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Studies on Genetic Variability, Heritability, Genetic Advance and Correlation in F4 Generation of Pumpkin (*Cucurbita moschata* Duch Ex. Poir)

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Abstract
The current study, titled "Variability studies in F_4 generations of pumpkin (*Cucurbita moschata* Duch Ex. Poir," took place in 2019 during the summer at All India Co-ordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra). The present investigation was undertaken with 5 progenies with their 20 plants of each progeny for a cross RHR PK-18-3-1 x RHR PK-09-4-6 (C:1x2) of pumpkin in F_4 generation for evaluating their genetic components such as variability, heritability, genetic advance, genetic advance as a per cent mean and correlation for growth, yield and yield attributes. Wide range of variability was observed for most of the characters. High values of GCV and PCV observed for number of primary branches per vine, number of fruits per vine, average yield per vine, average weight of fruit, and yield tonnes per hectare. high estimates of genetic advance as a percent of mean in characters, like final vine length at last harvest, number of primary branches per vine, days to first female flower appearance, node at which first female flower appeared, no. of fruit per vine, average length of fruit, average diameter of fruit, yield per vine, yield per plot, yield per hectare, fruit flesh thickness, number of ridges per fruit, seed cavity length, seed cavity width, number of seed per fruit, 100 seed weight and TSS. The significant and high positive correlation both at phenotypic and the genotypic level was observed between fruit yield per vine and the yield contributing characters such as final vine length, number of primary branches per vine, number of fruits per vine, average weight of fruit (at genotypic), average diameter of fruit and fruit flesh thickness.

Keywords: pumpkin, variability, heritability, genetic advance, growth, yield and quality

1. Introduction
Pumpkin (*Cucurbita moschata* Duch. ex Poir.) is a popular cucurbitaceous vegetable that can be grown in a variety of climates around the world. The crop is widely planted in the United States, Mexico, India, and China. Assam, West Bengal, Tamil Nadu, Karnataka, Madhya Pradesh, Uttar Pradesh, Orissa, Kerala, and Bihar are the main producers in India. It has a wide range of applications. Fresh vegetables, processed foods, and stock feed are all made from the fruits. When stewed, boiled, or baked, pumpkin pulp is delicious. Ripe fruits are used to make halwa, jams, and other sweets. Fruits are less nutritious than flowers. After the seed coats have been removed, the seeds are used in confectionery. It's a diuretic that's used to treat tapeworm infection.

Pumpkin is a monoecious, cross-pollinated crop with a low uniformity. The amount of variation present in a crop species is critical because it serves as the foundation for effective selection. The importance of genetic variability in crops is critical for selecting the best genotypes for rapid yield and related character improvement, as well as selecting the most promising parents for a successful hybridization programme. With the help of genetic parameters such as genotypic and phenotypic coefficients of variation and heritability, overall variability must be partitioned into heritable and non-heritable components. A good understanding of genetic diversity could also aid in the identification of commercially viable cultivars. Pumpkin has a wide range of variability, making it an attractive choice for hybridization. Early maturity, fruit yield, and fruit quality are the determining factors in making a variety/hybrid a success in pumpkin. Knowledge of the nature of the gene effect for yield and the contributing characters associated with it is always beneficial in selecting effective and efficient breeding methods. With this in view, the current study was undertaken with the following objectives:

1. To assess the variability for important qualitative and quantitative traits in F_4 generation
2. To estimate heritability and genetic advance for yield contributing characters in F_4 generation.
3. To study the correlation between yield and yield contributing characters in F_4 generation.

