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Combining Ability Analysis of Yield and Quality Traits in Pumpkin [*Cucurbita moschataduch*. Ex Poir]

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present analysis was carried out with aims to estimate the general and specific combining ability of pumpkin involving six parents namely, Arka Chandan (P1), Ambili (P2), Arka Suryamukhi(P3), Pusa Vishwas (P4), CO 2 (P5) and CO 1 (P6) and 30 F1 hybrids obtained through full diallel analysis in randomized block design with three replication. The observation were recorded for eighteen traits viz., vine length, node number at which first male flower anthesis, node number at which first female flower anthesis, number of primary branches vine-1, days to first male flower anthesis, days to first female flower anthesis, number of male flowers vine-1, number of female flowers vine-1, sex ratio, number of fruits vine-1, fruit weight, polar diameter of fruit, equatorial diameter of fruit, flesh thickness, 100 seed weight, carotene content, total soluble solids and yield vine-1.. The analysis of variance for combining ability among various traits in pumpkin revealed that there were significant differences for all the traits. Among the parents, Ambili was the

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best general combiner for number of fruits vine-1, yield vine-1 and yield contributing traits. The highest desirable SCA were obtained from a cross of Ambili x Arka Suryamukhi for yield and attributing traits, which was the best and promising hybrid.

Keywords: Pumpkin; crop improvement; diallel; GCA, SCA.

1. INTRODUCTION

Pumpkin is an economically important monoecious vegetable and belongs to the family cucurbitaceous which is one of the largest families of vegetable crops having diploid chromosome number of 2n=40. Originated in Central Mexico, it is cultivated in the tropical and subtropical regions of the world and its occupies the prominent position among the cultivated cucurbitaceous vegetables because of its higher yield, nutritive value, good storability, long period of availability, amenable to hot climate and better transport qualities. Pumpkin is extensively used as vegetables both in mature and immature stage and plays an important role against Vitamin A deficiency because of its high carotene content which is the precursor of Vitamin A. In India pumpkin is commonly known as 'Sitaphal', 'Kashiphal' or 'kaddu'. In India, pumpkin is cultivated in an area of 74,000 hectares with a production of 17,14,000 metric tonnes [1]. In Tamil Nadu, pumpkin is cultivated in an area of 1,154 hectares with a production of 29,866 metric tonnes. Being the cross pollinated crop, pumpkin exhibits considerable variation for most economic traits. Attempts to enlarge the production base of pumpkin by developing high yielding varieties/hybrids with a small or medium sized fruits with high carotene is very scarce. Therefore efforts are to be made to develop high yielding varieties or hybrids with high carotene content through hybridization. Combining ability analysis helps in the evaluation of inbreds in terms of genetic value and in the selection of suitable parent for hybridization. The superior specific cross combinations are also identified by this technique. Hence, the present investigation was carried out with new set of parent combinations to identify better parent and efficient hybrids of pumpkin for high yield and good quality through combining ability analysis.

2. MATERIALS AND METHODS

The experiment was carried out with six diverse genotypes *viz.*, Arka Chandan (P_1), Ambili (P_2), Arka Suryamukhi (P_3), Pusa Vishwas (P_4), CO 2 (P_5) and CO 1 (P_6) were crossed in diallel mating design including reciprocals during July, 2020 and the resultant 30 F_1 hybrids along with six parents were evaluated in randomized block design with two replications. The experiment was conducted in the horticultural farm in the Western block of Pandit Jawaharlal Nehru of Agriculture and Research Institute, Karaikal. Using diallel cross (Griffing, 1956), six parental lines were crossed in all possible combinations including reciprocals to produce F_1 seeds by hand pollination.

During summer, 2021 all the seeds were sown in polybags and transplanted to the field with a spacing of 2 m x 2 m. The plants were fertilized with 100 g of 6:12:12 (NPK) mixture per pit after 30 days of sowing. The field was irrigated once in a week. The fruits were allowed to mature in the field and harvested periodically.

