	3	2	14.40	10.80	9.00	5.40	5.40	5.40	5.40	3.60
1	3	2.70	6	3	3	3	3	3	3	2	16.20	8.10	8.10	8.10	8.10	8.10	8.10	5.40
1	4	3.60	5	3	3	3	3	3	2	2	18.00	10.80	10.80	10.80	10.80	10.80	7.20	7.20
1	6	5.40	3	3	3	2	2	2	2	2	16.20	16.20	16.20	10.80	10.80	10.80	10.80	10.80
2	1	1.80	8	6	5	3	3	3	3	2	14.40	10.80	9.00	5.40	5.40	5.40	5.40	3.60
2	2	3.60	5	3	3	2	2	2	2	2	18.00	10.80	10.80	7.20	7.20	7.20	7.20	7.20
2	3	5.40	3	3	2	2	2	2	2	2	16.20	16.20	10.80	10.80	10.80	10.80	10.80	10.80
2	4	7.20	3	3	2	2	2	2	2	2	21.60	21.60	14.40	14.40	14.40	14.40	14.40	14.40
2	6	10.80	3	3	2	2	2	2	2	2	32.40	32.40	21.60	21.60	21.60	21.60	21.60	21.60

V.% was expressed in equation form. The equation derived to show the relation between C.V. % and plot size, X using original data as well as log transformed data are as under.

1) Original data :

$$Y = \frac{a}{X^b}$$

C.V. = 11.08 – 0.0384X .... (R^2 = 0.40)

2) Log transformed data

Log C. V. = Log a ± b Log X
Y = 1.352 – 0.292 X .... (R^2 = 0.99)

The reduction in experimental error for treatment comparison can be achieved by (i) increasing number of replications and (ii) taking large plot (Agarwal *et al.*, 1967). Two criteria are complementary for a fixed experimental area. Hence, the effective number of replication and total area required per treatment were worked out for various plot sizes. The results (Table 2) revealed that the smaller plots with fairly large number of replications were observed to achieve 5 per cent accuracy in any of the block size. The increase in plot size from 0.90 m^2 to 10.80 m^2 resulted in reduction of 14 to 2 or 3 to 2 replications, respectively, to obtain the same precision. For controlling soil variation, a block of 3 x 3 plots was required with minimum 2 replications to a chive 5 per cent accuracy for field experiments in wheat crop in Saurashtra region. Similar results were reported by Saxena *et* al.,(1972) in oat grown for fodder, Thomas *et al.*,(1985) in brinjal, Patil *et al.*,(1987) in Indian mustard and Prajapati *et al.*,(2013) in mustard.

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GAU Research Journal **40** (1) : 60-62 January 2015 **Short communication**

Effect of sulphur on yield and quality of potato under North Gujarat conditions

ASHA PRAJAPATI[1], C. K. PATEL[2] AND R. N. PATEL[3]

Potato Research Station,
S. D. Agricultural University, Deesa - 385 535 (Gujarat)

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Potato (*Solanum tuberosum* L.) plays a vital role in food security for ever increasing world population (Scott and Sourez, 2012). It is highly capital and labour intensive crop (Khushwah and Singh, 2011). Presently India is the second largest potato producer in the world, which has got an unlimited potentiality of its cultivation in Gujarat State. For achieving higher productivity, balance fertilization of utmost important. In potato cultivation, some elements like Zn, B, S and Mg can help in increasing the foliage coverage at initial growth stages and in the later stages, the translocation of assimilate which is responsible for higher yield (Trehan and Grewal,1981). Many workers are of the opinion that application of minor nutrient in addition to major elements can play a good role in increasing the yield of potato (Mahmood *et al.*, 1995; Tiwari, 1995; Rybost *et al.*, 1993; Taya *et al.*, 1994).

Sulphur is one of the 16 essential plant nutrients. It is now considered as the fourth major nutrient in fertilizer management after N, P and K. It is absorbed by plants in amounts comparable to P. It plays major role in increasing protein and oil content . Therefore it is a key component of balanced nutrient application for top yields and superior quality produce. Its deficiencies are spreading in more and more areas due to intensive cropping with high yielding hybrids varieties, scare use of organic manure, use of high analysis S free fertilizers, depletion of soil sulphur due to less sulphur added to soil as compared to crop removals, which ultimately results in negative sulphur balances. Distinct possibility of sulphur losses through leaching and runoff with the spread of flood irrigation to large areas. Keeping this in view, the present investigation was undertaken to study the effect of sulphur application on growth, yield and economics of potato production under loamy sand soils of North Gujarat.

