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Variability, correlation and path analysis in Pumpkin (*Cucurbita moschata* Duch. ex. Poir.)

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Abstract
Forty genotypes of pumpkin were evaluated to measure the variability among the genotypes for several characters, estimate genetic parameter, association among the character and their contribution to yield. There was a deal of significant variation for all the characters among the genotypes. High variability was observed in fruit yield per plant, first male flowering node, number of fruits per plant, fruit weight, flesh thickness, number of seeds per fruit and the quality parameter like total soluble solids, total sugar content and ß-carotene. All the character except days to opening first female flower and polar circumferences of fruit showed high heritability along with high genetic advance in per cent of mean. The positive and strong association of number of fruits per plant (rg = 0.898 and rp = 0.878), fruit weight (rg = 0.943 and rp = 0.875), flesh thickness (rg = 0.961 and rp = 0.915), polar circumferences of fruit (rg = 0.533 and rp = 0.377), equatorial circumferences of fruit (rg = 0.677 and rp = 0.514) and total soluble solids (rg = 0.378 and rp = 0.329) with fruit yield per plant revealed that the importance of this characters in determining the fruit yield per plant. On other hand, days to opening first female flower (rg = -0.243) was negatively and significantly correlated with fruit yield per plant. The path co-efficient analysis revealed that the highest positive direct effect was recorded in case of fruit weight (0.574) followed by number of fruits per plant (0.292) and flesh thickness (0.189). On other hand, the highest negative direct effect was recorded by equatorial circumferences of fruit (-0.003), but its indirect effect through fruit weight (0.434) was very high in magnitude and positive in direction. Overall, the result indicated that the number of fruits per plant, fruit weight, flesh thickness, polar circumferences of fruit and equatorial circumferences of fruit can be used as useful selection criteria to increase fruit yield per plant in pumpkin.

Keywords: correlation, path analysis, variability parameter, pumpkin

Introduction

Pumpkin (*Cucurbita moschata* Duch. ex. Poir.) belongs to the family Cucurbitaceae having somatic chromosome number 2n=40. Total 27 species under the genus *cucurbita*, Out of these five species *viz., C. moschata, C. maxima, C. ficifolia, C. pepo and C. mixta* found under cultivation. *Cucurbita moschata* widely grown species of *Cucurbita* and cross compatible with C. *maxima, C. pepo* and *C. mixta* (Tindall, 1987) [15]. Pumpkin contains relatively high energy and nutrient. The hundrad grams edible portions of fruit has 90 ml water, 8 g carbohydrates, 1 g protein, 0.5 g fibers, 20 mg calcium, 0.8 mg iron, 210 mg beta-carotene, 0.05 mg thiamine, 0.05 mg riboflavin, 0.5 mg niacin and 15 mg ascorbic acid (Tindall, 1987) [15]. It may contribute to improve nutritonal status of the people, particulaly the vulnerable groups in respect of vitamin A reqiurement. In India, the area under cultivation of pumpkin was 0.36 million ha, with a total production of 3.50 mt/annum with a productivity of about 9.72 t/ha (NHB, 2016) [3]. Though a fairly common crop, to date there is a less release varieties of pumpkin with high yield potential and good quality in India. There was a wide genetic variability among the existing genotypes (Aliu *et al.*, 2011) [1] and thus, the utilization of such varialbility in the breeding programmes of this crop is possible. In a crop selection programme, knowledge of the interrelationship among yield and yield contributing characters are necessary. Path analysis would help in partioning the correlation coefficient into direct and indirect effects of various traits on the genetic variability, character association and the direct and indirect contribution of some yield charcters towards fruit yield.

