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Character association among yield and market related traits in pumpkin (*Cucurbita moschata* L.)

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Pumpkin (*Cucurbita moschata* L.) is a tropical vine crop belonging to the family Cucurbitaceae. It is third most important vegetable after water melon and cucumber in the world among cucurbitaceous vegetables. Pumpkin is a high value crop due to its long shelf life, availability for long period, high nutritional composition and great medicinal properties. Both mature and immature fruits are consumed as a vegetable. In India pumpkin is also known as Kashiphal or Sitaphal. Fruits of pumpkin provide a valuable source of carotenoid and ascorbic acid that have a major role in nutrition in the form of provitamin A and vitamin C as antioxidants (Jha et al. 2009). Besides of this, pumpkin fruits are also very good source of carbohydrate. Pumpkin endows 25.0 K cal energy, 92.6 g moisture, 1.4 g protein, 0.1 g fat, 4.6 g carbohydrates and 0.5 g of fiber per 100 g of edible portion (Sharma 2009). Many countries, such as The Former Yugoslav republics, Argentina, India, Brazil and America also use pumpkin traditionally as medicine for diabetes (Fu et al. 2006). Presently China contributes around 50 % in the world's pumpkin production alone. Being a traditional crop, it has a special place in Indian markets. Due to its good storage life, initially people used to store large sized pumpkin fruits on their roof for months. In the changing trend instead of large sized pumpkin now days consumer prefers small sized lush green color fruits of about 1-1.5 kg weight, to full fill the requirement of a nuclear family. Though, pumpkin is a nutritionally rich and economically cheaper crop and may be considered as a hope to fight against hunger and malnutrition, the crop improvement in right direction is still needed. Research on variability and association between yield and other traits is utmost important in any crop improvement program. Indian breeding program is generally focused on yield traits. Farmers need high yielding varieties to maximize their profit, but market is demanding small sized fruits. The palatability of such small fruits is also high but small fruited genotypes have a drawback as these genotypes are less yielder as compare to big fruit sized genotypes. In such condition plant breeding plays an important role and provide a scope to develop such varieties which full fill requirement of both farmers and consumers. Any crop species needs to improve requires proper planning an effective breeding program for that crop. It would be more meaningful if the structure of yield is probed through its component traits rather than yield (Grafius, 1964). According to Santos and Vencovsky (1986) correlations are useful for simultaneous selection efficiency which saves time and labor. Therefore, knowledge of interrelationship among different trait is very important in plant breeding program to determine yield components which can be used for genetic improvement of cultivars for yield. Local cultivars or landraces saved and cultivated by farmers are the main reservoir of desirable genes. These neglected germplasms possess various agronomic and horticultural characteristics of interest. These genotypes could be exploited further to develop new varieties with desirable traits once the correlation among all traits is thoroughly studied. With this objective present study was attempted to evaluate the inter relationship among yield and market related traits in pumpkin genotypes.

The above objective was kept in mind and the experiment was executed during spring-summer season of 2018 and 2019 at Vegetable Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar which is situated 243.4 meters above sea level in the foot hills of sub-mountainous region of Shivalik hills, and known as *tarai* region. During summer season in month of March when average temperature range is 28 to 30 C pumpkin performs quite well. Forty diverse genotypes (including two checks) of pumpkin were

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collected from different parts of the country. Two standard check varieties Pusa Biswas and Pusa Vikas were obtained from IARI, New Delhi. The experiment was laid out in Randomized Block Design with three replications. The crop was raised adopting all standard agronomical practices. Each genotype had 5 plants to evaluate and spaced at 3 m distance between the channels and 1 m spacing plant to plant was maintained by thinning. Observations were recorded timely and appropriately on 19 horticultural traits *viz*., main vine length (m), diameter of main vine (cm), nodes to female flower, days to first female flower, male female flower ratio, days to first harvest, number of harvest, fruit set %, average fruit weight (kg), fruits per vine, seeds per fruit, fruit diameter (cm), flesh thickness (cm), central cavity (cm), total soluble solids (brix), ascorbic acid (mg/100g), carotenoid content (mg/100g), carbohydrate content (g/100g) and yield per plant (kg). Statistical analysis was done using website of OPSTAT, Hisar. Coefficients of correlation were estimated according to the formula given by Searle (1961). Ascorbic acid was measured with volumetric method and carotenoid pigment estimated using acetone as suggested by AOAC (1990). Determination of total carbohydrates was done using anthrone reagent method as proposed by Hedge and Hofreiter (1962).

