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Combining Ability Analysis in Pumpkin *(Cucurbita moschata* Duch. *ex* Poir.) for Small Size, Thick Flesh, High Yield and Beta Carotene Content

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ABSTRACT

Combining ability studies are more reliable as they provide useful information for the selection of parents in terms of performance of the hybrids and elucidate the nature and magnitude of various types of gene actions involved in the expression of quantitative traits. A line x tester mating design was used to study the combining ability for developing small size, thick flesh, high yield and beta carotene content varieties and hybrids in pumpkin according to consumer preferences. In India consumers prefer dark yellow color, round shaped fruit with thick and deep yellow internal flesh color which have high beta carotene and ascorbic acid content to alleviate the vitamin A deficiency problem. A study was undertaken using nine parents which include 6 lines and 3 testers during 2016-17 at Department of vegetable crops, Horticultural College & Research Institute, Tamil Nadu Agriculture University, Coimbatore to study the heterosis and combining ability for yield and its contributing characters. Evaluation of parents based on per se and general combining ability (gca) effects revealed that the parents CO_2*, Rajasthan Local and Odisha Local excelled for small size, thick flesh with high yield and beta carotene content respectively. The hybrids viz., Rajasthan Local and Pusa Viswas had registered favourable values of mean and significant sca for yield and other important characters. Further these top performing* F_1 *hybrid can be tested in different seasons over different locations for assessing their stability for high yield and other important characters.*

Key words: *Pumpkin, Vegetable, Fruit, Gene, crops*

INTRODUCTION

Pumpkin *(Cucurbita moschata* Duch. *ex* Poir.) originated from Central Mexico is cultivated in tropical and subtropical region all over the World. It is an important monoecious and cross pollinated cucurbitaceous vegetable crop and used as principal ingredient of several Indian dishes[7].

Pumpkin is consumed as culinary vegetables at immature and mature fruit stage.

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It provides a valuable source of carotenoid and ascorbic acids that have a major role in nutrition in the form of pro-vitamin A and vitamin C as antioxidants. Pumpkin seeds contain appreciable quantities of protein and oil. It may serve as good substitute for edible oil, similar to that of oil of summer squash (*Cucurbita pepo*). Therefore, pumpkin as vegetable is becoming important ingredient in daily diet but relatively less attention has been paid towards development of hybrids varieties rich in beta carotene with high yielding capacity.

Heterosis in cross pollinated crops has been known to offer good potentialities for improvement of yield. Combining ability studies help to assess the prepotency of parents in hybrids combinations and also a powerful tool in selection of superior parents and superior cross combinations. For identifying these superiority in parents and hybrids, estimation of General combining ability of parents and specific combining ability of cross combinations was important. Hence, the present study was undertaken to generate information for identification of good general and specific combiners for the improvement of desirable horticultural traits.

MATERIAL AND METHODS

The experimental material comprised of nine monoecious lines *viz.*, Punjab Samrat, Pusa Viswas, CO_2, Mysore Local, Ambili, Saras, Odisha Local, Rajasthan Local and CO1 of pumpkin. All these nine genotypes were crossed according to line x tester mating design which include six lines and three testers during summer 2016 to produce F_1 seeds by hand pollination.

In 2017 all the 18 cross combinations and 9 parents along with commercial check 'Arjuna' were sown in Randomized Block Design with 2 replications. Each replication consists of 10 plants following a spacing of 2.0 x 1.5 m. All the recommended cultural practices were adopted and plant protection measures were also used to obtain a successful crop of pumpkin. Five plants were selected and tagged for recording the observation on different characters *viz.,* vine length, days to first female flower appearance, node number for first female flower appearance, sex ratio, days to first harvest, fruit number per vine, fruit weight, fruit equatorial diameter, fruit polar diameter, seed number per fruit, seed weight per fruit, 100 seed weight and fruit yield per vine along with quality traits such as ascorbic acid content, β carotene content and crude fibre content of the fruit. The Line x Tester analysis was calculated by the method suggested by Kempthrone.

RESULT AND DISCUSSION

The Variance due to general combining ability (*gca*) of parents (line and tester) and specific combining ability (*sca*) of crosses were significant for all the traits under study. The ratio of V_g /V_s indicated greater role of non-additive gene action in the inheritance of all the traits. The traits ascorbic acid (0.33), fruit yield per vine (0.22), seed weight per fruit (0.25), sex ratio (0.19) and 100 seed weight (0.18) had more non-additive effects than other traits. The GCA and SCA variance for the traits studied have been presented in Table 3.

