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Breeding mineral rich high yielding genotypes in monoecious ridge gourd (*Luffa acutangula* Roxb.) utilizing hermaphrodite inbreds

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Abstract
The present experiment was carried out at IARI, Pusa, New Delhi during 2007-09 to evaluate the combining ability of hermaphrodite lines in combination with monoecious inbreds for the mineral content and yield potential in ridge gourd (*Luffa acutangula* Roxb.). Twenty-one half-diallel derived crosses along with their seven parents were sown in randomized block design with three replications. A large amount of genetic variation was found for fruit yield & mineral content (phosphorus, calcium, potassium, sodium, sulfur, iron, zinc and manganese) in parents, hybrids and parents vs. hybrids; and general combining ability and specific combining ability. Hermaphrodite parents (Satputia Long and Satputia Small) and "monoecious × hermaphrodite" crosses were found to be superior for mineral content along with yield potential in terms of *per se* performance and combining ability. The crosses possessing higher *per se* performance, significant desirable specific combining ability estimates, and involving hermaphrodite line as one of the parents would be helpful for accumulating favorable alleles to enhance the mineral content along with productivity in ridge gourd.

Keywords: Mineral content, combining ability, hermaphrodite, satputia, ridge gourd

Introduction

Ridge gourd is an important cucurbitaceous vegetable in tropical and subtropical countries, especially in South-east Asia including India and Africa (Jansen *et al*. 1993 and Neuwinger 1994) [10, 13]. The young tender fruits of the non-bitter types are eaten as vegetable. Monoecism is the most familiar sex form in ridge gourd; but hermaphroditism (bisexual flowers) is found in Satputia, a feral form, cultivated in Eastern parts of India (Chandra 1995) [3]. Satputia bears numerous small size fruits in cluster, while monoecious ridge gourd produces solitary longer fruits. The ridge gourd fruits contain fair amount of minerals and fiber (Hussain *et al*. 2010) [9]. Minerals are integral part of human and plant nutrition to support the various biological processes during various phases of growth and development. An appropriate plant-based diet can provide adequate amount of minerals to fulfill human dietary requirements. Minerals, including both macro- and micro-nutrients are essential for living organisms. In developing countries, billions of people suffer from micronutrient malnutrition. Recent estimates indicate that nearly half of world population suffers from Zn deficiency, and more than two billion (37%) people worldwide are anaemic and much of it is due to Fe deficiency (Singh *et al*. 2010) [17].

It has been assumed that increase in yield has resulted in decrease in the concentrations of mineral elements due to a ''dilution effect'' caused by environmental and genetic factors (Davis *et al*. 2004) [4]. The recent studies have indicated that higher yielding genotypes have low mineral content (Garvin *et al*. 2006) [5]. In vegetables, the negative correlation between mineral content and yield was reported in kohlrabi, kale & savoy cabbage (Broadley *et al*. 2008) [2] and cabbage (Singh *et al*, 2012) [18]. Ridge gourd fruits are integral part of North and South Indian culinary dishes because of its cheaper market price and almost round the year availability. The knowledge of combining ability in terms of general combining ability (GCA) and specific combining ability (SCA) effects would facilitate in selecting the superior parents and hybrids, respectively. The significant variations among genotypes for the concentration of different mineral elements have been reported in cabbage (Singh *et al*. 2010) [17], kale (Kopsell *et al*. 2005) [12] and wild Jerusalem artichoke (Seiler and Campbell 2004) [15]. Heterosis for Ca and P in ridge gourd (Hedau 2002) [8] and gene action for nutritional traits in bottle gourd

(Sit and Sirohi 2000) [20] has been reported. However, a negative heterobeltiosis has been reported (Singh *et al*. 2009) [16] for Zn, Fe, Cu, Mn, K and Ca in cabbage but its magnitude was higher for micronutrients than macronutrients.