Materials and Method

The experiment comprising of 40 diverse genotypes was laid out in a randomized block designs with two replications during *kharif* 2016 at Main Vegetable Research Station, AAU, Anand. Each plot consisted of single row of seven plants and the spacing was 2 m × 1 m inter row and intra row distance, respectively. The package of practices was followed as per the recommendation for raising good and healthy crop. Three plants were selected excluding border plants for recording the observation. For studying different genetic parameters and inter-relationships, sixteen characters were taken into consideration namely, fruit yield per plant, Days to opening of first male flower, Days to opening of first female flower, First male flowering node, First female flowering node, Number of fruits per plant, Days to harvest, Polar circumferences of fruit, Equatorial circumferences of fruit, Fruit weight, Flesh thickness, Number of seeds per fruit, Test weight of 100 seeds, Total sugar content, ß-carotene and Total soluble solids. Analysis of variance (ANOVA), mean and range were calculated by using software programme. Phenotypic and genotypic variances were estimated by the formula given by Johnson *et al.*, 1955. Genotypic and phenotypic co-efficient of variation were calculated by the formula given by Burton (1952) [4]. Heritability and genetic advance in percentage of were measure using the formula given by Allard (1960) [2]. Genotypic and phenotypic correlation coefficient was worked out by adopting method described by Singh and Chaudhari (1979). The genotypic and phenotypic correlations will be worked out as per procedure suggested by Hazel (1943) [6]. Path co-efficient analysis was done following the method outlined by Dewey and Lu (1959) [5].

Result and Discussion

Genetic Variability

The estimate of genotypic (σ2g) and phenotypic (σ2p) variances of each character as well as other genetic components viz., heritability in broad sense (h2bs), genetic coefficient of variance (GCV %), phenotypic coefficient of variance (PCV %) and genetic advance as per cent of mean (GA % mean) are narrated in Table 1. The genotypic variances and genotypic coefficient of variation was greater than the corresponding phenotypic variance and phenotypic co-efficient of variation for most of all the character under study. That suggest the environment expression is very less for the expression of these character. The highest genotypic variance (5886.31) as well as phenotypic variance (6994.22) was found in number of seeds per fruit followed by days to first harvest and flesh thickness. Rasul *et al.* (2013) [10] also found the high genotypic variance (2094.67) and phenotypic variance (2095.63) in number of seeds per fruit.

The minimum differences between genotypic variance and phenotypic variance were observed for the quality character like total soluble solids, ß – carotene and total sugar indicating that less influences of environment on this character. While, the differences between genotypic variance and phenotypic variance were maximum in polar circumferences of fruit and equatorial circumferences of fruit, which indicated that the genotypes were highly variable for this trait. High heritability was observed for characters like fruit yield per plant, number of fruits per plant, fruit weight, flesh thickness, test weight of 100 seeds, number of seeds per fruit, first male flowering node, first female flowering node, days to opening first male flower, days to harvest, total soluble solids, total sugar and Beta-carotene. Moderate heritability obtained for characters like polar circumferences of fruit, equatorial circumferences of fruit and days to opening first female flower.

The high heritability with high GA were recorded for the traits *viz.*, fruit yield per plant, first male flowering node, first female flowering node, number of fruits per plant, fruit weight, flesh thickness, days to harvest, number of seeds per fruit, test weight of 100 seeds, total soluble solids, total sugar and ß-carotene content. The results suggested that selection would be effective for improvement due to preponderance of additive gene action in the expression of these characters. Rest of the characters showed low to moderate heritability, indicating high influence of environmental factors on expression of these characters. Rasul *et al.* (2013) [10] have suggested that characters with high heritability coupled with high genetic advance would respond better to selection than those with high heritability and low genetic advance.

Table 1: The estimates of genotypic and phenotypic variance and other genetic parameters for different characters in pumpkin

Sr. No	Characters	$\sigma^2 g$	$\sigma^2 p$	GCV (%)	PCV (%)	H^2_{bs} (%)	GA % Mean
1	Fruit yield per plant	3.42	3.90	39.71	42.42	87.61	76.57
2	Days to opening of first male flower	10.30	14.94	7.04	8.48	68.94	12.04
3	Days to opening of first female flower	9.67	16.09	6.00	7.74	60.08	9.58
4	First male flowering node	7.42	8.70	20.76	22.49	85.24	39.49
5	First female flowering node	7.37	9.04	17.06	18.89	81.56	31.74
6	Number of fruits per plant	0.07	0.08	26.12	29.50	78.36	47.62
7	Days to harvest	134.94	156.84	11.78	12.70	86.04	22.50
8	Polar circumferences of fruit	28.03	85.16	7.03	12.25	32.91	8.31
9	Equatorial circumferences of fruit	49.15	90.00	10.38	14.04	54.61	15.80
10	Fruit weight	1.01	1.23	21.86	24.01	82.90	41.00
11	Flesh thickness	77.75	81.51	27.79	28.45	95.39	55.91
12	Number of seeds per fruit	5886.31	6994.22	24.72	26.94	84.16	46.71
13	Test weight of 100 seeds	6.31	7.71	14.88	16.44	81.84	27.72
14	Total soluble solids	1.24	1.29	21.68	22.07	96.50	43.88
15	Total sugar	0.42	0.42	47.83	47.95	99.53	98.23
16	Beta – carotene	0.45	0.45	24.22	24.35	98.97	49.64

