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Studies on variability, heritability (Narrow sense) and genetic advance analysis for growth, yield and quality traits in pumpkin (*Cucurbita moschata* Duch. ex. Poir)

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Abstract
The experiments were laid out in RBD with three replications having each experimental unit of single row with spacing of 3.0 m (R×R) × 0.5 m (P×P) involving 7 parents namely, Narendra Agrim (P_1), Narendra Amrit (P_2), Narendra Upkar (P_3), NDPK-76-1 (P_4), NDPK-724 (P_5) and NDPK-39-2 (P_6) and NDPK-12-10 (P_7) of pumpkin and their 21 F_1 hybrids produced in diallel mating design excluding reciprocals at MES, Vegetable Science, NDUA.&T, Kumarganj, Faizabad (U.P.) India in *Zaid*, 2016. The observations were recorded on parents and F_1's for twenty quantitative traits including six quality traits *viz*., node number to first male flower appearance, node number to first female flower appearence, days to first male flower anthesis, days to first female flower anthesis, days to first fruit harvest, vine length (m), internodal length (cm), number of primary branches per plant, fruit weight (kg), number of fruits per plant, equatorial circumference of fruit (cm), polar circumference of fruit (cm), flesh thickness (cm), fruit yield per plant (kg), and six quality/biochemical traits namely ascorbic acid, reducing sugars (%) non-reducing sugars (%), total sugars (%), dry matter content and total soluble solids. Analysis of variance revealed that the mean square differences due to genotypes, parents and hybrids were found highly significant for all the traits. The mean squares due to parents *vs.* hybrids was also found significant for all traits studied in experiment except for node number to first male and female flower appearance, days to first male and female flower anthesis, days to first marketable fruit harvest, average fruit weight and total sugars. The highest phenotypic as well as genotypic coefficients of variation were observed in case of node number to first male flower appearance, vine length, fruit yield per plant recorded high estimates of PCV and GCV suggesting substantial variability for the observed traits, thereby ensuring ample scope for improvement of these traits through selection. The estimates of high heritability coupled with high genetic advance as per cent of mean were observed for node number to first male flower appearance, node number to first female flower appearance and non-reducing sugar. The most important trait fruit yield per plant had exhibited significant and positive phenotypic correlation with number of fruits per plant, average fruit weight, total soluble solids, vine length, flesh thickness, ascorbic acid content, total sugars, number of primary branches per plant, equatorial circumference of fruit and negative significant association with days to first male flower anthesis, days to first female flower anthesis, days to first fruit harvest, inter nodal length and node number to first male flower appearance at phenotypic level.

Keywords: Pumpkin (*Cucurbita moschata* Duch. ex. Poir), variability, heritability (narrow sense) and genetic advance

Introduction
Pumpkin (*Cucurbita moschata* Duch. ex. Poir) is one of the most important vegetable crop of family Cucurbitaceae. It is grown throughout the world due to its good nutritional value and also higher returns to the farmers. The centre of orgin of pumpkin is central Mexico. Pumpkin is a herbaceous annual, sexually propagated vegetable allopolyploid having chromosome number 2n=2x=40. Stem is angular, five ridged without hairs, trailing and branched. Trailing vine strikes roots at nods. Leaves are deeply or shallowly lobed not pinnatifid. Fruits have diuretic and vermetic action. Seeds are non bitter, tasty and nutritious. The flowers are large and yellow coloured with showy companulate corolla. Ovary is inferior and tricarpellary. Corolla is companulate, gamopetalous, lobed. Plants are monoecious, highly cross pollinated, entamophilous with three anthers. The word pumpkin was derived from the Greek word *pepon*, which means "large melon", something round and large.

Based on commercial significance the cultivated *Cucurbita* species rank among the 10 leading vegetable crops worldwide. China and India lead the world production and other major producers are U.S., Egypt, Mexico, Ukraine, Cuba, Italy, Iran and Turkey (Ferriol and Pico,

2008) [1]. The total area of pumpkin in India is 19,760 hectares whereas, the total production is 0.42 million tonne with productivity 21.25 mt/ha (Annonymous, 2015).
The colour of pumpkin is due to the orange pigments. The main compound are lutein and α and β-carotene, the later of which generates vitamin A in the body. Pumpkins are very versatile in their uses for cooking. Most parts of the pumpkin are edible, including the fleshy shell, seeds, leaves, and even flowers. In the United States and Canada, pumpkin is a popular Halloween and thanks giving staple. Pumpkin puree is sometimes prepared and frozen for later use.
Pumpkin is relatively high in energy and carbohydrates and a good source of vitamins, especially high caretenoid pigments and minerals. It may certainly contribute to improve nutritional status of the people, particularly the vulnerable groups in respect of vitamin A requirement. Night-blindness is a serious problem of South Asian countries. Encouraging the mass people to take more pumpkin can easily solve the problem.
The path coefficient technique developed by Wright (1921) [4] helps in estimating direct and indirect contribution of various components in building up the total correlation towards yield. On the basis of these studies the quantum importance of individual characters is marked to facilitate the selection programme for better gains.