[1] Ex. Junior Research Fellow, [2] Associate Research Scientist, Main Cotton Reseach Station, NAU, Navsari, [3] Assistant Research Scientist

MATERIALS AND METHODS

A field experiment was conducted during *rabi* seasons of 2011-12 and 2012-13 at Main Potato Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa (Gujarat) on loamy sand soil having pH 8.2, organic carbon(0.32 %) low in available N, available P (31.2 kg/ha) and K (282.5 kg/ha). The four treatments *i.e.*, T_1 : control (No Sulphur), T_2 : 25 kg S (Bensulf) /ha , T_3 : 37.5 kg S (Bensulf) /ha and T_4 : 50 kg S (Bensulf) were laid out in randomized block design with six replications. Seed tubers were planted on 18th November in both the years at the spacing of 50 x 20 cm. Recommended dose of N:P:K *i.e.*, 275:140:275 kg/ha were applied. Half dose of nitrogen and full dose of P_2O_5 and K_2O were applied as a basal at the time of planting. Remaining half dose of nitrogen was applied at 30 days after planting. Other cultural operations and plant protection measures were followed as per package of practices recommended for potato crop in the region. Haulm was removed at 100 days after planting and crop was harvested next day. The tubers were graded into three categories *i.e.*, A grade(>125g), B grade (25-125g) and C grade(<25g) and weighed. Stastical analysis was carried out by following standard analysis of variance as described by Gomez and Gomez(1984).

RESULTS AND DISCUSSION

The results a presented in Table 1 revea-d that different levels of sulphur failed to exert sig-ficant effects on a A grade tuber yield of potato uring 2012-2013 and in pooled results. However grade tuber yield increased significantly with increas- level of sulphur in year 2011-12. Significantly high- tuber yield (301.94 q/ha) was recorded with the ap- cation of 50 kg S /ha as compared to rest of the treatments. The pooled result showed non significant differences in A grade tuber yield. Similarly, B grade tuber yield was also in pooled not affected significantly due to

Table 1 Effect of levels of sulphur on grade wise tuber yield (q/ha) of potato

Treatments	A grade tuber yield			B grade tuber yield			C grade tuber yield			Total tuber yield		
	2011-12	2012-13	Pooled	2011-12	2011-12	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
Sulphur levels (kg/ha)												
00.0	275.00	276.90	276.00	129.24	34.04	81.60	24.19	33.58	28.90	428.43	344.52	386.48
25.0	285.28	286.05	285.70	142.50	33.85	88.20	22.78	30.27	26.50	450.56	350.17	400.37
37.5	294.44	272.02	283.20	142.22	36.17	89.20	22.64	39.94	31.30	459.31	348.14	403.73
50.0	301.94	279.41	290.70	137.78	36.63	87.20	21.94	32.28	27.10	461.67	348.31	404.99
SEm ± (For T)	1.57	13.12	6.88	5.64	2.11	2.96	2.78	3.43	3.04	5.64	11.67	6.72
CD(0.05)	4.62	NS	NS	NS	NS	NS	NS	NS	NS	16.66	NS	NS
SEm ± (For Y X T)	-	-	9.33	-	-	2.00	-	-	2.58	-	-	8.99
CD(0.05			NS			6.03			NS			NS
C. V. %	1.22	11.67	4.03	9.04	17.0	5.05	6.52	24.66	11.53	2.76	8.22	2.76

S treatments during both the years as well as in pooled results. However, numerically treatment receiving 37.5 kg S/ha produced higher B grade tuber yield. This also ture for yield of C grade potato.