To the best of our knowledge and available literature, only few studies describe the mineral content in cucurbitaceous crops and none describe the combining ability for mineral content in ridge gourd fruits. Therefore, the present experiment was designed with the objective to identify promising genotypes and crosses on the basis of GCA and SCA estimates following 7×7 half-diallel mating design and utilizing the small fruited hermaphrodite Satputia lines for increasing the minerals (P, Ca, K, Na, S, Fe, Zn and Mn) content in the fruits of monoecious ridge gourd (*Luffa acutangula*).

Materials and Methods

The field experimental trials were conducted at Vegetable Research Farm, I.A.R.I, Pusa, New Delhi during 2007-08 and 2008-09. The experimental materials were comprised of seven genetically diverse inbreds, including five monoecious (DRG-2, Pusa Nasdar, Utkal Tripti, Arka Sumeet and HARG-110) and two hermaphrodite inbreds (Satputia Long and Satputia Small). The seeds of all parental lines were sown to produce F_1 hybrids during spring-summer of 2007-08 and all the recommended package of practices were followed during cropping season. Twenty-one F_1 crosses were produced by hand pollination following half-diallel mating design. During rainy season of 2008-09, a total of 28 genotypes (21 F_1 crosses and seven parental inbreds) were grown in field. Six seeds of each genotype were sown in hill and the hills were spaced 2.5 m × 0.75 m but only four plants per hill were maintained for taking observations on various traits. The experiment was laid out in randomized block design with three replications and a plot size of 200 square meters was allotted for each replication. In each replication, observations were taken on 20 plants. The yield per plant was computed by multiplying the number of fruits per plant with average fruit weight.

Ten fruits at edible maturity stage were harvested randomly from all the 7 parents and 21 crosses in each replication, chopped to homogenize and 100 g of the chopped material was kept in hot air oven at 60–65^{0}C for drying. The dried samples were grounded, passed through 1 mm sieve and finally stored in airtight container until the digestion (Singh *et al*. 1999) [19]. An amount of 0.5 g dried sample was pre-digested in 15 ml diacid mixture of perchloric acid ($HClO_4$) and nitric acid (HNO_3) in a ratio of 1:1 (w/w) overnight and then predigested samples were heated up to 250^{0}C on hot plate until the solution become colourless. Finally, the volume of digested sample was made up to 100 ml with double distilled water and thereafter filtered through Whatman No.-1. The filtrate sample was taken to estimate the content of Zn, Fe and Mn on Atomic Absorption Spectrophotometer (AAS-4141); K, Na and Ca using Flame Photometer (ELICO CL-361); while P and S content were determined through spectrophotometry (ECIL, India). Finally, the content of P, Ca, K and Na was expressed as mg/ 100 g; and S, Fe, Zn and Mn in µg/ 100 g on the basis of fresh weight.

The data relating to mineral contents and yield were computed statistically for combining ability estimates (GCA and SCA) using Griffing's Method II of Model I (Griffing 1956) [7]. The statistical analyses were done using Statistical Package for Agricultural Research (SPAR 2.0) of Indian Agricultural Statistical Research Institute (IASRI), New Delhi.

Results and Discussion

Food security was the major concern in India during 1960s which was almost achieved through Green Revolution. Presently malnutrition is an acute problem in modern India, especially in rural society. Plant breeding could be used as a potential tool for bio fortification of food materials to achieve nutritional security. Now-a-days vegetable breeders are paying attention to simultaneous improvement for both yield and nutritional parameters. As like yield, nutritional improvement in vegetable crops also need abundant genetic diversity for nutritional traits.