The biometrical observations were recorded on five randomly selected vines for eighteen characters *viz*., vine length (m), node of first male flower anthesis, node of first female flower anthesis, number of primary branches vine^{-1}, days to first male flower anthesis, days to first female flower anthesis, number of male flowers vine^{-1}, number of female flowers vine^{-1}, sex ratio, number of fruits vine^{-1}, fruit weight (kg), polar diameter of fruit (cm), equatorial diameter of fruit (cm), flesh thickness (cm), 100 seed weight, carotene content (mg 100g^{-1}), total soluble solids (^{0}brix) and yield vine^{-1}(kg). The estimation of general and specific combining ability was worked out according to Griffing [2], method 1 Model of diallel analysis which included parents, F1 and reciprocals.

3. RESULTS AND DISCUSSION

The analysis of variance for combining ability of the six parents and their 30 hybrids showed significant GCA and SCA variance for all the characters studied (Table 1).

Therefore, in general all the characters were influenced by both additive and non-additive gene action. These results agreed with those of Singh et al. [3], Hussien and Hamed [4], Mohsin et al. (2017) in pumpkin, Bhatt et al. [5] in bitter gourd, Tak et al. [6] in Cucumber and Snapmelon and also confirmed the present findings.

In the present study higher GCA:SCA ratio in respect of direct crosses was found for almost all the traits except days to first male flower anthesis, number of fruits vine^{-1} and total soluble solids indicating the predominance of additive gene action. The lower ratio of these three characters *viz.,* days to first male flower anthesis, number of fruits vine^{-1} and total soluble solids suggests the predominance of non-additive gene action. Similar findings in different crops were obtained by Bhatt *et al.* [5] in bitter gourd, Shashikumar and Pitchaimuthu [7] and Hassan *et al.* [8] in muskmelon.

The general combining ability is the average performance of a strain or genotypes in series of hybrid combinations. It is estimated from half-sib families. Dhillon [9] suggested that combining ability provides useful information on the choice of parents in terms of expected performance of the hybrids and their progenies.GCA reveals the preponderance of additive gene effects. The parent Pusa Vishwas exhibited positive and significant *gca* effects for vine length (0.38), fruit weight (0.36) and polar diameter of fruit (1.66). Ambili recorded positive and significant *gca* effects for number of fruits vine^{-1}(0.17) and yield vine^{-1}(0.65), while the CO 1 for number of primary branches vine^{-1} (0.35), 100 seed weight (1.70) and carotene content (0.35). The parent Arka Suryamukhi recorded positive and negative significant value for number of female flowers vine^{-1}(2.24) and sex ratio (-2.53). In terms of earliness, Arka Chandan and CO2 recorded negative and significant *gca* effects for node of first female flower anthesis (-0.99) and days to first female flower anthesis (-2.04) (Table 2). These types of similar results with different set of parents were reported by Lawande and Patil [10] and Marxmathi et al. [11].

From the above discussion, it can be easily comprehended that the parents Ambili, Pusa Vishwas and CO 1 were superior for most of the yield and yield contributing characters. Therefore, these three parents were designated as good general combiners and hence they could be used in future breeding programme, whereas in terms of earliness (node of first female flower anthesis and days to first female flower anthesis) and flesh thickness, the parent Arka Chandan recorded a significant value. Hence, this parent would be useful in breeding programme for earliness.