Materials and Method

The present investigation was carried out at All India Co-ordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) during the *summer* 2019. The seeds of cross RHR PK-18-3-1 x RHR PK-09-4-6 (C: 1x2) along with their parents were obtained from Department of Horticulture, MPKV, Rahuri. F_3 progenies from the cross were selected on the basis of shape of fruit and flesh colour. Five progenies (20 plants/progeny) were sown along with parents in randomized block design with three replications. Seeds of these generations were sown at a spacing of 5m x 1m. Observations were recorded on various growth and yield parameters such as final vine length (cm)**,** number of primary branches per vine, days to 1st female flower appearance, sex ratio, node at which first female flower appeared, days to first harvest, no. of fruit per vine, average weight of fruit (Kg), average length of fruit (cm), average diameter of fruit (cm), yield per vine (kg), yield per plot (Kg), yield per hectare (tonnes), fruit flesh thickness (cm), number of ridges per fruit, seed cavity length (cm), seed cavity width (cm), number of seeds per fruit, 100 seed weight (g) and TSS (^{0}Brix). Estimation of variations and genetic advance was done following [6] coefficient of variations following [3] and heritability following [9]. The correlation coefficient was estimated as suggested by [12].

Results and Discussion

The RHR PK-18-3-1 x RHR PK-09-4-6 (C_1: 1 x 2) cross in the F_4 generation showed a wide range of variability for most of the pumpkin characters (Table 3). The final vine length at harvest ranged from 472.33 to 633.67 cm, with 3.20 to 4.35 number of primary branches per vine, 46.03 to 59.33 days to first female flower appearance, 16.13 to 18.60 sex ratio, 10.32 to 14.73 node at which first female flower appeared, 91.11 to 104.65 days to first fruit harvest, and 1.86 to 2.96 fruit per vine, 4.55 to 5.56 g average weight of fruit, 17.40 to 24.42 cm average length of fruit, 12.57 to 24.27 cm average diameter of fruit, 8.45 to 19.06 kg yield per vine, 42.27 to 95.30 kg yield per plot, 16.91 to 38.12 tonnes yield per hectare, 2.82 to 4.83 cm fruit flesh thickness, 10.72 to 19.68 number of ridges per fruit, 11.36 to 17.76 cm seed cavity length, 13.77 to 21.18 cm seed cavity width, 135.16 to 227.59 number of seeds per fruit, 6.31 to 14.73 g 100 seed weight from and 7.31 to 9.18 ^{0}Brix TSS. Wide range of variability for these traits was observed in the present investigation. This result is encouraging because the presence of high variability, among the traits has been an indicated a good opportunity for selecting desirable genotypes [2, 10].

In the present studies high values of genotypic and phenotypic coefficients of variation were found in the number of primary branches per vine, number of fruits per vine, average yield per vine, average weight of fruit, and yield tonnes per hectare. At the node where the first female flower appeared, crop duration, days to the first female flower appearance, average diameter of fruit and average length of fruit, the genotypic and phenotypic coefficients of variation were moderate. For the remaining traits such as final vine length at last harvest, days required for first harvest of fruit average diameter of fruit recorded low values of genotypic and phenotypic coefficients of variations. Characters with higher GCV and PCV estimates could be fully exploited in a future selection programme due to the large amount of variation within segregating populations, i.e., scope for improvement through selection. Characters with lower GCV and PCV estimates would be the least exploited in future selection programmes due to the small amount of variation observed within segregating populations, implying a lack of scope for improvement through selection [1, 2, 7].

In case of high estimates of heritability were associated with high estimates of genetic advance as a percent of mean in characters, like final vine length at last harvest (99.99 and 25.26 percent), number of primary branches per vine (96.16 and 24.01 percent), days to first female flower appearance (98.85 and 20.60 percent), node at which first female flower appeared (95.20 and 23.74 percent), no. of fruit per vine (96.43 and 34.37 percent), average length of fruit (93.75 and 27.06 percent), average diameter of fruit (98.95 and 45.18 percent), yield per vine (95.97 and 51.56 percent), yield per plot (95.95 and 51.57 percent), yield per hectare (95.95 and 51.57 percent), fruit flesh thickness (94.15 and 41.58 percent), number of ridges per fruit (95.17 and 45.00 percent), seed cavity length (97.37 and 37.70 percent), seed cavity width (98.17 and 33.81 percent), number of seed per fruit (99.95 and 45.94 percent), 100 seed weight (82.53 and 52.45 percent) and TSS (99.28 and 23.45 percent). Whereas the high estimates of heritability with moderate estimates of genetic advance as per cent of mean was observed for no. of male and female flowers per vine (95.30 and 11.18), days to first harvest (98.80 and 10.83). The high estimates of heritability and genetic advance as a percentage of mean could be due to the predominance of additive gene effects. As a result, character selection for the characters mentioned in the preceding crosses, as well as their respective generations, appears to be feasible [8, 4, 11].