The *GCA* component is primarily a function of the additive genetic variance and play a significant role in choice of parents. A parent with higher positive significant *GCA* effects is considered as a good general combiner. The *SCA* effects signify the role of non-additive gene action in the expression of the characters. It indicates the highly specific combining ability leading to highest performance of some specific cross combinations. High *SCA* effects may not arise only in crosses involving good combiners but also in those involving poor combiners.

Maturity characters

Earliness is one of the major considerations of preferring hybrids over pure line varieties. The variance due to *sca* being more than *gca* indicated the pre-ponderance of non-additive gene action for days to first female flowering and node at which first female flower appear. The line Ambili (L_2) was good general combiner for days to first female flower appearance and node number at which first female flower appear, as it exhibited the significant *gca* estimates with negative value of -5.91 and -2.27 respectively. Other lines with significant *gca* values were Rajasthan Local (-2.74), Odisha Local (-0.51) and Saras (-0.11). The tester Punjab Samrat (-0.66, -0.70) was good general combiner for the two traits mentioned Table 1. Out of eighteen cross combinations, five combinations showed significant negative *sca* effects and five showed significant positive estimates. Highest negative *sca* estimate for days to first female flower appearance and for node number for first female flower appearance was observed in the cross of CO1 x Mysore Local (-6.38) and Odisha Local x Pusa Viswas (-6.13) respectively (Table 2). These crosses involved poor x poor, medium x good combining parents respectively. For sex ratio, highest negative *sca* estimate was observed for cross Ambili x Mysore Local (-1.94) followed by CO 1 x Mysore Local (-1.73) Table 2. Similar findings in Muskmelon were reported by Major S Dhaliwal in W321 x H 173 cross, Tamilselvi *et al*.[3], in pumpkin cross Kasi Harit x Avinashi Local.

Number of fruits per vine

Fruit number per vine is a direct contributor to yield and its heterosis contributes toward total yield. Preponderance of non-additive gene action was observed for number of fruits per vine, as the variance due to *sca* was found more than *gca*. These results are in agreement with those of Maurya and Singh[6]. The lines Ambili (1.16), Odisha Local (0.87) and Rajasthan Local (0.43) were good general combiners for number fruits per vine, as they exhibited highly significant positive *gca* values. Saras (-2.44) and CO1 (-2.12) were poor general combiner for this trait. Tester Pusa Viswas (0.87) was good general combiner for number of fruits per vine (Table 1). Among eighteen hybrids, eleven cross combinations exhibited significant positive *sca* effects for fruits number per vine. Highest positive *sca* effects for fruit number per vine was observed in the crosses of Saras x Pusa Viswas (1.73), CO 1 x Punjab Samrat (0.74), Rajasthan Local x CO 2 (0.64) and Odisha Local x Punjab Samrat (0.61) Table 2. Similar findings were reported by Dubey and Maurya[5] in bottle gourd cross (UL-1 x INGR -9909), Tamil selvi *et al*.[3], in pumpkin cross (Kashi Harit x Avinashi Local). Crosses involved poor x good, poor x good, good x good, good x poor general combiners respectively.

Fruit weight and fruit yield per plant

Consumer preference is for small to medium sized fruit. Hence hybrid development with small size is the main breeding objective now a days. The line CO1 (-0.51), Saras (-0.27) and Mysore Local (-0.12) were good general combiner for small fruit as they exhibited the significant *gca* estimates with highest negative values. The tester Punjab Samrat (-017) was good general combiner for less fruit weight. Among eighteen cross combinations cross Ambili x Pusa Viswas (-0.81), Saras x CO 2 (-0.48) and Mysore Local x Punjab Samrat (-0.37) had highest negative *sca* estimate for less fruit weight Table 2. These crosses involved good x poor, good x poor and good x good combining parents respectively. Similar results are in close conformity with the findings of Tamilselvi *et al*.[3], in pumpkin.

High yield per vine is the main ultimate aim of any breeding programme since it play main role in adoption or rejection of a variety or hybrid by the farmers. Combining ability estimates revealed that non-additive gene action is main role in genetic control for fruit yield per vine. The best general combiners were Odisha Local (3.08) Rajasthan Local (2.73) and Ambili (1.64) since these lines had significant positive *gca* effect for fruit yield per vine. The tester Pusa Viswas (2.81) had higher *gca* effect for the trait and hence was good general combiner Table 1. Among eighteen cross combination eleven hybrids recorded significant positive *sca* effect for fruit yield per vine. Crosses Rajasthan Local x Pusa Viswas (2.67), CO2 x Punjab Samrat (1.97) and Odisha Local x Punjab Samrat (1.73) had highest positive *sca* effect Table 2. Similar results were found by choudhary *et al*.[4], in muskmelon crosses MS1 x Punjab Sunheri and MS I x Hara Madhu.

