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Research Article

Genetic analysis in F_3 generation of pumpkin (*Cucurbita moschata* Duch Ex. Poir)

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Abstract
The study was conducted at the Department of Horticulture, Agricultural College and Research Institute, Madurai during 2018. The experimental plot was laid out in Randomized block design without replication due to segregating population with four crosses P2 X P5, P3 x P5, P5 x P6 and P6 x P5 selected from the F_2 generation based on the yield attributes of a single plant from the plant population and raised as F_3 generation to find out GCV, PCV, heritability, genetic advance, correlation and path analysis for growth and yield traits. Though in segregating generation the plant possesses bizarre of traits in plant population. However, a wider genetic variability was observed in the crosses. The mean performance for vine length (7.47), average fruit weight (1.15) and the number of fruits per plant (3.42) was estimated for the crosses P2 x P5, P3 x P5, P5 x P6 and P6 x P5. The PCV was registered high with low genetic advance over the mean for average fruit weight (40.44), the number of seeds per fruit (30.55) and fruit yield per plant (64.31). From the correlation it was revealed that the traits *viz*., average fruit weight (0.822), fruit diameter (0.417), the number of seeds per fruit (0.460) and hundred seed weight (0.340) showed a significant and positive association with fruit yield per plant in the F_3 generation. Path coefficient analysis revealed that the biometric traits *viz*., number of fruits per vine (0.5767) and average fruit weight (0.981) showed a positive direct effect on fruit yields per plant and traits like fruit diameter (0.4566), fruit length (0.3221), flesh thickness (0.1728), number of seeds per fruit (0.5719) and hundred seed weight (0.4939) exhibited positive indirect effect through average fruit weight.

Key words
Heritability, GCV, PCV, genetic advance, pumpkin, *Cucurbita moschata*

INTRODUCTION

Pumpkin is a type of winter squash that belongs to *Cucurbitaceae* family native to North America. It's also a great source of beta-carotene, a carotenoid that the body converts into vitamin A. Pumpkin is packed with nutrients and has 20 calories per 100 g. This makes it a nutrient dense food and it's also a good fibre, which may suppress your appetite. Pumpkin is extensively cultivated in the tropical and sub-tropical regions of India. It is gaining a lot of importance due to its short duration and high production potential as well as its high nutritive, medicinal and industrial value. Pumpkin is the cheapest source of Vitamin A when compared to a carrot which necessitates the specific climatic requirement for its production and pumpkin has high productivity per unit area compared to the carrot. There are a number of local cultivars with a wide range of variability in size, shape and colour of fruits available in India that can be exploited for its improvement. The success of any crop improvement program depends, to a large extent, on the amount of genetic variability present in the population. Larger variability existing among the population better is the chance of selection (Singh and Singh, 1982). Frenkel (1947) emphasized the importance of variability in plant populations in designing the most breeding programme. Genetic mechanism of growth, earliness and yield attributes are important for crop improvement, significant relationships between growth, earliness, and yield related attributes facilitate selection of high yielding lines

(Singh, 2001). Investigation of the interrelationships between yield and its components will improve the efficiency of a breeding programme with appropriate selection criteria. Correlation and path coefficient analyses have been extensively used in plant breeding to discern the nature of the relationships between yield and its contributing components. The high genetic variability can be exploited by selection (Burton, 1952). In the present investigation, the major emphasis is development of small fruited variety with high yield besides, having good fruit quality.

MATERIALS AND METHODS

The field experiment in pumpkin (*Cucurbita moschata* Duch. ex Poir) was carried out at the Department of Horticulture, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai during 2018. The experimental site is located at an altitude of 158 m above MSL between 09º 58´30.5´N latitude, and 078º 12´27.4E longitude. The location has a warm tropical climate and the experimental field was sandy loam soil. The experiment was laid out in randomized block design without replication due to segregating population. The F_3 generation was raised at a spacing of 2. x 2 m during May 2018 with recommended cultural practices. The details of crosses are given in **Table 1**. Fifty plants were evaluated in each cross on thirteen traits *viz*., vine length, days to first male flowering, days to first female flowering, sex ratio, the number of fruits per vine, days to the first harvest, average fruit weight, fruit length, fruit diameter, flesh thickness, the number of seeds per fruit, hundred seed weight, and fruit yield per plant. Variability analysis (Lush, 1940), correlation coefficients (Al-Jibouri *et al*., 1958) and Path analysis were estimated (Dewey and Lu, 1959).

