International Journal of Plant Breeding ©2012 Global Science Books

Genetic Variability and Inter-Relationship among some Nigerian Pumpkin Accessions (*Cucurbita* spp.)

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ABSTRACT

Ten Nigerian pumpkin accessions were evaluated during the 2007 and 2008 planting seasons to estimate the magnitude of genetic variability and the character association among some yield characters. The results revealed wide genetic variability among the accessions. The genotypic and heritabilty estimates were high in days to 50% emergence, days to 50% flowering, fruit diameter and number of seeds/fruit in both planting seasons. However, genotypic and heritability estimates were low in number of male and female flowers at both planting seasons. At both plantings, the number of seeds/fruit had a significant ($P < 0.01$) positive correlation with the number of male flowers/plant and fruit diameter. A significant positive correlation was also obtained between the number of female flowers and the number of fruits/plant in both planting seasons, an indication that both traits increased or decreased simultaneously. Thus, increasing the number of female flowers would favour fruiting in pumpkin. In both planting seasons, path analysis revealed that days to 50% flowering had the highest positive direct effect on fruit weight and also, had a high direct contribution to the fruit yield. The significant positive correlation between the weight of harvested fruits and fruit diameter in the 2007 planting season was due to the combination of the direct and indirect effects of fruit diameter to fruit yield. In 2008 planting, the number of female flowers recorded high positive direct effects on the weight of fruits/plant but its influence was nulified by the high negative indirect effects (-0.46) of number of fruits/plant. The results indicated that days to flowering, fruit diameter and number of seeds/fruit can be used as selection criteria to increase fruit yield in Nigerian pumpkins.

Keywords: genotypic coefficient of variation (GCV), heritability (broad sense), path-coefficient, phenotypic coefficient of variation (PCV)

INTRODUCTION

Pumpkin (*Cucurbita* spp.) is one of the cucurbitacous fruit vegetables consumed and relished by most local people in Nigeria and in the sub-Saharan Africa. It is important as a good source of minerals, fibres, vitamins, antinutrients, antioxidants and phytonutrients (Pandey *et al.* 2003; Pratt and Matthew 2003; Ward 2007; Aruah *et al.* 2010a; Atuonwu and Akobundu 2010) and this makes the fruit wholesome and healthy for human consumption. Some authors have reported that pumpkin fruits have high medicinal values (Jones 1996; Keleş *et al.* 2001; Sentu and Debjani 2007; Mahasneh and El-Oqlah 1999; Abd El-Aziz and Abd El-Kalek 2011). The different parts of the plant have also been used as medicine in the developed world and the leaves are haematinic, analgesic, and also used externally for treating burns (ayurvedakalamandiram.com). Traditionally, the pulp is used to relieve intestinal inflammation or enteritis, dyspepsia and stomach disorders. Pumpkin seed is an excellent source of protein and also has pharmacological activities such as anti-diabetic (Li *et al*. 2003), antifungal (Wang and Ng 2003), antibacterial and antiinflammation activities (Fu *et al*. 2006) and antioxidant effects (Nkosi *et al*. 2006).

Despite its health and dietary benefits, the production of pumpkin in Nigeria is mostly done on a small scale and the average yield of the crop is low. However, cultivation of this multi-purpose and nutrient rich food crop is most desirable for the purpose of overcoming the problems of undernourishment and food poverty most especially in the sub-Saharan and arid regions of the world. With current emphasis on consumption of fruits and vegetables to promote good health and longevity, it is expected that consumption and the demand of pumpkins may be increased in Nigeria and, this increase must be matched with an increase in pumpkin production. A large number of pumpkin accessions are cultivated in Nigeria but no serious attempts have been made to improve them for higher productivity and acceptability.