Flesh thickness

In pumpkin, flesh thickness is an important parameter. The best general combiners for flesh thickness were Odisha Local (0.87) and Rajasthan Local (0.43) since these lines had significant positive *gca* effect for flesh thickness. The tester Pusa Viswas (0.08) and CO 2 (0.02) are good and moderate combiners respectively for this trait Table 1. Among eighteen crosses, nine hybrids recorded significant positive *sca* effects for flesh thickness. Crosses Saras x Pusa Viswas (1.02), Mysore Local x CO 2 (0.65) and Rajasthan Local x CO 2 (0.62) had highest positive *sca* effects Table 2. This is in agreement with the findings of Nisha in pumpkin.

Ascorbic acid

The best general combiners for ascorbic acid content were Rajasthan Local (1.09) and Odisha Local (0.95) since these lines had significant positive *gca* effect for ascorbic acid. The tester Pusa Viswas (1.15) was good combiner for this trait Table 1. Among eighteen hybrids, eight hybrid showed positive and significant *sca* effects for ascorbic acid content. Highest significant positive *sca* effect was observed in Rajasthan Local x CO 2 (1.47), Ambili x Punjab Samrat (0.76) and Odisha Local x Pusa Viswas (0.56) Table 2. Crosses involve good x poor, poor x poor and good x good general combiners respectively.

β carotene

β carotene content is one of the most important quality parameters in the processing industry. The variance due to *sca* was higher than the variance due to *gca* indicating the greater role of non-additive genetic variance. The lines Saras (17.22) and Mysore Local (9.51) was the good general combiners for β carotene since these lines had positive significant highest *gca* effect for the trait. The tester Pusa Viswas (8.42) was good combiner for β carotene Table 1. Among eighteen crosses, nine hybrids showed positive *sca* effect was observed in Saras x Pusa Viswas (43.39), Mysore Local x Punjab Samrat (12.80) and CO 1 x Punjab Samrat (9.68) Table 2. These crosses involved good x good, good x poor and poor x poor general combiners respectively. Similar findings were found in pumpkin by Tamilselvi *et al*.(2015), Hazara *et al.*[1], and Moon *et al*.[2], in muskmelon.

Table 1. General combining ability effects of pumpkin parents

Parents	Vine length (m)	Days to first female flower appearance	Node number for first female flower appearence	Sex ratio	Days to first harvest	No. of fruit per vine	Fruit weight (kg)	Fruit equ. Diameter (cm)	Fruit polar diameter (cm)	Flesh thickness (cm)	No. of seed/ fruit	Seed wt./ fruit (g)	100 seed wt. (g)	Ascorbic acid content (mg/100g)	Crude fiber (%)	β carotene (µg/g)	Fruit yield/vine (kg)
L_1	-0.09 **	1.19 **	0.07 ns	-0.84 **	7.93 **	0.10 **	-0.12 **	-0.82 **	2.06 **	-0.27 **	-42.61 **	5.51 **	4.70 **	-0.88 **	-0.06 **	9.51 **	0.10 *
L_2	0.39 **	-5.91 **	-2.27 **	-2.59 **	-0.94 ns	1.16 **	-0.10 **	0.48 **	-2.47 **	-0.37 **	-1.61 ns	-5.35 **	-2.35 **	-0.17 **	-0.06 **	-1.25 **	1.64 **
L_3	-0.51 **	-0.11 ns	2.24 **	2.65 **	-2.80 **	-0.44 **	-0.27 **	-1.78 **	0.56 **	-0.10 **	-9.28 **	-0.95 **	-0.31 **	1.09 **	0.14 **	17.22 **	-2.10 **
L_4	0.67 **	-0.51 ns	0.81 **	-3.43 **	-6.81 **	0.87 **	0.46 **	1.65 **	0.39 **	0.87 **	61.39 **	4.91 **	-0.50 **	0.95 **	0.42 **	-16.38 **	3.08 **
L_5	0.00 ns	-2.74 **	1.41 **	-1.37 **	-7.60 **	0.43 **	0.54 **	2.08 **	1.83 **	0.43 **	42.05 **	1.11 **	-1.27 **	1.78 **	-0.14 **	-2.56 **	2.73 **
L_6	-0.46 **	8.06 **	-2.26 **	5.57 **	10.22 **	-2.12 **	-0.51 **	-1.62 **	-2.37 **	-0.57 **	-49.95 **	-5.23 **	-0.28 **	-2.78 **	-0.31 **	-6.55 **	-5.44 **
SEd	0.020	0.293	0.061	0.970	0.495	0.023	0.011	0.075	0.077	0.014	1.251	0.137	0.035	0.032	0.007	0.198	0.043
T_1	0.07 **	-0.66 **	-0.70 **	1.19 **	-3.73 **	-0.59 **	-0.17 **	-0.85 **	-0.57 **	-0.10 **	43.06 **	-0.45 **	-1.58 **	-0.45 **	-0.07 **	-2.56 **	-1.95 **
T_2	-0.06 **	-0.16 ns	1.16 **	-1.25 **	-3.66 **	0.87 **	0.14 **	0.18 **	1.39 **	0.08 **	-35.11 **	-2.55 **	-0.30 **	1.15 **	0.16 **	8.42 **	2.81 **
T_3	-0.01 ns	0.81 **	-0.46 **	0.06 ns	7.40 **	-0.28 **	0.02 **	0.67 **	-0.82 **	0.02 ns	-7.95 **	3.01 **	1.88 **	-0.70 **	-0.10 **	-5.86 **	-0.86 **
SEd	0.014	0.207	0.043	0.069	0.350	0.016	0.008	0.053	0.055	0.010	0.884	0.097	0.025	0.023	0.005	0.140	0.030