Highly significant mean squares due to parents, hybrids and parents vs. hybrids were found for all minerals (P, Ca, K, Na, S, Fe, Zn and Mn) and yield (Table 1) indicating the presence of ample genetic variability which is essential to improve the mineral content of ridge gourd fruits. The present result is in accordance with the findings in brinjal (Raigon *et al*. 2008) [14], in ridge gourd (Karmakar *et al*. 2013) [11] and cabbage (Singh *et al*. 2010) [17]. The mineral content such as P, Ca, K, Na, S, Fe, Zn and Mn were considerably higher in hermaphrodite parents (1.47 to 2.43-fold more) as compared to monoecious parents (Table 2; Figure 1) which could be due to smaller fruit size of hermaphrodite Satputia inbreds. The negative correlation between yield and mineral content was also observed for Zn, Fe, Cu, Mn, K and Ca in cabbage (Singh 2007). The maximum fruits yield per plant was harvested in DRG-2 followed by Pusa Nasdar, Satputia Long and Satputia Small. Moreover, mineral concentrations were highest in the "hermaphrodite × hermaphrodite" hybrid (1.72 to 3.19-fold) and "monoecious × hermaphrodite" hybrids (1.51 to 2.12-fold) over "monoecious × monoecious" hybrids (Table 3; Fig. 1) which is because of inclusion of hermaphrodite lines as one of the parents in the hybrid combinations. Maximum fruit yield was realized in "monoecious × hermaphrodite" hybrids (1.74-fold) as compared to "monoecious × monoecious" hybrids and least was noted in "hermaphrodite × hermaphrodite" hybrid which may be due to the presence of divergent parents (different sex forms) in cross combinations and justifying the heterotic effects. The results indicate that hermaphrodite parents have potential to improve mineral content as revealed in their hybrids. In present context, keeping in view the importance of both yield and mineral content, the use of both hermaphrodite and monoecious parents in breeding programmes would definitely improve yield and mineral content concurrently in ridge gourd.

The knowledge of *per se* performance and combining ability of parental lines and cross combinations is key to the plant breeders for selecting suitable parents and crosses, and the appropriate breeding strategies to improve the traits of economic importance. The mean squares due to GCA and SCA (Table 4) were highly significant for all minerals (P, Ca, K, Na, S, Fe, Zn and Mn) and fruit yield. Highly significant mean squares for GCA and SCA reflect the presence of additive and non-additive variance, respectively. Additive and non-additive variance for mineral content was also reported in maize (Brkic *et al*. 2003) [1], and rice (Gregorio and Htut 2003) [6]. All the minerals exhibited higher values of additive variance (σ2A) than corresponding non-additive variance (σ2D), while fruit yield showed vice-versa pattern (Table 4).

Table 1: Analysis of variance (ANOVA) for mineral content and yield in parents and hybrids of ridge gourd

Source of variation	D.F.	Mean square								
		P	Ca	K	Na	S	Fe	Zn	Mn	Yield/ plant
Replicates	2	0.9	0.2	0.4	2.0	2485	1736	895	100	0.003
Parents	6	120.7**	188.4**	245.2**	170.4**	193294**	49125**	165956**	10733**	0.454**
Hybrids	20	200.0**	289.1**	423.5**	309.1**	1004040**	85342**	363478**	17029**	2.438**
Parents vs. Hybrids	1	686.4**	1024.1**	1322.1**	998.4**	4604317**	271729**	1982410**	100680**	25.186**
Error	54	0.9	0.8	0.9	1.2	978	2351	401	81	0.002

**$P<0.01$

Table 2: Mean performance of parents for mineral content and yield in ridge gourd