Materials and Methods
The experimental materials for the present study comprised of six promising and diverse inbreds and varieties of pumpkin selected on the basis of genetic variability from the germplasm stock maintained in the Department of Vegetable Science, N.D. University of Agriculture & Technology, Kumarganj, Faizabad (U.P.) India. The selected parental lines *i.e*. Narendra Agrim (P_1), Narendra Amrit (P_2), Narendra Upkar (P_3), NDPK-76-1 (P_4), NDPK-724 (P_5), NDPK-39-2 (P_6) and NDPK-12-10 (P_7) were raised and crossed in the all possible combinations, excluding reciprocals, during summer, 2016 to develop 21 F_1 hybrids. The experiments were conducted in Randomized Block Design (RBD) with three replications to assess the performance of 21 F_1 hybrids and 7 parents. The treatments were planted in row to row at 3.0 m apart with a plant to plant spacing of 0.50 m. The seeds were sown on 9th March, 2017. All the recommended agronomic package of practices and plant protection measures were followed to raise good crop. Observations were recorded on fourteen economic traits including biochemical analysis *viz*., node number to first male flower, node number to first female flower, days to first male flower anthesis, days to first female flower anthesis, days to first marketable fruit harvest, number of primary branches per plant, equatorial circumference of fruit (cm), polar circumference of fruit (cm), flesh thickness (cm), internodal length (cm), vine length (m), average fruit weight (kg), number of fruits per plant, fruit yield per plant (kg), ascorbic acid (mg/100g), reducing sugars (%), non-reducing sugars (%), total sugars (%), dry matter content (%) and total soluble solids (%).The analysis of variance was carried out as suggested by Panse and Sukhatme (1967) [3].

Results and Discussion
Mean squares (Table 1) due to replications, genotypes, parents, hybrids and parents *vs*. hybrids for fourteen quantitative traits and six biochemical traits were worked out to test the significance of differences among the genotypes.
The differences due to genotypes, parents and hybrids were found highly significant for all the traits. The mean squares due to parents *vs.* hybrids were also found significant for all traits studied in experiment except for node number to first female flower appearance, days to first male flower anthesis, days to first female flower anthesis, days to first marketable fruit harvest, average fruit weight and total sugars.
The estimates of genotypic and phenotypic coefficients of variation for twenty characters are presented in Table 2. The estimates of phenotypic coefficients of variations (PCV) were higher than genotypic coefficients of variations (GCV) for all the characters. Aforementioned findings are also in close conformity with the earlier researchers *viz.,* Pandey *et al.* (2002) [5] and Dhatt and Singh (2008) [6].
The highest phenotypic as well as genotypic coefficients of variation were observed in case of node number to first male flower appearance (29.62%, 29.10 %), vine length (28.55%, 27.74%), fruit yield per plant (24.51%, 22.29 %). While, moderate phenotypic as well as genotypic coefficients of variation were observed for node number to first female flower appearance (20.37 %, 17.77%) and non-reducing sugar (19.85 %, 19.10%) and only PCV was moderate for average fruit weight (11.07%) and GCV for reducing sugars (15.80%) only GCV. Mohanty (2002) [9]; Laxmi *et al.* (2002) and Dhatt and Singh (2008) [6] also reported the high GCV as well as PCV. The moderate PCV and GCV indicated that variation could be attributed due to differences in experimental material and growing environments. Whereas, the rest of characters showed low estimates of phenotypic as well as genotypic coefficients of variation.
Estimates of heritability (in broad sense), heritability (in narrow sense) and genetic advance (in per cent of mean) for different characters is presented in Table 2. Heritability in broad sense of a character is important to the breeder since it indicates the possibility and extent to which improvement is possible through selection. It also indicates direction of selection pressure to be applied for a trait during selection because it measures relationship between parents and their progeny, hence widely used in determining the degree to which a character may be transmitted from parents to offspring. However, high heritability alone is not enough to make efficient selection in advanced generation unless accompanied by substantial amount of genetic advance (Burton, 1952) [7]. High estimate of heritability along with high genetic advance in per cent of mean provides good scope for further improvement in advance generations.
High estimates of heritability were observed for node number to first male flower appearance and vine length. Days to first male flower anthesis, days to first female flower anthesis, node number to first male flower appearance, node number to first female flower appearance, number of primary branches per plant, equatorial circumference of fruit, polar circumference of fruit, flesh thickness, internodal length, number of fruits per plant, fruit yield, dry matter content, total soluble solids, total sugars, reducing sugars, non reducing sugar and ascorbic acid exhibited high heritability, which revealed that these traits are governed by additive gene action and phenotypic selection would be effective for improvement of these traits. The earlier researchers *viz.,* Rana *et al.* (1986) [8] and Mohanty (2000) [9] also reported high heritability for either of the traits. However, the moderate estimates of heritability observed for days to first male flower anthesis, node number to first male flower appearance, node number to first female flower appearance, days to first fruit harvest, number of primary branches per plant, equatorial circumference of fruit, polar circumference of fruit and total soluble solids.