Correlation co-efficient

Correlation studies have been done at both genotypic and phenotypic level. The perusal of the data revealed that the correlation at the genotypic as well as phenotypic levels has the same trend for most of the traits studied. The magnitude of genotypic correlation coefficients was relatively higher than the corresponding phenotypic correlation coefficients in almost all the characters paired indicated the inherent association between various characters (Table 2). Similar result was obtained by sultana *et al.* (2015) [13]. Lower phenotypic correlation coefficients than genotypic correlation coefficients indicate that both genotypic and environment correlation in those study act in same direction, and finally maximize their expression at phenotypic level.

In present study Fruit yield per plant had highly significant positive association with number of fruits per plant (rg = 0898 and rp = 0.878), fruit weight (rg = 0.943 and rp = 0.875), flesh thickness (rg = 0.961 and rp = 0.915), polar circumferences of fruit (rg = 0.533 and rp = 0.377), equatorial circumferences of fruit (rg = 0.677 and rp = 0.514) and total soluble solids (rg = 0.378 and rp = 0.329) at both the levels. While, negatively and significantly correlated with days to opening first female flower (rg = -0.243) at genotypic level only. This increase in all above character would result in increase the fruit yield per plant. The result confirmed the findings of shivananda *et al.* (2013) [11] and Tamilsevi *et al.* (2012) [14].

A significant positive correlation was also obtained between days to opening of first male flower and days to opening of first female flower (rg = 0.967 and rp = 0.713). This suggests that earliness and late in days to opening of first male and days to opening of first female flower simultaneously, and this could be linked to enhance pollination efficiency in plant. Positive genetic correlation was reported between the days to opening of first male flower and days to opening of first female flower in pumpkin (Kumar *et al.* 2005).

Four component characters *viz.*, first male flowering node, first female flowering node, days to opening of first male flower and days to opening of first female flower showed positive and significant correlation with each other at genotypic as well as phenotypic levels indicating possibility of simultaneous improvement for these traits. A similar result was observed for these four characters by Kumar *et al.* (2011) [8]. The picture become more clear when correlation co-efficient was partitioned into direct and indirect effects by path analysis at genotypic level

Table 2: Genotypic (below diagonal) and phenotypic correlation (above diagonal) among different characters in pumpkin.