Table1. Analysis of variance for combining ability among various traits in pumpkin

S. No	Characters	Mean squares			
		GCA	**SCA**	**RCA**	**GCA/SCA**
1.	Vine length	0.88**	0.51**	0.14**	1.72
2.	Node of first male flower anthesis	1.43**	0.81**	0.88**	1.75
3.	Node of first female flower anthesis	6.71**	3.17**	4.3**	2.11
4.	Number of primary branches vine^{-1}	0.44**	0.21**	0.11**	2.01
5.	Days to first male flower anthesis	2.71**	3.94**	1.07**	0.68
6.	Days to first female flower anthesis	17.98**	9.95**	7.47**	1.80
7.	Number of male flowers plant^{-1}	407.95**	44.65**	98.76**	9.13
8.	Number of female flowers plant^{-1}	18.31**	1.64**	7.89**	11.10
9.	Sex ratio	22.16**	3.06**	17.06**	7.22
10.	Number of fruits plant^{-1}	0.15**	0.17**	0.14**	0.90
11.	Fruit weight	1.87**	0.191**	1.17**	9.83
12.	Polar diameter of fruit	30.80**	5.12**	9.91**	6.01
13.	Equatorial diameter of fruit	42.77**	8.62**	13.48**	4.95
14.	Flesh thickness	1.90**	0.85**	1.10**	2.22
15.	100 seed weight	23.25**	11.62**	3.75**	2.00
16.	Yield plant^{-1}	3.45**	0.81**	3.80**	4.23
17.	Carotene content	0.46**	0.10**	0.22**	4.55
18.	Total soluble solids	4.90**	7.35**	1.26**	0.66

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

Table 2. Estimates of *gca* values of parents for growth and yield traits of pumpkin

Parents	Vine length	Node of first male flower anthesis	Node of first female flower anthesis	Number of primary branches vine^{-1}	Days to first male flower anthesis	Days to first female flower anthesis	Number of male flowers vine^{-1}	Number of female flowers vine^{-1}	Sex ratio
P_1	-0.16**	0.15**	-0.99**	-0.03	-0.49*	-2.04**	-1.50**	-1.30**	1.22**
P_2	0.24**	0.37**	0.77**	-0.02	0.31	-0.07	0.15	0.45**	1.03**
P_3	-0.34**	-0.55**	-0.36	-0.16**	-0.48*	1.36**	11.52**	2.24**	-2.53**
P_4	0.38**	-0.28**	0.29	-0.18**	-0.15	0.03	-3.62**	-0.59**	-0.02
P_5	0.04**	0.24**	-0.55*	0.04	0.21	-0.43	-3.73**	-0.53**	-0.18
P_6	-0.16**	0.07	0.84**	0.35**	0.60*	1.14**	-2.82**	-0.28**	0.49**
SE	9.28	5.30	0.25	4.56	0.23	0.35	0.29	7.72	0.16

Cont…

Parents	Number of fruits vine^{-1}	Fruit weight	Polar diameter of fruit	Equatorial diameter of fruit	Flesh thickness	100 seed weight	Yield vine^{-1}	Carotene content	Total soluble solids
P_1	-0.00	0.03	0.73**	0.35**	0.56**	-1.34**	0.07	0.07**	0.64**
P_2	0.17**	0.33**	0.10	1.08**	-0.07**	0.32**	0.65**	-0.20**	0.19**
P_3	0.09	-0.70**	-2.95**	-3.80**	-0.45**	-1.89**	-0.89**	-0.14**	-1.20**
P_4	-0.14*	0.36**	1.66**	0.55**	0.30**	0.06**	0.26	-0.00	-0.09**
P_5	-0.07	-0.16**	-0.36**	1.15**	-0.42**	1.14**	-0.32*	-0.08**	0.09**
P_6	-0.04	0.15**	0.82**	0.67**	0.08**	1.70**	0.23	0.35**	0.37**
SE	5.76	0.04	5.75	2.92	3.71	6.87	0.14	1.02	7.97

Table 3. Estimates of *sca* values of hybrids for growth and yield traits of pumpkin