Significant at 5 per cent level** * Significant at 1 per cent level**

Mysore Local (L_1),Ambili (L_2), Saras (L_3),Odisha Local (L_4), Rajasthan Local (L_5), CO1 (L_6), Punjab Samrat (T_1), Pusa Viswas (T_2), CO2 (T_3)

Table 2. Specific combining ability effects of hybrids for different traits in pumpkin

Hybrids	Vine length (m)	to first female flower appear	r for first female flower	Sex ratio	Days to first harvest	No. of fruit per vine	Fruit weight (kg)	Fruit equ. Diameter (cm)	Fruit polar diameter (cm)	Flesh thickness (cm)	No. of seed/ fruit	Seed wt./ fruit (g)	100 seed wt. (g)	ic acid content (mg/10	Crude fiber (%)	β carotene (µg/g)	Fruit yield/vine (kg)
L_1 x T_1	0.49 **	-1.01 NS	-1.73 **	0.38 *	-8.88 **	0.36 **	-0.37 **	-0.02 NS	2.74 **	-0.13 **	-43.05 **	0.52 *	0.82 **	0.50 **	0.02 ns	12.80 **	0.63 **
L_1 x T_2	-0.43 **	0.79 NS	4.20 **	-0.33 NS	-1.08 NS	-0.51 **	-0.17 **	0.15 NS	-4.23 **	-0.52 **	105.11 **	4.92 **	-2.89 **	-0.12 *	-0.15 **	-13.04 **	-0.26 **
L_1 x T_3	-0.06 NS	0.22 NS	-2.47 **	-0.05 NS	9.96 **	0.15 **	0.54 **	-0.13 NS	1.49 **	0.65 **	-62.06 **	-5.44 **	2.07 **	-0.38 **	0.13 **	0.24 NS	-0.37 **
L_2 x T_1	0.42 **	6.69 **	0.96 **	-1.94 **	8.36 **	0.39 **	0.10 **	-0.82 **	-0.23 NS	0.17 **	15.95 **	-0.31 NS	-0.10 NS	0.76 **	-0.10 **	-4.32 **	-2.30 **
L_2 x T_2	-0.09 *	-3.31 **	-1.13 **	1.15 **	-2.21 *	0.43 **	-0.81 **	-2.85 **	-1.19 **	-0.42 **	-52.89 **	-1.51 **	1.13 **	-0.79 **	0.10 **	0.32 NS	1.14 **
L_2 x T_3	-0.33 **	-3.38 **	0.17 NS	0.79 **	-6.16 **	-0.82 **	0.71 **	3.67 **	1.42 **	0.25 **	36.94 **	1.82 **	-1.03 **	0.03 ns	0.00 ns	4.00 **	1.16 **
L_3 x T_1	-0.39 **	0.79 NS	1.10 **	2.51 **	6.12 **	-1.21 **	0.53 **	-0.85 **	-0.26 NS	0.50 **	25.61 **	-0.11 NS	-0.70 **	0.41 **	0.04 **	-21.07 **	0.99 **
L_3 x T_2	0.37 **	0.59 NS	-1.86 **	-3.71 **	0.35 NS	1.73 **	-0.04 *	1.42 **	-0.23 NS	1.02 **	-20.22 **	-2.91 **	-0.31 **	-0.07 NS	0.05 **	43.39 **	0.95 **
L_3 x T_3	0.03 NS	-1.38 *	0.76 **	1.20 **	-6.47 **	-0.52 **	-0.48 **	-0.57 **	0.49 **	-1.52 **	-5.39 *	3.02 **	1.01 **	-0.34 **	-0.09 **	-22.32 **	-1.94 **
L_4 x T_1	0.12 **	2.29 **	1.83 **	-1.09 **	-1.37 NS	0.61 **	0.00 NS	0.82 **	-0.09 NS	-0.57 **	-29.06 **	0.12 NS	1.04 **	-0.35 **	-0.21 **	0.91 *	1.73 **
L_4 x T_2	-0.39 **	-3.21 **	-6.13 **	1.91 **	2.37 *	-0.98 **	0.28 **	1.08 **	1.94 **	0.35 **	-20.89 **	0.22 NS	1.17 **	0.56 **	0.18 **	-8.02 **	-2.04 **