In the case of total tuber yield, it was aftected significantly due to treatment only during first year. Among the treatments, significantly higher total tuber yield (461.67 q/ha) was recorded with the application of 50 kg S/ha was at par with treatments receiving 37.5 and 25 kg S/ha. Treatment receiving no S recorded significantly the lowest total tuber yield. During 2012-2013 and in pooled analysis, total tuber yield did not very significantly due to S treatments. In contract, the results of Sud and Sharma (2002) showed that these was increase in tuber yield with increasing levels of S application. This was attributed to its role in better partitioning of the photosynthates in the shoot and tubers. Similarly , Lalitha *et al.*, (2002) have also reported significant effect on grade wise tuber yield and increase in bulking rate with sulphur application. Absence of significant response to S application by potato grown on loamy sand soil seems to be due to medium status of available S in soil and Dia ammonium phosphate used as source of P fertilizer in control.

There was an appreciable increase in net realization due to sulphur application up to 25 kg S/ha as shown in Table 2. The highest net return of 115120 /ha was obtained with treatment T_4 (50 kg S/ ha) followed by ₹ 114672 /ha) with T_3 (37.5 kg S/ ha). The lowest returns of ₹108240/ha was accured under treatment T_1(O kg S/ha).

Thus, it is concluded that application of sulphur in addition to recommended dose of nitrogen, phosphorus and potash were more effective for higher net returns of potato

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Table 2 Effect of sulphur on economics of potato

Treatments	Tuber yield (q/ha)	Cost of cultivation (₹/ha)	Cost of Sulphur (₹/ha)	Total cost (₹/ha)	Gross income (₹/ha)	Net return (₹/ha)
Sulphur levels (kg/ha)						
00.0	386.48	85000	0	85000	193240	108240
25.0	400.37	85700	875	86575	200185	113610
37.5	403.73	85860	1333	87193	201865	114672
50.0	404.99	85925	1750	87375	202495	115120
Control V/S Treatment	403.03	85828	1319	87047	201515	114467

Selling price of potato ₹ 500/q

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Short communication

Response of fenugreek (*Trigonella foenum-graecum* L.) to irrigation scheduling based on IW/CPE ratio and method of sowing

P. J. PRAJAPATI[1], R. M. SOLANKI[2], R. P. SOLANKI[3] J. B. VASAVE[4], J. M. MODHVADIA[5] AND D. V. SRINIVASULU[6]

Department of Agronomy, College of Agriculture
Junagadh Agricultural University, Junagadh-362001 (Gujarat)

Received : 28 January, 2014

Fenugreek (*Trigonella foenum-graecum* L.) commonly known as *methi* is an important seed spices grown in arid and semiarid region of india during *rabi* season and cultivated in an area of 82,900 hectors with production of 1.25 lakh tonnes of seed in the country (Anonymous, 2012). In India, it is mainly grown in Rajasthan, Gujarat, Madhya Pradesh, Maharashtra, Haryana, Punjab and Karnataka. Water is a major factor for every metabolic activity of plant and limited quantity of water is available for irrigation, which calls for scheduling of irrigation to improve water productivity of fenugreek. Recently irrigation is being scheduled on the basis of climatological approach which is now considered as most scientific, since it indicate all whether parameters in a given climate, plant continuum giving them natural weightage (Pariher *et. al*, 1976). Maintenance of optimum plant population is essential for interception of solar radiation without exerting competition for nutrient and water in plants.

Precise information regarding appropriate scheduling of irrigation based on IW/CPE ratio and method of sowing for fenugreek is meagre. Keeping in view the above considerations this research programme was planned to study the judicious use of irrigation water which may provide information not only on water use by crop but also when to irrigate and to find suitable method of sowing for fenugreek. Hence there is an urgent need to generate precise information on irrigation requirement and method of sowing.

[1] Agricultural Officer, Wheat Research Station, [2] Associate Professor, [3] Young Professional-I, Directorate of Groundnut Research, Junagadh, [4] Ph.D. Scholar, Navsari Agricultural University, Navsari, [5] Assistant Professor, SWE Department, Agril. Engineering and Tech. College, [6] Ph.D. Scholar, S.V. Agril. College, Tirupati, Chittor.