Table 1. Details of crosses, parents and their sources

S.No	Name of the Cross	Parentage	Characters
1	P_2 x P_5	Ottanchathiram local x Attur local	Small fruited (2.04kg) and early maturity (85 days).
2.	P_3 x P_5	Harur local x Attur local	Small fruited (2.82kg), early maturity(89days) and high β-carotene content (0.90mcg/100g).
3.	P_5 x P_6	Attur local x Acc. No. MDU CM31	Medium fruited (3.55kg), early flowering (51days)and high TSS (9.68).
4.	P_6 x P_5	Acc. No. MDU CM31 x Attur local	Medium fruited (4.09kg) and narrow sex ratio (14.36).
5.	C1	Check variety, CO2, TNAU, Coimbatore.	Small sized fruit (1.5kg) (Anon.2013).
6.	C2	Check variety, CO1 TNAU, Coimbatore	Large sized fruit (8-10kg) (Anon.2013).

RESULTS AND DISCUSSION

Among the crosses evaluated P5 x P6 (1.11kg) and P6 x P5 (1.15kg) had recorded the lowest fruit weight (**Table 2**) besides, P2 x P5 (1.54kg) exhibited medium fruited plants. The vine length was marked highest in P2 x P5 (7.47m) and lowest in P6 x P5 (3.15m) by the genomic pattern of the female parent. Moreover, the sex ratio was recorded high in P3 x P5 (20.18) and low in P6 x P5 (14.44) due to inheritance of the recessive parent. The fruit yield per plant was high in P3 x P5 (4.26kg) and low in P5 x P6 (2.47kg) due to the heredity action of the female parent. The yield may be attributed to the influence of the contributing component traits fruit weight, fruit diameter and flesh thickness are due to the genetic effect of the female parent. Similar findings were reported by Sampath and Krishnamoorthy (2017) in pumpkin.

The pre-eminent factor of segregating generations is variability studies, which witnesses the selection process to the next generations. The variations exhibited by the 13 traits in the F_3 generation indicated the presence of high variability in the plant population. The traits *viz*., the number of fruits per vine, average fruit weight (40.44), fruit length (25.50), fruit diameter (20.07), flesh thickness (27.05) and fruit yield per plant (64.31) recorded higher PCV than GCV (**Table 3**) in the four crosses witnesses that the environment had a greater influence on the expression of the traits. The number of seeds per fruit recorded high in both PCV and GCV in the following crosses P2 X P5, P3 x P5, P5 x P6 and P6 x P5. It indicates the existence of a broad genetic base, which would be amenable for further selection (Muttur *et al*., 2017). The other traits *viz*., vine length, days to first male flowering, days to first female flowering and days to first harvest had recorded the lowest PCV and GCV in the four crosses indicating that the influence of environment is less.

The P2 x P5 had the highest (GCV < 20%) for average fruit weight, the number of seeds per fruit and fruit yield per plant. This high genetic variability can be exploited by selection and this was supported by Sundaram *et al*. (2011) in watermelon. The moderate GCV was recorded for the traits *viz*., fruit length, flesh thickness, fruit diameter and hundred seed weight; the low degree of GCV (> 10%) was observed in traits vine length, days to first male flowering, days to first female flowering, sex ratio, the number of fruits per vine and days to first harvest. A further selection of these characters would be least effective in this cross.

Table 2. Mean performance of pumpkin crosses.

Particulars	P_2xP_5	P_3xP_5	P_5xP_6	P_6xP_5
Vine length (m)	7.47	7.28	3.29	3.15
Days to first male flowering	44.92	45.22	46.52	44.74
Days to first female flowering	54.16	52.70	52.58	53.30
Sex ratio	17.96	20.18	16.25	14.44
Number of fruits per vine	2.20	2.30	2.34	2.42
Days to first harvest	83.78	85.44	87.00	88.96
Average fruit weight (kg)	1.54	1.92	1.11	1.15
Fruit length (cm)	10.15	11.15	8.88	8.50
Fruit diameter (cm)	9.23	9.27	7.86	8.21
Flesh thickness (cm)	2.20	2.22	1.80	2.07
Number of seeds per fruit	356.08	426.32	288.14	322.22
Hundred seed weight (g)	15.82	16.38	12.72	12.30
Fruit yield per plant (kg)	3.42	4.26	2.47	2.73

Table 3. Phenotypic and genotypic coefficient of variations of pumpkin crosses.