The significant and high positive correlation [Table-2] both at phenotypic and the genotypic level was observed between fruit yield per vine and the yield contributing characters such as final vine length, number of primary branches per vine, number of fruits per vine, average weight of fruit (at genotypic), average diameter of fruit and fruit flesh thickness. While, the characters such as days required for first female flower appearance, sex ratio**,** node at which first female flower appeared and days to first harvest of fruit were significantly and negatively correlated with average yield per plot, which were helpful relationships. The majority of these characters were also noticed to have a positive relationship with each other. These findings in F_4 generations indicate that the ideal vine should have more vine length, more number of primary branches per vine, more number of fruits per vine, more weight of fruit, more length of fruit and more diameter of fruit and less days required for first female flower appearance, the first female flower appeared at a lower node position, and it took fewer days for the first fruit to be harvested. The selection of a better yielder should also emphasis for improvement in these components [5, 13].

Table 1: Mean, range, GCV, PCV, ECV, heritability, genetic advance and percent mean of genetic advance of two parents and F_4 population of cross RHR PK-18-3-1 x RHR PK-09-4-6 (C: 1 x 2)

Sr. No.	Character	Mean	Range	GCV (%)	PCV (%)	ECV (%)	h^2 (bs) (%)	GA	GAM (%)
1.	Final vine length (cm)	570.57	472.33-633.67	12.26	12.26	0.26	99.99	144.13	25.26
2.	No. of primary branches per vine	3.89	3.20-4.35	11.88	12.12	4.11	96.16	0.93	24.01
3.	Days required for first female flower appearance	51.22	46.03-59.33	10.06	10.12	1.88	98.85	10.55	20.60
4.	Sex ratio	17.15	16.13-18.60	5.56	5.70	2.14	95.30	1.92	11.18
5.	Node at which first female flower appeared	12.70	10.32-14.73	11.81	12.11	4.59	95.20	3.02	23.74
6.	Days to first harvest	96.46	91.11-104.65	5.29	5.32	1.01	98.80	10.45	10.83
7.	No. of fruits per vine	2.52	1.86-2.96	16.99	17.30	5.66	96.43	0.87	34.37
8.	Average weight of fruit (kg)	5.25	4.55-5.56	4.88	6.27	6.82	60.51	0.41	7.81
9.	Average length of fruit (cm)	22.06	17.40-24.42	13.57	14.01	6.07	93.75	5.97	27.06
10.	Average diameter of fruit (cm)	20.40	12.57-24.27	22.05	22.16	3.93	98.95	9.22	45.18

Table 1: Contd…

Sr. No.	Character	Mean	Range	GCV (%)	PCV (%)	ECV (%)	h^2 (bs) (%)	GA	GAM (%)
11.	Yield per vine (kg)	14.33	8.45-19.06	25.55	26.08	9.07	95.97	7.39	51.56
12.	Yield per plot (kg)	71.64	42.27-95.30	25.55	26.09	9.09	95.95	36.94	51.57
13.	Yield per hectare (t)	28.66	16.91-38.12	25.55	26.09	9.09	95.95	14.78	51.57
14.	Fruit flesh thickness (cm)	4.11	2.82-4.83	20.80	21.44	8.98	94.15	1.71	41.58
15.	Number of ridges per fruit	15.09	10.72-19.68	22.39	22.96	8.73	95.17	6.79	45.00
16.	Seed cavity length (cm)	14.60	11.36-17.76	18.55	18.79	5.28	97.37	5.50	37.70
17.	Seed cavity width (cm)	18.14	13.77-21.18	16.56	16.72	3.91	98.17	6.13	33.81
18.	Number of seeds per fruit	201.05	135.16-227.59	22.31	22.31	0.83	99.95	92.36	45.94
19.	100 seed weight (g)	11.00	6.31-14.73	28.02	30.85	22.33	82.53	5.77	52.45
20.	T.S.S (˚Brix)	8.13	7.31-9.18	11.42	11.47	1.69	99.28	1.91	23.45