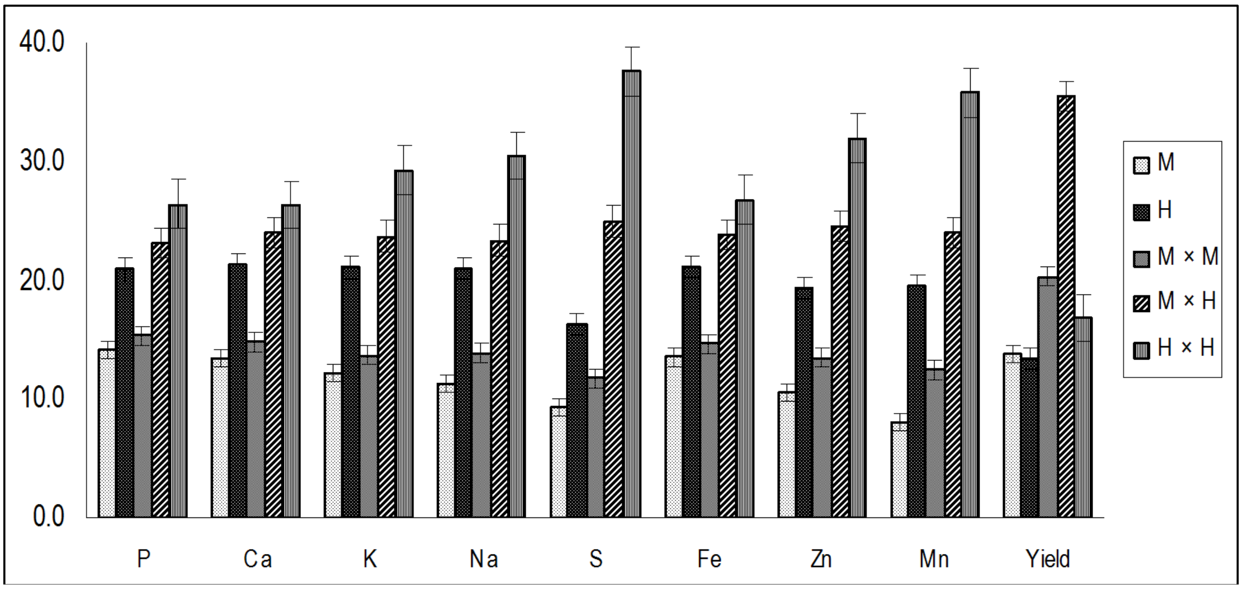
Parents	P (mg/ 100 g)	Ca (mg/ 100 g)	K (mg/ 100 g)	Na (mg/ 100 g)	S (µg/ 100 g)	Fe (µg/ 100 g)	Zn (µg/ 100 g)	Mn (µg/ 100 g)	Yield (kg/ plant)
DRG-2 (P_1)	28.5	30.1	26.7	19.4	816.7	480.0	577.3	105.0	2.09
Pusa Nasdar (P_2)	27.4	28.9	23.9	20.5	671.3	446.7	629.0	84.7	1.30
Utkal Tripti (P_3)	25.0	22.8	25.4	16.7	491.7	431.7	523.7	76.0	1.00
Arka Sumeet (P_4)	25.6	26.5	27.3	17.3	566.7	465.0	548.7	92.3	1.06
HARG-110 (P_5)	27.4	25.3	23.9	15.2	586.0	476.7	537.3	60.7	0.94
Satputia Long (P_6)	38.8	41.3	45.1	31.6	1088.3	701.7	1011.3	199.3	1.25
Satputia Small (P_7)	40.2	43.1	42.3	34.0	1118.3	736.7	1066.7	206.7	1.23
SEm	0.1	0.1	0.1	0.1	3.4	5.3	2.2	1.0	0.01
CD ($P<0.01$)	0.5	0.4	0.5	0.5	15.2	23.5	9.7	4.4	0.02
M (5 parents)	26.8	26.7	25.4	17.8	626.5	460.0	563.2	83.7	1.28
H (2 parents)	39.5	42.2	43.7	32.8	1103.3	719.2	1039.0	203.0	1.24

M: Monoecious parents H: Hermaphrodite parents

Table 3: Mean performance of hybrids for mineral content and yield in ridge gourd