Hybrids	Vine length	Node of first male flower anthesis	Node of first female flower anthesis	Number of primary branches vine^{-1}	Days to first male flower anthesis	Days to first female flower anthesis	Number of male flowers vine^{-1}	Number of female flowers vine^{-1}	Sex ratio	Number of fruits vine^{-1}	Fruit weight	Polar diameter of fruit	Equatorial diameter of fruit	Flesh thickness	100 seed weight	Yield vine^{-1}	Carotene content	Total soluble solids
P_1 xP_2	-0.09**	-0.59**	0.50	0.38**	0.84	0.06	3.24**	0.06	1.51**	-0.21	0.06	-0.60**	2.08**	-0.22**	1.87**	-0.13	0.07**	-0.88**
P_1x P_3	-0.15**	-0.37**	-0.68	-0.07	-1.01	0.48	-3.08**	-0.73**	0.19	0.67**	0.13	0.35*	0.29**	0.56**	2.83**	0.58	0.03**	0.88**
P_1 xP_4	0.04	0.45**	-1.28*	-0.25*	-0.29	-2.59**	0.11	-0.09	-0.39	-0.15	0.25*	-0.34*	2.60**	-0.34**	1.78**	0.01	-0.15**	0.35**
P_1 xP_5	-0.14**	0.93**	-0.28	0.33**	-0.25	-2.68**	-5.63**	0.25	-2.21**	-0.07	0.21	-0.63**	2.49**	-0.17**	-0.11**	0.08	-0.30**	2.72**
P_1 xP_6	0.01	1.06**	-1.03	-0.43**	0.36	-1.05	0.81	-0.40*	-0.23	-0.25	-0.22	-1.34**	-1.70**	-0.43**	-1.32**	-0.73*	0.03**	-0.39**
P_2 xP_3	-0.48**	0.36**	-1.13	-0.44**	-1.16*	-1.79*	0.12	2.02**	0.44	0.34*	0.56**	1.16**	0.58**	0.08**	-0.96**	1.65**	0.10**	0.98**
P_2 xP_4	0.28**	0.33**	0.97	0.23*	-0.14	-0.31	-4.09**	0.21	-0.81*	0.13	-0.27*	-0.62**	0.34**	0.15**	-2.08**	-0.64	0.07**	0.49**
P_2 xP_5	0.18**	-0.43**	1.11	-0.19	0.40	0.00	-5.33**	-0.05	-0.27	0.00	-0.19	-0.85**	-0.32**	1.27**	-0.38**	-0.26	-0.31**	-2.78**
P_2 xP_6	0.04*	-0.76**	0.82	-0.40**	-0.49	2.49**	3.21**	-0.65**	1.87**	-0.12	0.27*	0.68**	-0.62**	0.05**	-0.16**	-0.36	-0.06**	0.20**
P_3 x P_4	-0.85**	0.05	2.04**	-0.02	-0.90	0.81	3.04**	-0.24	0.80*	-0.19	-0.28*	-0.93**	-2.07**	-0.50**	2.44**	-0.68*	0.06**	0.68**
P_3 xP_5	-0.29**	-0.52**	0.78	0.00	-0.91	2.12*	-0.51	-0.64**	0.91*	-0.26	-0.10	-0.06	1.83**	0.49**	-2.51**	-0.52	-0.06**	-1.66**
P_3 xP_6	-0.36**	0.06	-1.21*	0.54**	0.85	-3.00**	-5.66**	-0.64**	-1.47**	-0.29*	-0.14	-1.09**	-1.20**	-0.65**	1.50**	-0.28	-0.03**	0.04*
P_4 xP_5	0.22**	0.06	-0.32	0.08	0.32	-1.75*	1.84*	-0.36*	-0.36	0.07	-0.02	-0.42**	-1.00**	-0.17**	1.32**	0.35	-0.01**	-1.73**
P_4 xP_6	0.32**	-0.27*	0.19	-0.28*	1.03	-0.41	-7.07**	1.19**	-0.43	0.34*	-0.20	-2.25**	-0.64**	0.03**	-3.96**	0.56	-0.40**	-0.34**
P_5 x P_6	0.12**	0.22	0.53	-0.01	-0.63	-0.26	0.24	1.43**	0.07	0.42**	-0.27	3.23**	-0.40**	-0.47**	3.45**	0.32	0.41**	4.18**
SE	2.11	0.12	.58	0.10	0.52	0.80	0.68	0.17	0.38	0.13	0.11	0.13	6.66	8.46	1.56	0.33	2.32	1.81