Table 2: Genotypic and Phenotypic Correlation co-efficient for yield and yield contributing characters in F_4 generation of (C: 1 x 2) (RHR PK-18-3-1 X RHR PK-09-4-6)

Sr. No.	Character		1	2	3	4	5	6	7	8	9	10	11	12
1	Final vine length (cm)	G	1.000	1.006**	-0.982**	-0.932**	-0.942**	-0.968**	0.986**	0.774*	0.362	0.852*	1.020*	0.965**
		P	1.000	0.986**	-0.977**	-0.908**	-0.920**	-0.962**	0.968**	0.603	0.350	0.848**	0.990**	0.943**
2	Number of primary branches per vine	G	-	1.000	-1.023**	-0.969**	-0.977**	-1.016**	1.053*	0.870**	0.437	0.913**	1.0288*	1.015**
		P		1.000	-0.995**	-0.935**	-0.945**	-0.991**	0.996**	0.622	0.420	0.896**	0.9938*	0.972**
3	Days to first female flower appearance	G	-	-	1.000	0.963**	0.971**	1.004**	-1.013**	-0.839**	-0.378	-0.942**	-1.023**	-1.009**
		P			1.000	0.936**	0.949**	0.987**	-0.992**	-0.674	-0.354	-0.933**	-0.988**	-0.975**
4	Sex ratio	G	-	-	-	1.000	0.903**	0.942**	-0.993**	-0.566	-0.351	-0.907**	-0.990**	-0.931**
		P				1.000	0.864**	0.9158*	-0.939**	-0.464	-0.328	-0.888**	-0.922**	-0.901**
5	Node at which first female flower appeared	G	-	-	-	-	1.000	0.960**	-0.992**	-0.889**	-0.525	-0.883**	-0.982**	-1.002**
		P					1.000	0.930**	-0.933**	-0.634	-0.457	-0.863**	-0.924**	-0.955**
6	Days to first harvest	G	-	-	-	-	-	1.000	-1.025**	-0.892**	-0.439	-0.914	-1.024**	-1.008**
		P						1.000	-0.997**	-0.676	-0.431	-0.901	-0.975**	-0.983**
7	No. of fruit per vine	G	-	-	-	-	-	-	1.000	0.824**	0.446	0.933**	1.038**	1.008**
		P							1.000	0.634	0.435	0.911**	0.984**	0.974**
8	Average weight of fruit (Kg)	G	-	-	-	-	-	-	-	1.000	-0.209	0.977**	0.780*	1.002**
		P								1.000	-0.132	0.730	0.599	0.727
9	Average length of fruit (cm)	G	-	-	-	-	-	-	-	-	1.000	0.191	0.401	0.403
		P									1.000	0.180	0.393	0.377
10	Average diameter of fruit (cm)	G	-	-	-	-	-	-	-	-	-	1.000	0.929**	0.913**
												1.000	0.892**	0.892**
11	Fruit flesh thickness (cm)	G	-	-	-	-	-	-	-	-	-	-	1.000	1.005**
		P											1.000	0.941**
12	Yield per plot (kg)	G	-	-	-	-	-	-	-	-	-	-	-	1.000
		P												1.000

S: Symbol, G: Genotypic, P: Phenotypic*, **: Significance at 5% and 1%, respectively.

Conclusion

The characters showing wide range of variation provide ample scope for selecting the desirable plant types. The high values of genotypic and phenotypic coefficients of variation were found in the number of primary branches per vine, number of fruits per vine, average yield per vine, average weight of fruit, and yield tonnes per hectare and remaining character shows moderate and low PCV and GCV in the cross RHR PK-18-3-1 x RHR PK-09-4-6 (C: 1 x 2). The presence of high variability, among the traits has been an indicated a good opportunity for selecting desirable genotypes and high estimates of heritability, indicating that they were least affected by environment and that selection based on phenotypic performance would be reliable. The significant and positive correlation both at phenotypic and the genotypic level was observed between fruit yield per vine and the yield contributing characters. Thus, association of characters should be considered for improvement.

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