Particulars	PCV (Per cent)				GCV (Per cent)			
	P_2xP_5	P_3xP_5	P_5xP_6	P_6xP_5	P_2xP_5	P_3xP_5	P_5xP_6	P_6xP_5
Vine length	3.39	5.86	10.02	11.13	1.60	2.05	6.71	5.74
Days to first male flowering	3.21	2.97	3.05	4.67	2.01	2.50	1.64	2.22
Days to first female flowering	3.41	3.52	3.26	2.38	2.87	2.99	2.42	1.10
Sex ratio	13.25	16.85	10.22	5.39	8.35	9.21	6.32	1.08
Number of fruits per vine	20.53	25.57	28.12	20.60	5.39	6.69	17.43	15.93
Days to first harvest	1.60	1.62	1.49	0.88	1.59	0.92	1.23	0.66
Average fruit weight	31.49	37.09	40.44	30.96	29.42	35.53	35.58	24.73
Fruit length	24.49	25.50	20.19	15.63	19.20	21.89	11.37	15.05
Fruit diameter	20.07	12.98	17.68	15.67	19.99	12.83	17.58	15.60
Flesh thickness	22.65	25.09	25.73	27.05	19.72	22.36	5.62	5.06
Number of seeds per fruit	30.55	21.12	21.61	26.93	27.50	19.72	14.39	24.30
Hundred seed weight	19.41	16.54	15.32	15.17	15.54	15.60	4.71	11.49
Fruit yield per plant	44.72	40.52	64.31	35.20	24.85	36.12	16.41	31.45

The P3 x P5 had exhibited the highest GCV for average fruit weight, fruit length, flesh thickness, and fruit yield per plant this degree of variability shows that there is an opportunity for their improvement in segregating population through selection. The moderate GCV was observed in fruit diameter, the number of seeds per fruit and hundred seed weight; low GCV was exhibited by vine length, days to first male flowering, days to first female flowering, sex ratio, the number of fruits per vine and days to first harvest indicates there is less opportunity for their improvement and these findings were similar to the earlier works of Kamagoud and Shet (2018) in oriental pickling melon. In P5 x P6 the average fruit weight and in the P6 x P5 the traits *viz*., average fruit weight and the number of seeds per fruit exhibited higher GCV, contributes good potential for selection and remaining character exhibits moderate and low GCV in the crosses. High GCV alone is not sufficient for a determination of heritable variation, because it simply measures the extent of genetic variability present for a character. The GCV together with heritability estimates give the best possibility of advance through selection (Burton, 1952). Heritability measures the expression of a trait (Allard, 1960). Johnson *et al*. (1955) stated that high heritability, combined with high genetic advance for a character, indicates the predominance of additive gene action on the trait and that trait is likely to respond effectively to phenotypic selection.

High heritability coupled with genetic advance over per cent mean (**Table 4**) was recorded by all crosses in F_3 generation for the traits *viz*., average fruit weight, fruit diameter, the number of seeds per fruit, fruit yield per plant, revealed the additive gene action on these characters in the population and these traits would be effective for phenotypic selection. High heritability coupled with genetic advance over per cent mean was exhibited by the crosses *viz*., P2 x P5, P3 x P5 and P6 x P5 for fruit length and P2 x P5 and P3 x P5 for flesh thickness besides, P2

x P5, P3 x P5 and P6 x P5 for hundred seed weight and these was in corroboration with Kanimozhi *et al*. (2015) in the wax gourd. Traits like vine length, days to first male flowering, days to first female flowering and sex ratio showed high heritability coupled with low or moderate genetic advance over mean indicated the prevalence of non-additive components and there can be little response to selection and these traits can be exploited through heterosis breeding.

Table 4. Heritability and genetic advance as per cent of mean in pumpkin crosses.