Hybrids	P (mg/ 100 g)	Ca (mg/ 100 g)	K (mg/ 100 g)	Na (mg/ 100 g)	S (µg/ 100 g)	Fe (µg/ 100 g)	Zn (µg/ 100 g)	Mn (µg/ 100 g)	Yield (kg/ plant)
$P_1 \times P_2$	30.4	32.3	27.2	22.9	956.7	500.0	905.0	151.0	3.01
$P_1 \times P_3$	29.2	27.1	33.1	20.1	866.7	485.0	692.3	131.3	2.27
$P_1 \times P_4$	26.4	29.9	31.9	19.2	891.7	521.7	797.7	182.3	2.74
$P_1 \times P_5$	32.7	31.7	25.6	17.3	871.7	565.0	720.0	123.7	2.03
$P_1 \times P_6$	43.7	47.2	53.1	37.3	2048.3	838.3	1320.0	258.7	3.87
$P_1 \times P_7$	46.3	49.8	48.7	38.9	2353.3	728.3	1405.0	297.3	4.00
$P_2 \times P_3$	26.9	28.2	25.3	18.9	716.7	481.7	708.3	129.0	1.54
$P_2 \times P_4$	26.6	30.7	29.4	23.3	746.7	485.0	791.7	155.3	1.89
$P_2 \times P_5$	31.6	29.3	24.1	19.5	796.7	496.7	673.3	105.0	1.49
$P_2 \times P_6$	41.8	47.9	49.5	39.2	1528.3	800.0	1405.0	234.3	3.51
$P_2 \times P_7$	44.9	48.1	48.1	43.5	1788.3	825.0	1540.7	268.0	3.62
$P_3 \times P_4$	26.0	27.5	30.5	19.7	681.7	451.7	626.7	127.7	1.33
$P_3 \times P_5$	30.1	25.9	26.3	35.8	701.7	481.7	693.3	100.7	1.30
$P_3 \times P_6$	40.1	45.3	47.7	38.7	1238.3	788.3	1202.3	229.7	3.00
$P_3 \times P_7$	43.3	47.7	44.1	19.9	1328.3	806.7	1295.3	245.7	2.80
$P_4 \times P_5$	30.3	30.9	29.9	20.0	721.7	501.7	615.0	90.3	1.20
$P_4 \times P_6$	44.2	48.1	55.6	36.9	1428.3	805.0	1185.0	239.7	3.21
$P_4 \times P_7$	44.9	48.9	50.2	39.5	1648.3	835.0	1334.3	251.3	3.27
$P_5 \times P_6$	42.6	46.1	49.7	35.2	1715.7	821.7	1193.0	218.7	2.81
$P_5 \times P_7$	45.1	48.3	45.4	37.6	1808.7	845.0	1312.3	242.7	2.73
$P_6 \times P_7$	50.0	52.3	60.7	47.8	2536.7	910.0	1716.0	370.7	1.56
SEm	0.5	0.5	0.2	0.6	16.2	25.1	10.4	4.7	0.02
CD ($P<0.01$)	1.5	1.4	1.4	1.7	48.1	74.7	30.8	13.9	0.07
M×M (10 hybrids)	29.0	29.4	28.3	21.7	795.2	497.0	722.3	129.6	1.88
M×H (10 hybrids)	43.7	47.7	49.2	36.7	1688.6	809.3	1319.3	248.6	3.28
H×H (1 hybrid)	50.0	52.3	60.7	47.8	2536.7	910.0	1716.0	370.7	1.56

M: Monoecious parents H: Hermaphrodite parents



M: Monoecious parents
H: Hermaphrodite parents
M×M: Monoecious × monoecious hybrids
M×H: Monoecious × hermaphrodite hybrids
H×H: Hermaphrodite × hermaphrodite hybrid

Fig. 1 Relative content of various minerals and fruit yield in parents and hybrids of ridge gourd

Less than unity value of average degree of dominance (ADD) along with predictability ratio (PR) values > 0.5 for all the minerals analysed indicate the presence of additive gene effect. On the other hand, non-additive gene effect was observed for fruit yield/ plant as reflected by higher estimate of σ^2_D over σ^2_A and >1.0 ADD along with <0.5 PR values.