A field experiment was conducted at Instructional Farm, College of Agriculture, JAU, Junagadh (Gujarat) during *rabi* season of 2011-12. The soil of the experimental field was clayey in texture having field capacity moisture of 28.88 % and PWP of 12.86 % and soil moisture before sowing was 22.15 %, pH 7.9 Ec 0.33 dS m^{-1}. The soil in experimental site was medium in available nitrogen (267.0 kg ha^{-1}), P_2O_5 (38.3 kg ha^{-1}), high in available K_2O (232.0 kg ha^{-1}) and rich in organic carbon (0.83 %). The experiment was laid out in split plot design with four replications. Keeping four levels of irrigation [0.4, 0.6, 0.8 and 1.0 irrigation water (IW) cumulative pan evaporation (CPE) ratio] in main plot and two sowing method [M_1 = line sowing at 30 cm and M_2 = broadcasting] in sub plots. Fenugreek (GM-2) was sown in first week of November-2011 as per treatments using a seed rate of 15 kg ha^{-1}. A full dose of 20 kg nitrogen and 40 kg phosphorus per hectare was drilled manually through DAP and urea as a basal at sowing. Two common irrigations each of 50 mm depth were applied, first immediately after sowing and second at 5 DAS for better germination and establishment of seedlings. Rest of the irrigations were applied as per treatments. A total of 1400 mm water was measured by parshall flume, installed in the field channel and total of 5, 6, 8 and 9 irrigations of 5.0 cm each at IW/CPE ratio of 0.4, 0.6, 0.8 and 1.0, respectively were provided. Cumulative pan evaporation was taken as the sum of the daily pan evaporation from USWB class-A evaporimeter. The soil samples collected from five different depths *viz.*, 0-15, 15-30, 30-45, 45-60 and 60-75 cm before irrigation and 48 hours after irrigation and sample were used for estimation of moisture content. Other packages of practises were followed as per recommendation made for the crop in the region. The crop was harvested on 5th March, 2012.

Table 1. Effect of irrigation levels and sowing method on growth, yield attributes and yields of fenugreek

Treatments	Plant height (cm)	Branches/ plant	Dry matter/ plant (g)	Pods/ plant	Pod length (cm)	Seeds/ pod	Test weight (g)	Yield (kg ha^{-1})	
								Seed	Straw
Irrigation (IW/CPE ratio)									
I_1: 0.4	42.6	5.9	14.1	18.1	6.2	10.9	12.3	1615	2777
I_2: 0.6	45.1	6.7	15.7	19.9	7.0	11.2	12.8	1740	2892
I_3: 0.8	50.5	7.2	21.6	23.1	7.8	12.8	15.2	1981	3517
I_4: 1.0	52.9	7.8	22.9	24.9	8.4	13.4	15.3	2031	3551
S. Em ±	1.54	0.22	0.84	0.66	0.20	0.23	0.20	83.0	174.5
C.D. at 5%	4.95	0.71	2.6	2.11	0.66	0.76	0.65	265.7	558.2
C.V. %	9.1	9.1	12.8	8.7	8.0	5.6	4.1	12.7	15.5
Sowing method									
M_1: 30cm Line sowing	50.1	7.2	19.5	22.6	7.8	12.4	14.1	1996	3331
M_2: Broadcasting	45.5	6.6	17.6	20.4	6.9	11.8	13.7	1688	3037
S. Em ±	0.82	0.13	0.45	0.30	0.11	0.14	0.09	42.2	51.7
C.D. at 5%	2.54	0.41	1.3	0.93	0.35	0.44	0.28	130.1	159.6
C.V. %	6.9	7.8	9.8	5.6	6.3	4.7	2.6	9.1	6.5
Interaction (I x M)	NS	Sig.	NS	NS	NS	Sig.	Sig.	Sig.	Sig.

Table 2 Effect of irrigation levels and sowing method on water use, WUE and economics of fenugreek

Treatments	Total no. of irrigation applied	Total quantity of irrigation water applied (mm)	WUE (kg ha^{-1} mm)	Realization (₹ ha^{-1})		BCR
				Gross	Net	
Irrigation (IW/CPE ratio)						
I_1: 0.4	5	250	6.46	42571	16337	1.62
I_2: 0.6	6	300	5.80	45816	18972	1.71
I_3: 0.8	8	400	4.95	52274	24210	1.86
I_4: 1.0	9	450	4.51	53566	24892	1.87
Sowing method						
M_1: 30cm line sowing	-	-	5.85	52564	25980	1.98
M_2: Broadcasting	-	-	5.01	44563	16239	1.57