The estimates of high heritability coupled with high genetic advance as per cent of mean were observed for node number to first male flower appearance, node number to first female flower appearance, vine length, fruit yield per plant and non-reducing sugars. High heritability coupled with moderate genetic advance were observed for number of primary branches per plant, flesh thickness, dry matter content, total soluble solids and total sugars which indicating the additive gene action for these traits and the phenotypic selection could be relied upon. Kumaran *et al.* (1997) [10]; Bindu *et al.* (2000) [11] have reported high heritability with high genetic advance and Mohanty and Mishra (1999) [12] reported moderate heritability with high genetic advance and Dhatt and Singh (2008) [6] have reported high heritability accompanied by moderate to high genetic advance for most of the above traits.

Table 1: ANOVA (mean squares) for a set of 7×7 diallel cross in pumpkin

Source of Variation	d.f.	Node number to first male flower	Node number to first female flower	Days to first male flower anthesis	Days to first female flower anthesis	Days to first marketable fruit harvest	Number of primary branches per plant	Equatorial circumference of fruit (cm)	Polar circumference of fruit (cm)	Flesh thickness (cm)	Internodal length (cm)
Replications	2	0.30	0.76	0.32	10.90	9.11	0.71	24.65	3.67	0.18	0.26
Genotypes	27	8.00**	27.79**	76.08**	34.28**	36.76**	3.16**	79.66**	62.04**	0.52**	2.43**
Parents	6	6.34**	37.35**	74.05**	41.64**	40.90*	3.67**	133.54**	95.63**	0.64**	2.63**
Hybrids	20	8.31**	26.03**	78.53**	33.58**	36.05*	1.43**	56.29**	33.45**	0.33**	2.39**
Parents *vs.* Hybrids	1	11.74**	5.58	39.29	3.99	26.23	34.77**	223.65**	432.14**	3.57**	1.85*
Error	54	0.09	2.64	10.09	8.39	16.16	0.29	13.46	11.09	0.06	0.35

Source of Variation	d.f.	Vine length (m)	Average fruit weight (kg)	No. of fruits per plant	Fruit yield per plant (kg)	Ascorbic acid (mg/100)	Reducing sugars (%)	Non-reducing sugars (%)	Total Sugars (%)	Dry matter Content (%)	Total soluble solids (%)
Replications	2	0.01	0.03	0.03	0.25	0.08	0.00	0.00	0.05	0.05	0.19
Genotypes	27	2.56**	0.07*	0.69**	5.33**	3.16**	0.63**	0.48**	1.09**	1.98**	1.41**
Parents	6	3.45**	0.11*	0.74**	4.79**	1.00**	0.28**	0.51**	0.53**	2.96**	0.69**
Hybrids	20	2.15**	0.06	0.44**	4.43**	3.30**	0.73**	0.48**	1.30**	1.08**	0.37**
Parents *vs.* Hybrids	1	5.37**	0.00	5.32**	26.62**	13.40**	0.66**	0.21**	0.09	14.05**	26.55**
Error	54	0.05	0.04	0.07	0.35	0.09	0.03	0.01	0.09	0.09	0.07

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table 2: Estimates of variability parameters for growth, yield and quality traits in pumpkin

Traits/ Component of variation	Node number to first male flower	Node no. to first female flower	Days to first male flower anthesis	Days to first female flower anthesis	Days to first fruit harvest	Number of primary branches per plant	Equotorial circumference of fruit (cm)	Polar circumference of fruit (cm)	Flesh thickness (cm)	Internodal length (cm)
PCV (%)	29.62	20.37	11.62	8.58	7.50	13.91	10.52	10.93	14.16	11.39
GCV (%)	29.10	17.77	9.62	6.11	4.10	12.19	8.29	8.50	12.02	9.29
ECV(%)	5.48	9.97	6.51	6.03	6.29	6.70	6.47	6.87	7.48	6.59
h^2 (broad sense) (%)	97	76	69	51	58	92	84	83	89	86
h^2 (narrow sense) (%)	84	35	63	55	33	29	57	46	56	47
Genetic advance (% of mean)	58.93	31.93	16.42	8.97	4.61	22.00	13.46	13.62	21.04	15.60
General Mean	5.58	16.29	48.73	48.05	63.91	8.02	56.65	48.46	3.26	8.96

Traits/ Component of variation	Vine length (m)	Average fruit weight (kg)	No. of fruits per plant	Fruit yield per plant (kg)	Dry matter Conten t (%)	Total soluble solids (%)	Total Sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Ascorbic acid (mg/100 gm)
PCV (%)	28.55	11.07	19.12	24.51	11.50	11.47	13.37	16.99	19.85	16.40
GCV (%)	27.74	5.16	16.58	22.29	10.76	10.64	11.82	15.80	19.10	15.72
ECV(%)	6.71	9.80	9.53	10.18	4.06	4.27	6.24	6.25	5.38	4.67
h^2 (broad sense) (%)	98	53	90	94	96	95	92	95	97	97
h^2 (narrow sense) (%)	28	44	54	27	34	66	24	19	27	24
Genetic advance (% of mean)	55.55	4.96	29.60	41.76	20.75	20.35	21.53	30.25	37.89	31.04
General Mean	3.29	2.00	2.74	5.78	7.37	6.27	4.87	2.83	2.05	6.43

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