The GCA estimates were positively significant in both the hermaphrodite lines Satputia Long and Satputia Small, and their respective magnitude was estimated as 6.36 & 8.01 for P, 8.01 & 9.31 for Ca, 11.81 & 9.07 for K, 8.19 & 7.84 for Na, 369.49 & 483.71 for S, 145.13 & 151.43 for Fe, 258.03 & 335.02 for Zn and 58.68 & 74.09 for Mn; while monoecious parents showed negative (undesirable) GCA effects (Table 5). It reveals that hermaphrodite parents are good general combiner for mineral accumulation in the fruits, hence additive nature of gene effect could efficiently be exploited for developing mineral rich ridge gourd genotypes. Three parents including both the hermaphrodite genotypes (Satputia Long and Satputia Small) and one monoecious line (DRG-2) were recognized as good general combiners for fruit yield/ plant. The results indicate that the parental lines having high *per se* performance for mineral content (hermaphrodite lines) also exhibited higher positive GCA effects, while negative GCA estimates were observed in the parents having lower mineral content (monoecious lines). The average fruit weight of the hermaphrodite and monoecious parents ranged from 33.2 to 40.09 g and 101.35 to 115.60 g respectively with corresponding mean value of 36.55 g and 107.98 g. There was a comprehensible inverse association between mineral content and average fruit weight such as P (r = -0.956), Ca (r = -0.912), K (r = -0.967), Na (r = -0.964), S (r = -0.862), Fe (r = -0.974), Zn (r = -0.971) and Mn (r = -0.946). The result is in accordance with findings in rice (Gregorio and Htut 2003) [6] and cabbage (Singh *et al*. 2012) [18].

The SCA estimate is a function of dominance effects and also epistatic effects, if present (non-additive) which helps in the identification of superior cross combinations for commercial exploitation of heterosis. Among 21 cross combinations studied, all the 11 crosses having hermaphrodite line as one of the parents revealed significant positive SCA estimates for P and Ca content (Table 6). The magnitude of SCA estimates for P and Ca content were significantly higher (>2.50 and >4.10, respectively) in “monoecious × hermaphrodite” hybrids than the “monoecious × monoecious” and “hermaphrodite × hermaphrodite” hybrids, indicates that poor × good general combiner parents performed better over poor × poor and good × good general combiner parents and role of non-additive dominance gene action. Furthermore, SCA effects were significantly higher in 11 crosses involving hermaphrodite parent(s) and one cross of monoecious × monoecious parents for K content, but its magnitude is considerably higher in monoecious × hermaphrodite parent. Like P and Ca, the accumulation of K also expressed the cumulative effect of both additive and non-additive genes. On the other hand, significant desirable SCA estimates were also computed in all crosses involving hermaphrodite parental line(s) except one cross (Utkal Tripti × Satputia Small) for Na content. For S content, eight crosses of monoecious × hermaphrodite parent and hermaphrodite × hermaphrodite parent showed significantly positive SCA effects.

All the crosses between monoecious and hermaphrodite parents except DRG-2 × Satputia Small derived from one poor and one good general combiner parent exhibited significant SCA estimates in desirable direction for Fe accumulation in the fruits of ridge gourd.