Significantly higher plant height, dry matter accumulation, number of branches per plant, pods per plant, pod length, number of seeds per pod, test weight, seed and straw yields were recorded at IW/CPE ratio of 1.0 than rest of the treatments but it remained at par with IW/CPE ratio of 0.8 (Table 1). While in case of water use efficiency it was maximum (6.46 kgha^{-1}mm) at 0.4 IW/CPE ratio (Table 2). Significantly higher seed and straw yields (2031 and 3551 kgha^{-1}) were produced at higher IW/CPE ratio (1.0) it might be due to frequent irrigation at shorter interval under this treatment which maintain optimum moisture level in the soil during the entire growth period resulted in better translocation of photosynthates from source to sink which in turn resulted higher yield attributes and yield of fenugreek. These findings are in close agreement with studies of Dutta and Chatterjee (2006).

The higher values of growth and yield attributes; seed and straw yields were observed when crop was sown at 30cm row spacing (Table 1). Significantly the maximum seed yield (1996 kg ha^{-1}) was produced under line sown crop at 30 cm row spacing which was 18.2% higher than broadcast method of sowing. The probable reason for higher yield under line sowing might be due to intra-space competition and competitive interactions among the plant can be avoided by providing suitable stand geometry by which all the strata of leaves can get copious sunlight and carry out effective photosynthesis and consequently higher dry matter and yield (Duncan, 1977). Yadav *et al.*, (2000) also reported higher seed yield of fenugreek under 30 cm row spacing.

Data of one year revealed the presence of significant interaction of irrigation (I) and sowing method (M). Significantly for the higher no. of branches per plant, seeds per pod, test weight, seed and straw yields were recorded when crop was irrigated at 1.0 IW/CPE ratio along with 30cm row spacing (Table 3). Treatment combination I_4M_1 recorded significantly higher seed yield than rest of the combinations, but it remained at par with I_3M_1 combinations (irrigation at 0.8 IW/CPE ratio along with 30cm row spacing). Irrigating the crop at an IW/CPE ratio 1.0 and sowing the crop at 30cm row spacing significantly increased yields which might be due to the contribution of more pods, pod length and seeds per pod as evidenced by test weight and grain yield per plant resulting from more nutrition to plants. These findings are corroborating with the reports of Davut Karaaslan (2007) in sesame.

Table 3 Interaction effects of irrigation and sowing method on growth, yield attributes, seed and straw yield

Treatments	Branches/plant				Seeds/pod				Test weight(g)				Seed yield(kgha^{-1})				Straw yield(kgha^{-1})			
	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4
M_1	6.1	6.5	7.6	8.4	11.1	11.0	13.4	14.0	12.4	12.8	15.4	15.9	1729	1792	2108	2354	2913	2933	3583	3896
M_2	5.7	6.9	6.7	7.1	10.7	11.4	12.2	12.7	12.3	12.7	15.1	14.7	1500	1688	1854	1708	2642	2850	3450	3206
C.D. at 5%		0.83				0.88				0.57				260.3				329.2		

The maximum amount of moisture was extracted from 0-15 cm soil depth irrespective of irrigation and it was decreased with soil depth (Fig. 1). About 60.91% soil mois-ture was extracted from the top 30 cm of soil depth under 0.4 IW/CPE ratio but in case of 1.0 IW/ CPE ratio more than 65.57% soil mois-ture was extracted at the same depth. This indicated that irrigation levels had promi-nent effect on soil moisture extraction pat-tern.

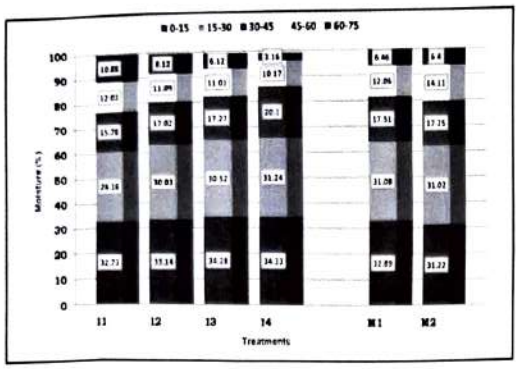

Fig. 1 Moisture extraction pattern of fenugreek under different IW/CPE ratio and sowing method