During present study both genotypic and phenotypic correlation coefficient was studied. In general the values of genotypic correlation coefficient were higher than phenotypic correlation coefficient, indicating less environmental governance and strong inherent genotypic relationship between the characters studied. Genotypic correlation coefficient is more stable and primarily important for any plant breeder for genetic improvement because it is heritable (Singh and Narayanan, 2015). Therefore, only genotypic correlation coefficient is explained in the study. The inter correlation among yield and its components was estimated during first season and second season of experiment. The pooled data of both the seasons is presented in Table 1. The economic trait yield per plant reported highly significant positive correlation with average fruit weight (0.810), fruit set percent (0.323), fruit diameter (0.281), flesh thickness (0.289), central cavity (0.219), main vine length (0.395) and carotenoid content (0.379) in the pooled data of both the seasons. Therefore, these traits would be effective for simple selection and selection for any of these characters would simultaneously improve the fruit yield. Fruit flesh thickness significantly influenced the fruit weight and hence the yield. The r value is high for

Table 1: Genotypic correlation among different traits of pumpkin genotypes (Pooled data)

	LMV	DMV	NFF	DFF	MFFR	DFH	NOH	FS%	AFW	FPV	SPF	DIA	FL	CAV	TSS	AA	CARO	CAR
LMV	1.000	0.372**	0.095	0.096	-0.166	-0.170	0.029	0.145	0.292**	-0.152	-0.125	0.474**	0.587**	0.343**	0.310**	-0.137	0.250**	-0.06
DMV		1.000	0.098	0.080	-0.177	0.520**	0.547**	0.412**	0.289**	-0.162	-0.002	0.439**	0.211*	0.428**	0.053	0.237**	-0.005	-0.16
NFF			1.000	0.224*	0.312**	-0.223*	0.103	0.213*	0.144	-0.130	-0.142	0.185*	0.293**	0.113	0.000	0.140	0.221*	0.06
DFF				1.000	0.302**	-0.114	0.365**	0.171	0.065	-0.062	0.209*	0.279**	0.224*	0.249**	0.192*	-0.219*	0.158	0.203
MFFR					1.000	-0.067	-0.141	-0.170	-0.069	0.006	-0.016	-0.041	0.253*	0.037	0.085	0.157	0.065	0.04
DFH						1.000	0.408**	0.402**	-0.084	0.026	-0.141	0.253**	-0.192*	-0.228*	-0.090	-0.158	-0.103	-0.18
NOH							1.000	0.423**	0.076	0.049	0.060	0.147	0.096	0.135	0.179	-0.051	0.131	0.371
FS%								1.000	0.206*	-0.014	0.212*	0.295**	0.494**	0.172	-0.037	0.063	0.166	0.14
AFW									1.000	0.830**	0.093	0.334**	0.171	0.319**	-0.073	0.075	0.265**	-0.12
FPV										1.000	-0.019	0.304**	-0.041	0.329**	0.088	0.080	-0.153	0.09
SPF											1.000	0.253**	0.121	0.251**	0.187*	-0.106	0.007	0.02
DIA												1.000	0.528**	0.961**	0.085	0.050	0.364**	-0.09
FL													1.000	0.272**	0.328**	-0.157	0.198*	0.05
CAV														1.000	-0.009	0.106	0.349**	-0.13
TSS															1.000	0.317**	0.231*	0.246
AA																1.000	-0.206*	-0.252
CARO																	1.000	0.17
CARB																		1.00
YPP																		

MVL (Main vine length), DMV (Diameter of main vine), NFF (Nodes to female flower), DFF (Days to first female flower), MFFR (Male female flower ratio), DFH (Days to first harvest), NOH (Number of harvest), FS% (Fruit set%), AFW (Average fruit weight), FPV (Fruits per vine), SPF (Seeds per fruit), DIA (Fruit diameter), FL (Flesh thickness), CAV (Central cavity), TSS (Total soluble solids), AA (Ascorbic acid), CARO (Carotenoid content), CARB (Carbohydrate content), YPP(Yield per plant)

average fruit weight that means its association between yields is also strong and useful. The findings of this study were in accordance with Ullah et al. (2012) who showed that fruit diameter and flesh thickness correlated positively and significantly with fruit yield in cucumber.