** Significant at 5 per cent level; ** Significant at 1 per cent* levelP_1 - Arka Chandan, P_2 - Ambili, P_3 - Arka Suryamukhi, P_4 - Pusa Vishwas, P_5 - CO 2, P_6 - CO 1

Table 4. Estimates of *rca* values of hybrids for growth and yield traits of pumpkin

Hybrids	Vine length	Node of first male flower anthesis	Node of first female flower anthesis	Number of primary branches vine^{-1}	Days to first male flower anthesis	Days to first female flower anthesis	Number of male flowers vine $^{-1}$	Number of female flowers vine $^{-1}$	Sex ratio	Number of fruits vine^{-1}	Fruit weight	Polar diameter of fruit	Equatorial diameter of fruit	Flesh thickness	100 seed weight	Yield vine^{-1}	Carotene content	Total soluble solids
P_2 xP_1	0.39**	0.60**	0.70	0.15	1.00	1.95*	-1.75*	1.50**	-0.40	0.05	-0.39**	0.52**	-2.44**	-0.85**	-0.54**	-0.69	-0.12**	0.56**
P_3 x P_1	-0.22**	-0.40**	-0.40	0.05	-2.35**	0.90	7.00**	2.20**	-3.45**	0.55**	-0.98**	-2.64**	-2.18**	1.39**	-0.68**	-1.56**	0.20**	-0.25**
P_3 xP_2	-0.37**	-1.35**	-1.40	-0.50**	-1.10	-0.60	5.55**	0.50*	-6.11**	-0.40*	-1.86**	-3.75**	-5.15**	-0.86**	-0.87**	-3.95**	0.25**	0.76**
P_4 xP_1	0.27**	0.40**	-2.65**	-0.25*	-0.20	-2.00*	-2.85**	-0.30	1.03*	0.00	0.29*	1.50**	-0.49**	-0.10**	-1.13**	0.40	-0.03**	-0.48**
P_4 xP_2	0.13**	-1.10**	0.65	0.15	-0.05	1.55	-7.50**	-1.65**	-1.99**	-0.35*	-0.23	-0.37*	-0.15	-0.32**	2.61**	-0.14	0.16**	-0.42**
P_4 x P_3	-0.27**	0.20	-0.90	0.25*	0.40	-1.80	-8.50**	-3.40**	4.54**	-0.15	1.08**	2.75**	3.19**	-0.72**	0.69**	1.43**	0.02**	-1.01**
P_5 xP_1	-0.08**	-0.50**	1.70*	-0.25*	0.70	3.05**	-2.80**	0.10	-0.72	0.25	-0.53**	-1.84**	-2.18**	-1.44**	0.74**	-0.12	-0.02**	0.62**
P_5 xP_2	-0.04	-0.95**	-0.15	-0.15	1.75**	0.50	-10.15**	-1.25**	-3.80**	-0.10	-0.33*	0.13	-0.69**	1.06**	-0.81**	0.27	0.05**	-0.13**
P_5 xP_3	0.60**	0.85**	0.10	0.40**	0.45	-1.25	-9.15**	-3.25**	4.25**	0.05	0.96**	2.00**	6.23**	0.01	0.10**	1.43**	-0.28**	0.26**
P_5 x P_4	-0.03	0.40**	-2.15**	-0.25*	-1.60*	-1.95*	5.75**	0.00	1.10*	0.15	-0.15	-1.58**	0.01	-0.07**	3.24**	0.06	0.24**	0.85**
P_6 xP_1	0.01	-0.25	1.75*	0.20	0.40	0.85	-4.65**	0.00	-1.02*	0.10	0.27	0.35*	0.30**	0.53**	1.18**	0.52	0.48**	1.05**
P_6 xP_2	-0.23**	-0.55**	-1.35	-0.15	-0.05	-4.15**	-6.40**	-1.70**	-1.79**	0.10	-0.24	-1.05**	-1.39**	-0.36**	-1.57**	0.32	0.45**	1.69**
P_6 xP_3	0.35**	0.45**	-2.70**	-0.15	0.10	-2.40*	-11.50**	-2.90**	2.72**	-0.25	1.17**	1.61**	1.94**	-0.25**	1.51**	1.92**	0.07**	1.38**
P_6 xP_4	-0.25**	-0.20	0.55	0.20	-0.00	0.85	-2.75**	2.60**	-0.78	0.35*	0.34*	1.52**	-1.03**	-0.17**	-0.48**	1.18**	0.40**	0.17**
P_6 xP_5	-0.09**	-0.50**	1.25	0.20	-0.40	1.45	-9.55**	2.70**	-2.55**	0.40*	-0.03	5.21**	1.59**	0.76**	-0.03	0.48	0.91**	0.08**
SE	2.49	0.14	0.69	0.12	0.62	0.94	0.80	0.20	0.44	0.15	0.13	0.15	7.84	9.95	1.84	0.38	2.73	2.14