Table 4: ANOVA for combining ability and estimates of variance components for mineral content and yield in ridge gourd

Source of variation	d.f.	Mean square								
		P	Ca	K	Na	S	Fe	Zn	Mn	Yield/ plant
GCA	6	225.3**	326.7**	478.8**	274.9**	871745**	93387**	389332**	19978**	1.267**
SCA	21	21.5**	32.6**	42.0**	51.7**	161166**	9402**	51424**	2318**	0.855**
Error	54	0.3	0.3	0.3	0.4	326	784	134	27	0.001
Variance components		Estimates of variance components								
		P	Ca	K	Na	S	Fe	Zn	Mn	Yield/ plant
σ^2gca		25.00	36.28	53.16	30.50	96824.31	10289.31	43244.24	2216.77	0.14
σ^2 sca		21.20	32.36	41.70	51.25	160840.52	8618.53	51290.89	2291.15	0.85
σ^2_A		50.00	72.55	106.33	61.00	193648.62	20578.62	86488.49	4433.53	0.28
σ^2_D		21.20	32.36	41.70	51.25	160840.52	8618.53	51290.89	2291.15	0.85
PR		0.70	0.69	0.72	0.54	0.55	0.70	0.63	0.66	0.25
ADD		0.42	0.45	0.39	0.84	0.83	0.42	0.59	0.52	3.04

**$P<0.01$;σ^2gca: Variance due to GCA,σ^2sca: Variance due to SCA,σ^2_A: Additive variance,σ^2_D: Non-additive variance, PR: Predictability ratio, ADD: Average degree of dominance

Table 5: Estimates of general combining ability (GCA effects) of parents for mineral content and yield in ridge gourd

Parents	P	Ca	K	Na	S	Fe	Zn	Mn	Yield/ plant
DRG-2	-1.91**	-2.14 **	-3.02 **	-3.34 **	30.52 **	-51.35 **	-80.79 **	-7.54 **	0.486 **
Pusa Nasdar	-2.87 **	-2.58 **	-5.43 **	-1.80 **	-163.37 **	-64.31 **	-48.87 **	-23.35 **	-0.007
Utkal Tripti	-4.14 **	-5.58 **	-4.71 **	-4.26 **	-314.48 **	-78.02 **	-161.79 **	-34.02 **	-0.388 **
Arka Sumeet	-3.69 **	-3.17 **	-2.01 **	-3.48 **	-232.81 **	-58.94 **	-141.57 **	-21.21 **	-0.219 **
HARG- 110	-1.75 **	-3.85 **	-5.71 **	-3.19 **	-173.07 **	-43.94 **	-160.02 **	-46.65 **	-0.476 **
Satputia Long	6.36 **	8.01 **	11.81 **	8.19 **	369.49 **	145.13 **	258.03 **	58.68 **	0.303 **
Satputia Small	8.01 **	9.31 **	9.07 **	7.84 **	483.71 **	151.43 **	335.02 **	74.09 **	0.302 **
SEm	0.17	0.16	0.17	0.20	5.57	8.46	3.57	1.61	0.008
CD (*P*<0.01)	0.80	0.75	0.80	0.95	26.72	41.44	17.11	7.71	0.040

**$P<0.01$

Table 6: Estimates of specific combining ability (SCA effects) of crosses for mineral content and yield in ridge gourd