Soil moisture extraction increased from 15 cm soil depth with increasing irrigation level. The higher amount of moisture extraction from surface layer under different irrigation levels might be due to increased surface evaporation, shallow root density and higher water uptake due to availability of irrigation water. These findings are also cor-roborate with the findings of Dutta and Chatarjee (2006). In lower level of irrigation treat-ments, moisture extraction was higher from deeper (30-60 cm) soil layer. In this condi-tion moisture stress compelled the roots to go into deeper soil layer for utilization of water for their proper growth and develop-ment. In case of sowing method maximum moisture extraction of 63.97% was noted in line sowing followed by broadcast method of sowing with 62.24%, respectively.

The results presented in Table 2 on economics of different irrigation levels indicated that an application of irrigation water at 1.0 IW/CPE ratio recorded highest gross and net realization of Rs. 53566 and Rs. 24892/ ha, respectively, due to more yield followed by 0.8 IW/CPE ratio. In case of sowing method highest gross and net realization recorded under line sowing method.

It was concluded that for getting higher yield and maximum economics of fenugreek should be irrigated at an IW/CPE ratio of 1.0 with sown at 30cm row spacing along with other recommended package of practices.

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Short communication

Influence of sowing time and direction on powdery mildew incidence and loss assessment

B. G. CHAUDHARY[1], S. I. PATEL[2] AND V.A. SOLANKI[3]

Department of Plant Pathology, C. P. College of Agriculture,
S. D. Agricultural University, Sardarkrushinagar-385 506 (Gujarat)

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Fenugreek (*Trigonella foenum graecum*L.) is an important spice crop and occupies a prime position among different seed spices. Fenugreek suffers from number of diseases caused by various pathogens. Among them, powdery mildew of fenugreek caused by *Erysiphe polygoni* DC. is considered as the most destructive as it damages to all parts(Chattopadhyay and Maiti, 1990). The disease has been observed to occur at flowering and pod formation stages (Dhruj *et al.*, 2000). Change in sowing period may be an important cultural practice followed to minimize the extent of damage due to powdery mildew disease as it avoids coincidence with susceptible stage of the crop. The direction of sowing may also influence the disease incidence because disease severity increases if crop is sown such that lower canopy of plants has less exposure to sunlight.With that assumption, the present studies were carried out to observe their influence on powdery mildew.

A field experiment with three treatments ofdifferent sowing dates viz., 20th October (D_1), 10th November (D_2) and 30th November (D_3), was conducted in Randomized Block Design with Factorial concept during *rabi* season of 2012 at Agronomy Instructional farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The recommended fenugreek variety GM 2 was sown maintaining 30 cm distance between rows in a gross plot size of 4.5 m X 1.5 m as well as two directions of sowing *viz.*, North-South and East-West. The recommended agronomical practices were followed.

The observations on intensity of powdery mildew was recorded from 25 randomly tagged plants in each plot at three crop growth stages *viz.*, vegetative stage (45 days after sowing), pod formation stage (70 days after sowing), and maturity stage (95 days after sowing) using 0-5 scale as described follows :

0 = Healthy plant/No incidence
1 = Less than 50 per cent leaves covered with whitish growth
2 = > Fifty per cent leaves covered with whitish growth
3 = > Fifty per cent leaves, stem/branches covered with whitish growth
4 = > Fifty per cent leaves, stem/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).

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

For assessing the losses due to powdery mildew disease in fenugreek, 100 matured pods for each of the categories as mentioned below were harvested from diseased as well as healthy plants from the experimental plots.

1. Few whitish specks on pods
2. Fifty per cent area of the pods covered with whitish specks
3. Pods completely covered with whitish growth
4. Healthy pods

From the pods of above different categories, observations *viz.*, number of seeds per pod, weight of seeds per pod and 1000-seed weight were recorded and losses (%) were worked out as per Krishna *et al.* (1988).