However, average fruit weight (-0.830) and fruit yield per vine (-0.367) had negative relation with fruits per vine according to the pooled data of both the seasons. This might be due to the fact that increase in fruit size reduces the fruits per vine due to the source and sink relationship in pumpkin plants. More the size of fruit more the accumulation of dry matter and it ultimately increases the average fruit weight. A big fruit with high average fruit weight leads to increase in yield per plant as compare to more number of small sized fruits per vine. Lovely (2001) and Priya (2001) also noted decrease in fruit size as the number of fruits increases per vine in water melon and ash gourd, respectively. During the study genotypes PPU-27(First season S_1= 3.53 kg, Second season S_2= 2.67 kg) and PPU-16 (S_1= 3.17 kg, S_2= 2.97 kg) reported maximum fruit weight even more than check variety Pusa Vikas (S_1= 2.48 kg, S_2= 2.10 kg) and Pusa Biswas (S_1= 2.80 kg, S_2= 1.94 kg). Significantly more fruit yield also reported during both the seasons. Genotypes which produced more number of fruits per vine with small fruits are PPU-13(6.4 fruits, S_1= 1.51 kg), PPU-18 (6.5 fruits, S_1= 1.31 kg), PPU-29 (6.0 fruits, S_1= 1.63 kg) and PPU-31 (6.0 fruits, S_1= 1.71 kg) during first season and PPU-21 (6.2 fruits,S_2= 1.71kg), PPU-31(6.2 fruits, S_2= 1.39 kg), PPU-24(6.1 fruits, S_2= 1.66 kg) and PPU-13(6.3 fruits, S_2= 1.50kg) during second season.

Days required to first harvest was negatively inter related to number of harvest (-0.408), fruit set percent (-0.402), average fruit weight (-0.084), fruit diameter (-0.253), flesh thickness (-0.192), central cavity (-0.228) and non-

Table 2: Morphological characterization of pumpkin fruits

Genotypes	Fruit colour at green stage	Fruit flesh colour at ripening stage	Fruit shape	Ridges availability	Fruit size
PPU-1	Green	Yellow	Round	Intermediate Ridged	Medium
PPU-2	Green	Orange	Round	Intermediate Ridged	Medium
PPU-3	Deep green	Deep orange	Round	Highly Ridged	Large
PPU-4	Green	Orange	Round	Ridged	Small
PPU-5	Whitish Green	White	Elongated	Superficially Ridged	Large
PPU-6	Green	Orange	Round	Intermediate Ridged	Medium
PPU-7	Light green	Yellow	Round	Smooth	Large
PPU-8	Green	Orange	Flat	Intermediate Ridged	Medium
PPU-9	Green	Orange	Round	Intermediate Ridged	Large
PPU-10	Green	Orange	Round	Intermediate Ridged	Medium
PPU-11	Green	Deep orange	Bell shaped	Highly Ridged	Medium
PPU-12	Deep green	Orange	Round	Intermediate Ridged	Large
PPU-13	Deep green	Yellow	Round	Superficially Ridged	Small
PPU-14	Green	Deep orange	Flat	Highly Ridged	Large
PPU-15	Green	Yellow	Round	Intermediate Ridged	Small
PPU-16	Whitish green	Yellow	Highly flat	Highly Ridged	Large
PPU-17	Green	Yellow	Oval	Superficially Ridged	Small
PPU-18	Green	Yellow	Round	Intermediate Ridged	Large
PPU-19	Whitish green	Orange	Round	Intermediate Ridged	Large
PPU-20	Whitish green	Orange	Round	Intermediate Ridges	Medium
PPU-21	Whitish green	Yellow	Oval	Intermediate Ridged	Large
PPU-22	Green	Orange	Round	Ridged	Medium
PPU-23	Whitish green	Yellow	Flat	Smooth	Small
PPU-24	Green	Deep orange	Round	Highly Ridged	Medium
PPU-25	Green	White	Flat	Ridged	Large
PPU-26	Green	Orange	Round	Ridged	Medium
PPU-27	Whitish green	Yellow	Oval	Smooth	Large
PPU-28	Deep Green	Yellow	Round	Ridged	Large
PPU-29	Green	Yellow	Round	Ridged	Small
PPU-30	Green	Orange	Round	Ridged	Small
PPU-31	Deep Green	Deep orange	Elongated	Smooth	Small
PPU-32	Green	Orange	Round	Ridged	Large
PPU-33	Green	Yellow	Round	Ridged	Small
PPU-34	Green	Orange	Flat	Ridged	Medium
PPU-35	Green	Yellow	Round	Highly Ridged	Small
PPU-36	Green	Orange	Round	Highly Ridged	Small
PPU-37	Whitish green	White	Elongated	Smooth	Small
PPU-38	Green	Yellow	Round	Ridged	Large
Pusa Vikas	Green	Orange	Round	Intermediate Ridged	Large
Pusa Biswas	Light green	Yellow	Oval	Superficially ridged	Large