Crosses	P	Ca	K	Na	S	Fe	Zn	Mn	Yield/ plant
P_1xP_2	-0.18	-0.16	-1.87**	-0.03	-78.86**	-16.90	69.44**	4.12	0.310**
P_1xP_3	-0.08	-2.37**	3.31**	-0.40	-17.75	-18.19	-30.31*	-4.88	-0.047
P_1xP_4	-3.33**	-1.98**	-0.59	-2.05*	-74.42**	-0.60	54.81**	33.31**	0.258**
P_1xP_5	1.00	0.50	-3.19**	-4.24**	-154.16**	27.73	-4.42	0.08	-0.195**
P_1xP_6	3.89**	4.15**	6.79**	4.37**	479.95**	111.99**	177.55**	29.75**	0.863**
P_1xP_7	4.84**	5.45**	5.13**	6.33**	670.73**	-4.31	185.55**	53.01**	1.000**
P_2xP_3	-1.42*	-0.83	-2.09**	-3.14**	26.14	-8.57	-46.23**	8.60	-0.279**
P_2xP_4	-2.20**	-0.74	-0.69	0.52	-25.53	-24.31	16.88	22.12**	-0.105**
P_2xP_5	0.87	-1.46*	-2.29**	-3.57**	-35.27	-27.64	-83.01**	-2.77	-0.240**
P_2xP_6	2.96**	5.29**	5.59**	4.74**	153.84**	86.62*	230.62**	21.23**	1.000**
P_2xP_7	4.41**	4.16**	6.94**	9.39**	299.62**	105.32**	289.29**	39.49**	1.111**
P_3xP_4	-1.50*	-0.94	-0.30	-0.66	60.58*	-43.94	-35.19*	5.12	-0.281**
P_3xP_5	0.63	-1.86**	-0.80	15.15**	20.84	-28.94	49.92**	3.57	-0.047
P_3xP_6	2.52**	5.69**	3.07**	6.66**	14.95	88.66*	140.88**	27.23**	0.867**
P_3xP_7	4.07**	6.79**	2.22**	-11.79**	-9.27	100.69**	156.88**	27.82**	0.673**
P_4xP_5	0.35	0.73	0.10	-1.39*	-40.82	-28.01	-48.64**	-19.58**	-0.320**
P_4xP_6	6.17**	6.07**	8.27**	4.12**	123.29**	86.25*	103.32**	24.42**	0.907**
P_4xP_7	5.22**	5.57**	5.62**	7.07**	229.07**	109.95**	175.66**	20.68**	0.973**
P_5xP_6	2.64**	4.79**	6.07**	2.13*	350.88**	87.92*	129.77**	28.86**	0.765**
P_5xP_7	3.49**	5.69**	4.52**	4.88**	329.66**	104.95**	172.10**	37.45**	0.687**
P_6xP_7	0.31	-2.20**	2.30**	3.69**	515.10**	-19.12	157.73**	60.12**	-1.260**
SEm	0.49	0.46	0.49	0.58	16.20	25.12	10.37	4.67	0.024
CD (*P*<0.01)	1.83	1.71	1.82	2.17	60.89	94.43	38.98	17.57	0.092

*$P<0.05$ and **$P<0.01$

Hence, heterosis breeding and recurrent selection could be adopted to make use of both additive as well as non-additive gene action using monoecious × hermaphrodite combinations. Moreover, significant positive SCA estimates for Zn and Mn content were calculated in 11 cross combinations having hermaphrodite inbred as one of the parents. Additionally, only few monoecious × monoecious hybrids exhibited significant desirable SCA effects mineral content utilizing poor × poor general combiner parents which might be due to the presence of high magnitude of non-additive especially complementary epistatic effects. Differential GCA and SCA effects for parents and crosses have also been reported in maize (Brkic *et al*. 2003) [1] and cabbage (Singh *et al*. 2012) [18] for various minerals contents.

Among 21 crosses, 12 cross combinations (ten “monoecious × hermaphrodite” crosses and two “monoecious × monoecious” crosses) which either involve poor × good general combiner parents or good × good general combiner parents were superior with respect to SCA effects for fruit yield. But the magnitude of SCA estimates was found considerably higher in "monoecious × hermaphrodite" crosses signifying the role of diverse parents in hybridization to realize maximum yield potential by harnessing both additive as well as non-additive gene action. The results are in accordance with the previous findings in ridge gourd (Tyagi *et al*. 2010) [21] where F_1 hybrids were developed by crossing two monoecious lines. Moreover, the "monoecious × hermaphrodite" F_1 hybrids produced stable monoecious sex form uniformly with female flowers at lower nodes, more number of medium sized fruits/ vine and normal fruit shape as like monoecious cultivars, which has ability to attract the consumers and paved the way for commercial exploitation of these hybrids. Considering the importance of productivity and mineral content in ridge gourd, the present findings demonstrate the potentiality of "monoecious × hermaphrodite" crosses for simultaneous improvement of mineral content and yield.

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