The effects of different dates as well as direction of sowing on the development of powdery mildew disease are presented in Table 1. The data revealed significant differences in per cent intensity of powdery mildew

[1] P.G. Student, [2] Associate Research Scientist, Centre of Excelence for Research on Wheat, Vijapur, [3] Professor, Department of Plant Pathology, N. M. College of Agriculture, NAU, Navsari

disease at pod formation (70 days after sowing) and physiological maturity stage (95 days after sowing). The disease was not initiated at vegetative stage (45 days after sowing) of the crop. At pod formation and physiological maturity stages, significantly lowest powdery mildew intensity of 21.67 and 44.01 per cent was recorded when the crop was sown on 10th November (D_2), while it was highest (39.41 and 62.48 per cent, respectively) at delayed sown crop i.e. 30th November (D_3). Among two direction of sowing, the disease intensity was non-significant. Thus, it can fairly be concluded that late sown crop suffered more because of ready availability of inoculums build up in early sown crop and result in higher percent disease intensity. Kumari and Prasad (1998) reported minimum intensity of powdery mildew of pea caused by *E. polygoni* in early sown crop compared to late sown crop. Tripathi and Rathi (2000) revealed no effect of row direction on severity of Botrytis gray mold of chick pea. Singh and Sirohi (2003) reported increased intensity of powdery mildew in late sowing of black gram.The average powdery mildew severity was significantly lower in early and mid-sown green gram crop (Thakar *et al.*, 2004).The results obtained in present study are in agreement with earlier reports.

The data (Table 2) on number of seeds per pod, weight of seeds per pod and 1000-seed weight revealed that maximum reduction of 14.45, 30.24 and 12.68 per cent in number of seeds per pod, weight of seeds per pod and 1000-seed weight, respectively was observed when pods were completely covered with whitish growth as compared to healthy pods. When fifty per cent area of the pod covered with whitish growth, there was corresponding reduction of 6.62, 18.53 and 7.43 per cent in number of seeds per pod, weight of seeds per pod and 1000-seed weight, respectively, while, these parameters were reduced to nearly half when only few whitish specks were observed on pod. Thus, it can be concluded that powdery mildew caused considerable reduction in agronomic characters like number of seeds per pods, weight of seeds per pods and 1000 seed weight which in turn causes considerable reduction in seed yield of fenugreek. Reduction of 22.8-25.6, 16.3-18.8 and 14.3-17.2 per cent in pods per plant, seeds per pod and test weight, respectively was recorded when powdery mildew intensity in fenugreek was more than 80 per cent (Rathi *et al.*, 2002). Dakshayani and Mummigatti (2004) also reported that the number of pods per plant was reduced by 29 % , number of seeds per pod by

Table 1 Effect of sowing date and sowing direction on powdery mildew intensity in fenugreek

Treatments	Percent Disease Intensity (PDI)		
	Vegetative stage	Pod formation stage	Physiological maturity stage
Date of sowing (A)			
D_1- 20th Oct.	0.00	32.89* (29.48)	47.03 (53.54)
D_2- 10th Nov.	0.00	27.75 (21.67)	41.56 (44.01)
D_3- 30th Nov.	0.00	38.89 (39.41)	52.17 (62.38)
S. Em. ±	0.93	1.16	
C.D. at 5 %	2.80	3.51	
Sowing directions (B)			
North-South	0.00	33.31 (30.15)	47.50 (54.35)
East-West	0.00	33.04 (29.72)	46.35 (52.35)
S. Em. ±	0.76	0.95	
C.D. at 5%		NS	NS
Interaction (A X B)		NS	NS
C.V. %	7.94	7.03	

*Figures are Arc sin transformed values and in parentheses retransformed values

Table 2 Assessment of losses due to powdery mildew in fenugreek

Treatments	Vegetative stage	Pod formation stage	Physiological maturity stage	Vegetative stage	Pod formation stage	Physiological maturity stage
Few whitish specks on pod	16.10	3.01	0.19	6.82	11.92	3.71
Fifty per cent area of the pod covered with whitish growth	15.50	6.62	0.16	18.53	11.46	7.43
Pod completely covered with whitish growth	14.20	14.45	0.14	30.24	10.81	12.68
Healthy pod	16.60	-	0.20	-	12.38	-

27 % and test weight by 13 % due to powdery mildew (*E. polygoni*) of green gram.Thus, the results obtained in present study are more or less in conformity with the results reported earlier.

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