L_4 x T_3	0.27 **	0.92 NS	4.29 **	-0.82 **	-1.00 NS	0.37 **	-0.28 **	-1.90 **	-1.84 **	0.22 **	49.94 **	-0.34 NS	-2.21 **	-0.20 **	0.03 *	7.11 **	0.31 **
L_5 x T_1	-0.24 **	-2.38 **	-1.06 **	1.88 **	-1.06 NS	-0.90 **	-0.34 **	0.58 **	-1.03 **	-0.43 **	-11.72 **	0.22 NS	0.72 **	-1.59 **	-0.04 **	2.00 **	-2.99 **
L_5 x T_2	0.19 **	1.62 **	-0.23 *	-0.29 NS	0.06 NS	0.26 **	0.69 **	-0.45 **	2.81 **	-0.22 **	18.44 **	0.02 NS	-0.19 **	0.12 *	-0.19 **	-10.16 **	2.67 **
L_5 x T_3	0.04 NS	0.76 NS	1.29 **	-1.59 **	1.00 NS	0.64 **	-0.36 **	-0.13 NS	-1.78 **	0.65 **	-6.72 **	-0.24 NS	-0.53 **	1.47 **	0.23 **	8.16 **	0.31 **
L_6 x T_1	-0.41 **	-6.38 **	-1.10 **	-1.73 **	-3.18 **	0.74 **	0.08 **	0.28 *	-1.13 **	0.47 **	42.28 **	-0.44 NS	-1.78 **	0.28 **	0.30 **	9.68 **	1.94 **
L_6 x T_2	0.35 **	3.52 **	5.14 **	1.26 **	0.51 NS	-0.93 **	0.05 *	0.65 **	0.91 **	-0.22 **	-29.56 **	-0.74 **	1.08 **	0.30 **	0.00 NS	-12.49 **	-2.46 **
L_6 x T_3	0.06 NS	2.86 **	-4.04 **	0.47 *	2.67 **	0.19 **	-0.12 **	-0.93 **	0.22 NS	-0.25 **	-12.72 **	1.18 **	0.70 **	-0.58 **	-0.30 **	2.81 **	0.53 **
SEd	0.0351	0.5076	0.1057	0.168	0.8574	0.0398	0.0192	0.1294	0.1335	0.024	2.1664	0.2368	0.0609	0.0561	0.0119	0.3433	0.0743

Significant at 5 per cent level** * Significant at 1 per cent level**

Mysore Local (L_1),Ambili (L_2), Saras (L_3),Odisha Local (L_4), Rajasthan Local (L_5), CO1 (L_6), Punjab Samrat (T_1), Pusa Viswas (T_2), CO2 (T_3)

Table 3. Magnitude of genetic variance for yield components

Characters	*gca* variance	*sca* variance	Ratio *gca: sca*
Vine length	0.0113	0.1631	0.069283
Days to first female flower appearance	1.1805	15.5593	0.075871
Node number for first female flower appearance	-0.1708	14.0301	-0.01217
Sex ratio	0.8707	4.3613	0.199642
Days to first harvest	5.5757	39.2096	0.142202
No. of fruit per vine	0.1109	1.031	0.107565
Fruit weight	0.0038	0.3038	0.012508
Fruit equ. Diameter	0.1353	3.2542	0.041577
Fruit polar diameter	0.2121	5.2674	0.040267
Flesh thickness	0.0016	0.6024	0.002656
No. of seed / fruit	148.8819	2933.648	0.05075
Seed wt./ fruit	1.9936	7.9314	0.251355
100 seed wt.	0.5538	3.0206	0.183341
Ascorbic acid content	0.2544	0.7571	0.336019
Crude fiber	0.0049	0.0414	0.118357
β carotene	0.9054	373.9491	0.002421
Fruit yield/vine	1.0687	4.7681	0.224135

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