Particulars	Heritability (Per cent)				Genetic advance as per cent of mean			
	P_2xP_5	P_3xP_5	P_5xP_6	P_6xP_5	P_2xP_5	P_3xP_5	P_5xP_6	P_6xP_5
Vine length	22.30	12.24	44.84	26.61	1.56	1.43	9.26	6.10
Days to first male flowering	39.28	70.58	28.86	22.91	2.59	4.33	1.81	2.18
Days to first female flowering	71.20	72.08	55.14	21.19	5.00	5.24	3.71	1.04
Sex ratio	68.85	77.32	61.27	94.51	32.40	35.14	24.58	77.26
Number of fruits per vine	6.90	6.85	28.42	59.77	2.92	3.61	22.36	25.37
Days to first harvest	97.79	31.89	67.78	56.33	3.23	1.07	2.09	1.02
Average fruit weight	87.25	91.14	77.39	63.78	56.61	70.10	64.47	40.68
Fruit length	61.47	73.67	31.74	92.79	31.02	38.70	13.20	29.87
Fruit diameter	99.23	97.78	98.85	99.00	41.03	26.14	36.01	31.96
Flesh thickness	75.80	79.46	4.77	3.50	35.38	26.14	2.53	1.95
Number of seeds per fruit	81.07	87.20	44.37	81.47	51.01	37.93	19.75	45.19
Hundred seed weight	64.08	88.88	9.44	57.37	25.63	30.29	2.98	17.92
Fruit yield per plant	30.87	54.61	92.41	90.12	28.44	45.26	78.54	55.28

The association coefficient may also help to classify characters that have petite or no importance in the selection programme. The presence of correlation may be attributed to the presence of the linkage or pleiotropic effect of genes or the physiological and development relationship or the environmental effect or a combination of all (Johnson *et al*., 1955). In F_3 generation four crosses were evaluated and the traits like average fruit weight (0.822), fruit diameter (0.417), the number of seeds per fruit (0.460) and hundred seed weight (0.340) exhibits positive and significant association (**Table 5**) with fruit yield per plant and similar results were reported by Kumar *et al*. (2005) and Kumaran *et al*. (1998) in pumpkin. On the other hand, the sex ratio showed a negatively significant association (-0.437) to yield and revealed that yield can be improved by selecting the crosses with more the number of fruits per vine and average fruit weight. This indicated that yield can be improved by making the selection on the bases of these yield attributing characters. These findings are, in line with those of Husna *et al*. (2011) and Kamal *et al*. (2012) in bottle gourd, Arunkumar *et al*. (2012), Hossain *et al*. (2010), Kumar *et al*. (2008) in cucumber and Blessing *et al*. (2012) in pumpkin.

Doku (1970) suggested that inter correlation among the yield components need to be estimated because one component influences the other related components. The inter correlation among these traits revealed a significant and positive association for average fruit weight with fruit length, fruit diameter, the number of seeds per fruit and hundred seed weight and similar results were reported by Taha *et al*. (2003) in muskmelon. However, the number of fruits per vine had a significant negative correlation with average fruit weight. Though pre-eminence should be given during selection to the fruit length and fruit diameter for higher weight and larger fruit size. In the ambience of consumer preference (1-2 kg fruit weight) and market demand (both domestic and export trade), fruit size and number of fruits per vine need to be balanced. A similar result was reported by Pandit *et al*. (2008) in bottle gourd and Priyanka *et al.* (2018) in mithipagal

After getting information from the results of the correlation analysis, the path coefficient analysis was done to determine the direct and indirect effects of traits on fruit yield. The estimates of the correlation coefficients revealed only the relationship between yield and yield associated traits but did not show the direct and indirect effects of different traits on fruit yield. This is because the attributes which are in association do not exist by themselves, but are linked to other components. Partitioning of the correlation coefficient of the 13 characters on yield into direct and indirect effects was done (**Table 6**). The maximum positive direct effect on the fruit yield was exhibited by the number of fruits per vine (0.5767) and average fruit weight (0.981) in the F_3 generation. The results were parallel to the findings of Husna *et al*. (2011) in bottle gourd and Gupta *et al.* (2019) in pumpkin. The sex ratio (-0.0196), fruit length (-0.0278) and flesh thickness (-0.0134) showed a direct negative effect on yield per plant. To identify high yield, the cross P3 x P5 can be selected with bigger sized, medium sized fruit in P2 x P5 and small sized fruits P5 x P6, P6 x P5.