significant negative association with yield per plant (-0.09) was observed in the pooled data. Early maturing genotype showed lower yields while the late maturing varieties had higher yields. Similar findings were reported by Singh et al. (2008) in ridge gourd, Ullah et al. (2012) in cucumber and Jena et al. (2017) in pointed gourd. Trait number of nodes to first female flower reported significant and positive association with days to first female flower (0.224) which means early fruit setting was reported in genotypes showing less number of nodes to first female flower anthesis subsequently yield would also be high in such genotypes. Such findings may help in developing early varieties. Thakur et al. (2017) also showed similar results in bottle gourd. As the finding of this study genotype Pusa Vikas (6.41), PPU-23 (6.80) and PPU-34 (6.88) produced female flowers at earliest node in both the seasons thus starts early fruit setting. Number of harvests was significantly and positively associated with fruit set percent (0.423) and carbohydrate content (0.371). It indicates selection of genotypes for number of harvests would simultaneously select genotypes for fruit set percent and carbohydrate content.

It was found in this study that number of seeds per fruit showed positive significant interrelation with fruit diameter (0.253) and central cavity (0.251) in the pooled data of both the seasons. This might happen due to large cavity area available for seed development. This information would help in developing varieties with good seed yield in commercial seed production program. Deepthi et al. (2016) found similar results in bottle gourd. Qualitative trait carotenoid content showed significant positive association with yield per plant (0.379) in pooled data of both the seasons. Kumar et al. (2018) also noticed increase in carotenoid content with increase in fruit yield of pumpkin. Number of fruits per vine was negatively associated with carotenoid content (-0.153). This might happen due to distribution of carotenoid content in more number of fruits leading to less amount of distribution in each fruit. During present study genotypes reported to have high carotenoid content (mg/100g) are PPU-3(S_1=1.35 mg, S_2=1.27 mg), PPU-12(S_1=1.40 mg, S_2=1.27 mg), PPU-16(S_1=1.28 mg, S_2=1.29 mg) and Pusa Vikas (S_1=1.40 mg, S_2=1.23 mg) during both the seasons. Pooled data for ascorbic acid content shows that it had negative inter relation with TSS (-0.317), carotenoid content (-0.206) and carbohydrate content, (-0.252). Shiv prasad et al. (2017) in musk melon and Tamil selvi et al. (2012) in pumpkin observed similar decrease in ascorbic acid content with increase in TSS and carotenoid content.

Various morphological traits of pumpkin fruits which are important from market point of view were also observed and recorded in Table 2. For vegetable purpose consumer generally prefer lush green coloured small to medium sized round fruits. In mature fruits Orange to deep orange fruits are preferred by Indian consumers. According to the market demand one can select desired genotypes for further genetic improvement program. In general, it is challenging to full fill the requirement of both the consumer and farmers. In case of pumpkin, consumers need small sized fruit while farmers require cultivars with high yield. It is excellent if we land on a cultivar which proves ideal for all the traits but if it is not possible than we can depend on cultivars which are somewhat close to this idealism. During this study we have found that four cultivars *viz.,* PPU-27 (403.0 q/ha), PPU-16 (392.8 q/ha), PPU-14 (380.1 q/ha) and PPU-12 (365.0 q/ha) found promising for yield as against standard check Pusa Biswas (355.6 q/ha).Genotypes PPU-13 (6.3 fruits, 1.50 kg) and PPU-31 (6.1 fruits, 1.55 kg) were ideal for market demand as they produced average more number of small sized fruits during both the seasons. Genotypes reported to have high carotenoid content (mg/100g) are PPU-12 (1.33 mg), PPU-3 (1.31 mg), Pusa Vikas (1.31 mg) and PPU-16 (1.28 mg). Therefore, these genotypes can either be used as source material for development of desired genotypes or may be utilized as commercial cultivar after following standard release procedure as well as for future breeding program in pumpkin.

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