Character	FYP	DOFM	DOFF	FMFN	FFFN	NOF	DTH	PCF	ECF	FW	FT	NOS	TW	TSS	TS	ß-Car
FYP	1.000	-0.041	-0.215	-0.031	-0.119	0.878**	-0.048	0.377**	0.514**	0.875**	0.915**	0.044	0.172	0.329**	-0.046	0.108
DOFM	-0.041	1.000	0.713**	0.855**	0.722**	-0.081	0.343**	-0.132	-0.016	-0.091	-0.009	0.128	0.104	0.069	0.224**	0.284*
DOFF	-0.243*	0.967**	1.000	0.664**	0.686**	-0.156	0.389**	-0.240*	-0.200	-0.280*	-0.191	0.105	0.024	-0.177	0.136	0.206
FMFN	0.003	1.067**	0.880**	1.000	0.758**	-0.067	0.318**	-0.210	-0.011	-0.091	-0.045	0.189	0.128	0.071	0.157	0.311**
FFFN	-0.124	0.986**	1.067**	0.926**	1.000	-0.085	0.287**	-0.208	-0.006	-0.189	-0.123	0.126	0.140	-0.150	0.100	0.286*
NOF	0.898**	-0.083	-0.140	-0.009	-0.075	1.000	-0.025	0.444**	0.304**	0.591**	0.794**	0.018	0.094	0.324**	-0.189	0.044
DTH	-0.081	0.385**	0.542**	0.381**	0.373**	-0.056	1.000	-0.002	-0.187	-0.080	-0.053	0.019	0.073	-0.247*	0.011	-0.055
PCF	0.533**	-0.336**	-0.186	-0.332**	-0.493**	0.652**	-0.109	1.000	-0.024	0.337**	0.388**	0.153	-0.129	0.086	-0.078	0.063
ECF	0.677**	-0.090	-0.329**	0.027	-0.126	0.390**	-0.323**	-0.418**	1.000	0.588**	0.520**	-0.009	0.282*	0.146	0.119	0.088
FW	0.943**	-0.154	-0.368**	-0.107	-0.250*	0.728**	-0.119	0.430**	0.756**	1.000	0.822**	0.018	0.173	0.209	0.058	0.118
FT	0.961**	-0.037	-0.266*	-0.025	-0.117	0.863**	-0.086	0.602**	0.670**	0.907**	1.000	0.008	0.184	0.325**	-0.025	0.117
NOS	0.093	0.185	0.170	0.206	0.208	0.076	0.064	0.326**	0.018	0.029	0.007	1.000	0.024	-0.046	-0.051	0.150
TW	0.173	0.204	0.107	0.151	0.140	0.074	0.082	-0.321**	0.288**	0.198	0.220	0.040	1.000	0.133	-0.003	0.138
TSS	0.378***	0.052	-0.234*	0.076	-0.171	0.386**	-0.256*	0.183	0.191	0.243*	0.336**	-0.067	0.159	1.000	-0.006	0.038
TS	-0.049	0.275*	0.168	0.163	0.115	-0.215	0..017	-0.156	0.175	0.066	-0.026	-0.057	0.004	-0.005	1.000	-0.013
ß-Car	0.108	0.351**	0.299**	0.348**	0.322	0.042	-0.061	0.143	0.118	0.124	0.116	0.160	0.157	0.037	-0.012	1.000

*, ** Significnat at 5% and 1% levels, respectively.

FYP : Fruit yield per plant, DOFM : Days to opening first male flower, DOFF : Days to opening first female flower, FMFN : First male flowering node, FFFN : First female flowering node, NOF : Number of fruits per plant, DTH : Days to harvest, PCF : Polar circumferences of fruit, ECF : Equatorial circumferences of fruit, FW : Fruit weight, FT : Flesh thickness, NOS : Number of seed per fruit, TW : Test weight of 100 seeds, TSS : Total soluble solids, TS : Total sugar content and ß-Car : ß-carotene

Path co-efficient analysis

Path analysis breaks correlation between traits into their direct and indirect effects on the economic product, permitting a critical examination of specific trait contributing individually and collectively to produce the total effect. It also helps to measure the relative importance of each trait. Path analysis, in this study was carried out using the estimates of genotypic coefficients. The lower values of residual effect (0.00314) observed in present study indicated that the characters evaluated were associated with the fruit yield per plant and mostly all the yield attributing traits were included in the present study.

The path co-efficient analysis revealed that the highest positive direct effect was recorded in fruit weight (0.574) followed by number of fruits per plant (0.292). The positive and highly significant correlation (rg = 0.943**) obtained between fruit weight and fruits yield per plant. Although the direct selection of fruit weight, number of fruits per plant and flesh thickness had a high contribution to fruit yield per plant. Similar results were recorded by Naik *et al.* (2013).

The direct effect of flesh thickness was moderate (0.189), but its association with fruit yield per plant was positive because of positive and high indirect effect through fruit weight (0.521). Similarly, the direct effect of total soluble solids was also moderate in magnitude and positive in direction, but their indirect effects through fruit weight was very high in magnitude and positive in direction. The highest negative direct effect recorded for character like equatorial circumferences of fruit (-0.03) and polar circumferences of fruit (-0.021), but, the indirect effects of equatorial circumferences of fruit (0.434) and polar circumferences of fruit (0.247) through fruit weight were very high in magnitude and positive on fruit yield per plant. The direct effect of test weight was negative, but its indirect effect through fruit weight was very high. Similar result recorded for the polar and equatorial circumferences of fruit by Yadav *et al.* (2006) [16].