The specific combining ability is the performance of a specific cross combination expressed as deviation from the population mean. According to Sprague and Tatum [12], the specific combining ability is controlled by non-additive gene action. The estimates of *sca* effects of 30 crosses revealed that the cross CO 2 x Arka Suryamukhi had exhibited high *sca* effect for vine length had parents of positive x negative *gca* effects. The cross combinations, Arka Suryamukhi x CO 1 had maximum significant *sca* effect for number of number of primary branches vine^{-1}(Table 3).

As far as earliness is concerned, the hybrid Arka Suryamukhi x Ambili for node of first male flower anthesis and the hybrid CO 1 x Arka Suryamukhi for node of first female flower anthesis, recorded negative and significant *sca* effects. Tamilselvi et al. [13] and Acharya et al. [14] recorded similar results in pumpkin and bottle gourd. In terms of days to first female flower anthesis and sex ratio, the cross CO 1 x Ambili and Arka Suryamukhi x Ambili had negative and significant *sca* effect in desirable direction.

Regarding yield parameters, the cross combination CO 1 x Arka Suryamukhi, Ambili x Arka Suryamukhi and CO 1 x Pusa Vishwas exhibited high *sca* effects for yield vine^{-1} and fruit weight. Similar results were reported by Tamilselvi et al*.* [13] in pumpkin (Ambili x Arka Suryamukhi), Doloi et al. [15] in bottle gourd and Ahammed et al. [16] in cucumber for fruit weight. The cross Ambili x Arka Suryamukhi resulted from positive x negative general combiners with common parent Ambili having the highest significant *gca* effect, demonstrated its value has good general combiner for yield plant^{-1}. Further, the cross (Ambili x Arka Suryamukhi) having positive x negative *gca* effects revealed that the high *sca* effects is mainly due to the predominance of non-additive gene effects. The *gca* effects of the parents and *sca* effects of their crosses in the present study indicated that the crosses between two good general combiners were not always the best for their *sca* effects. Hence, these crosses could be advanced for selection in segregating generations to identify superior segregants for the development of improved varieties.

4. CONCLUSION

Based on the specific combing ability of the 18 characters studied, it could be concluded that the hybrids CO 1 x Arka Suryamukhi, Ambili x Arka Suryamukhi and CO 1 x Pusa Vishwas were the best for yield and yield contributing characters. Expression of yield to the fullest potential of the crop is the prime trait to be considered in any hybridization programme. Based on that, the hybrid CO 1 x Arka Suryamukhi, Ambili x Arka Suryamukhi and CO 1 x Pusa Vishwas had recorded high yield with maximum fruit weight.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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