Table 5. Correlation coefficients between fruit yield per plant and its yield components in F_3 generation of pumpkin

Characters	Day to first male flowering	Day to first female flowering	Sex ratio	Number of fruits per vine	Days to first harvest	Average fruit weight	Fruit length	Fruit diameter	Flesh thickness	Number of seeds per fruit	Hundred seed weight	Fruit yield per plant
Vine length	0.060	-0.059	0.097	-0.036	0.006	0.243	-0.150	-0.068	-0.167	0.227	0.075	0.187
Days to first male flowering		0.142	0.197	0.187	-0.064	-0.061	-0.062	0.131	-0.225	0.021	-0.023	0.070
Days to first female flowering			0.400**	0.111	-0.082	-0.223	-0.001	-0.174	0.043	0.089	-0.030	-0.208
Sex ratio				0.128	-0.014	-0.456**	0.000	-0.235	-0.017	-0.172	-0.250	-0.437**
Number of fruits per vine					0.011	-0.381**	-0.148	-0.202	-0.091	-0.217	-0.300*	0.178
Days to first harvest						0.011	-0.063	-0.129	-0.096	-0.110	0.074	0.031
Average fruit weight							0.322*	0.456**	0.173	0.571**	0.494**	0.822**
Fruit length								0.492**	0.471**	0.172	-0.021	0.246
Fruit diameter									0.253	0.221	-0.039	0.417**
Flesh thickness										-0.099	0.064	0.115
Number of seeds per fruit											0.398**	0.460**
Hundred seed weight												0.340*

** Significant at 1 percent level
*Significant at 5 percent level

Table 6. Direct and indirect effects in fruit yield and partitioned by path analysis in F_3 generations of pumpkin

Characters	Vine length	Day to first male flowering	Day to first female flowering	Sex ratio	Number of fruits per vine	Days to first harvest	Average fruit weight	Fruit length	Fruit diameter	Flesh thick ness	Number of seeds per fruit	Hundred seed weight	Fruit yield per plant
Vine length	**-0.039**	0.0012	0.0017	-0.0019	-0.021	0.0001	0.2431	0.0042	-0.0055	0.0022	0.0001	0.0014	0.187
Days to first male flowering	-0.0023	**0.0196**	-0.0041	-0.0039	0.1078	-0.0012	-0.0609	0.0017	0.0107	0.003	0.0000	-0.0004	0.070
Days to first female flowering	0.0023	0.0028	**-0.0292**	-0.0078	0.0642	-0.0016	-0.2231	0.0000	-0.0142	-0.0006	0.0000	-0.0006	-0.208
Sex ratio	-0.0038	0.0039	-0.0117	**-0.0196**	0.0737	-0.0003	-0.4559	0.0000	-0.0192	0.0002	-0.0001	-0.0048	-0.437**
Number of fruits per vine	0.0014	0.0037	-0.0032	-0.0025	**0.5767**	0.0002	-0.3816	0.0041	-0.0164	0.0012	-0.0001	-0.0057	0.178
Days to first harvest	-0.0002	-0.0012	0.0024	0.0003	0.0062	**0.0188**	0.0106	0.0018	-0.0105	0.0013	0.0000	0.0014	0.031
Average fruit weight	-0.0095	-0.0012	0.0065	0.0089	-0.2199	0.0002	**1.0008**	-0.0089	0.0372	-0.0023	0.0002	0.0094	0.822**
Fruit length	0.0059	-0.0012	0.0000	0.0000	-0.0854	-0.0012	0.3221	**-0.0278**	0.0402	-0.0063	0.0001	-0.0004	0.246
Fruit diameter	0.0026	0.0026	0.0051	0.0046	-0.1162	-0.0024	0.4566	-0.0137	**0.0816**	-0.0034	0.0001	-0.0008	0.417**
Flesh thickness	0.0065	-0.0044	-0.0012	0.0003	-0.0527	-0.0018	0.1728	-0.0131	0.0207	**-0.0134**	0.0000	0.0012	0.115
Number of seeds per fruit	-0.0088	0.0004	-0.0026	0.0034	-0.1252	-0.0021	0.5719	-0.0048	0.018	0.0013	**0.0004**	0.0076	0.460**
Hundred seed weight	-0.0029	-0.0005	0.0009	0.0049	-0.1733	0.0014	0.4939	0.0006	-0.0032	-0.0009	0.0002	**0.0191**	0.340*

Bold values refer to direct effects , Residual effect: 0.1834

The traits like fruit diameter, flesh thickness, the number of seeds per fruit and hundred seed weight approach a positive indirect effect for fruit yield through average fruit weight. The low residual effects were recorded in the F_3 generation indicated that all the important characters correlated with the fruit yield in pumpkin and this was also observed by Dey *et al*. (2009) and Yadav *et al*. (2013) in bitter gourd and Husna *et al*. (2011) in bottle gourd.

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