It was apparent from the path analysis that the maximum direct effect as well as appreciable indirect influences was exerted by fruit weight, number of fruits per plant, flesh thickness, first female flowering node and first male flowering node towards fruit yield per plant. These characters also exhibited positive association with fruit yield per plant. Hence, these traits may be considered as the most important yield contributing traits and due emphasis should be placed on these traits while breeding for high yield of edible fruits.

Table 3: Genotypic path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on fruit yield per plant in pumpkin (Residual effect = 0.00314)

Character	DOFM	DOFF	FMFN	FFFN	NOF	DTH	PCF	ECF	FW	FT	NOS	TW	TSS	TS	ß-Car	FYP
DOFM	-0.072	-0.009	0.043	0.109	-0.024	0.006	0.007	0.000	-0.088	-0.007	0.010	-0.006	0.005	-0.004	-0.008	-0.041
DOFF	-0.070	-0.010	0.035	0.117	0.041	0.009	0.004	0.001	-0.212	-0.050	0.009	-0.003	-0.023	-0.003	-0.006	-0.243*
FMFN	-0.077	-0.008	0.039	0.102	-0.003	0.006	0.007	-0.000	-0.061	-0.005	0.011	-0.005	0.007	-0.003	-0.007	0.003
FFFN	-0.072	-0.010	0.037	0.110	-0.022	0.006	0.011	0.001	-0.143	-0.022	0.011	-0.004	-0.017	-0.002	-0.007	-0.124
NOF	0.006	0.001	-0.000	-0.008	0.292	-0.001	-0.014	-0.002	0.418	0.163	0.004	-0.002	0.037	0.003	-0.003	0.898**
DTH	-0.028	-0.005	0.015	0.041	0.016	0.016	0.002	0.001	-0.068	-0.016	0.003	-0.002	-0.025	-0.000	0.001	-0.081
PCF	0.024	0.002	-0.013	-0.054	0.191	-0.002	-0.021	0.002	0.247	0.114	0.017	0.010	0.018	0.002	-0.003	0.533**
ECF	0.007	0.003	0.001	-0.014	0.114	-0.005	0.009	-0.003	0.434	0.127	0.001	-0.009	0.019	-0.003	-0.003	0.677**
FW	0.011	0.004	-0.004	-0.027	0.213	-0.002	-0.009	-0.003	0.574	0.172	0.002	-0.006	0.024	-0.001	-0.003	0.943**
FT	0.003	0.002	-0.001	-0.013	0.252	-0.001	-0.013	-0.003	0.521	0.189	0.000	-0.007	0.033	0.000	-0.002	0.961**
NOS	-0.013	-0.002	0.008	0.022	0.022	0.001	-0.007	-0.000	0.017	0.001	0.053	-0.001	-0.006	0.001	-0.003	0.093
TW	-0.015	-0.001	0.006	0.015	0.022	0.001	0.007	-0.001	0.114	0.042	0.002	-0.030	0.015	-0.000	-0.003	0.173
TSS	-0.004	0.002	0.003	-0.019	0.113	-0.004	-0.004	-0.001	0.140	0.064	-0.004	-0.005	0.097	0.000	-0.000	0.378**
TS	-0.020	-0.001	0.007	0.012	-0.063	0.000	0.003	-0.000	0.038	-0.005	-0.003	-0.000	-0.000	-0.016	0.000	-0.049
ß-Car	-0.025	-0.003	0.014	0.035	0.012	-0.001	-0.003	-0.001	0.072	0.022	0.009	-0.005	0.004	0.000	-0.022	0.108

*, ** Significnat at 5% and 1% levels, respectively.

FYP : Fruit yield per plant, DOFM : Days to opening first male flower, DOFF : Days to opening first female flower, FMFN : First male flowering node, FFFN : First female flowering node, NOF : Number of fruits per plant, DTH : Days to harvest, PCF : Polar circumferences of fruit, ECF : Equatorial circumferences of fruit, FW : Fruit weight, FT : Flesh thickness, NOS : Number of seed per fruit, TW : Test weight of 100 seeds, TSS : Total soluble solids, TS : Total sugar content and ß-Car : ß-carotene

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