Therefore, there is a need to improve the productivity and fruit yield of the crop to meet the nutritional and dietary need of the people most especially the rural populations who are among the poorest and most vulnerable to malnutrition and poverty. This can be achieved through vigorous breeding programs. The success of any crop improvement program depends, to a large extent, on the amount of genetic variability present in the population. Very few research works relating to variability of pumpkin accessions have been conducted in Nigeria. So, intensive research efforts are needed in several areas particularly in selection of superior pumpkin genotypes. There is wide genetic variability among the existing pumpkin accessions (Ferriol *et al.* 2003, 2004; Aruah *et al*. 2010b; Aliu *et al*. 2011) and thus, the utilization of such variability in the crop's breeding programmes is possible. The breeding programs depend on the knowledge of key traits, genetic systems controlling their inheritance, genetic and the environmental factors that influence their expression. Presently, there is dearth of information about the genetic systems controlling their inheritance in the crop.

Fruit yield is a complex character that is determined by complex associations among several agronomic traits (Chandra *et al.* 1990; Rao *et al*. 1990). An effective breed-

Received: 21 July, 2011. Accepted: 23 September, 2011.

Original Research Paper

Table 1 List of *cucurbita* genotypes showing the source of collection.

Accession No/Code	Name of the accession	Place of collection	Ecological zone
V1	Ogo-mega	Ogoja, Cross River State	Rain forest
V2	Ugwu-Lng	Ugwuoba, Enugu State	Derived savanna
V3	Uvu-Wart	Uvuru, Enugu State	Derived savanna
V4	Jos-Vari	Jos, Platuea State	Guinea savanna
V5	Akw-01	Akwanga, Nassarawa State	Guinea savanna
V6	Akw-02	Akwanga, Nassarawa State	Guinea savanna
V7	Akw-03	Akwanga, Nassarawa State	Guinea savanna
V8	Awka-RV	Awka, Anambara State	Derived savanna
V9	Ugwu-Rnd	Ugwuoba, Enugu State	Derived savanna
V10	Ngwo-Wart	Ngwo, Enugu State	Derived savanna

Table 2 Monthly rainfall (mm), temperature (°C), and the relative humidity during the 2007 and 2008 planting seasons.

Month	2007 planting season				2008 planting season			
	Temp. (°C)		RF (mm)	RH (%)	Min.	Max.	RF (mm)	RH (%)
	Min.	Max.						
April	22.67	32.67	121.66	74.53	22.00	29.73	143.00	74.83
May	21.90	31.13	193.55	76.32	21.81	30.16	254.01	75.00
June	21.83	29.37	327.66	77.53	20.82	28.83	186.43	76.93
July	21.20	28.50	62.99	78.74	20.84	28.94	246.1	87.16
August	21.87	27.65	323.60	79.06	20.68	27.81	203.20	79.55
September	21.37	28.27	169.67	78.07	20.80	27.60	362.02	78.67
Average	21.81	29.60	199.86	77.38	21.15	25.85	232.46	78.69

RH: relative humidity, RF: rainfall, Temp: temperature

ing programme aimed at improving fruit yield of a crop requires information on the nature and magnitude of variability. Thus, the assessment of the magnitude of variability present in the crop would help in the successful utilization of the crop characters in developing suitable cultivars for yield and yield stability (Singh *et al.* 1985). Therefore, to plan an efficient pumpkin breeding program, it is necessary to have an understanding of its genetic and breeding systems, information on the character association in pumpkin is very poor and this had made the improvement of the crop practically difficult. In a crop selection program, knowledge of the interrelationships among yield and yield contributing characters are necessary. Thus, the determination of correlation among the characters is important in selection. Correlation studies among yield and other traits of the crop will be of interest to breeders in planning hybridization programmes and evaluating the individual plants in the segregating populations. But, it does not give an exact contributions of the various characters on the fruit yield. Path analysis would help in partitioning the correlation coefficient into direct and indirect effects of various traits on the fruit yield. The current study was undertaken to estimate the genetic variability, heritability, character association and the direct and indirect contributions of some yield characters towards fruit yield in the Nigerian pumpkin accessions.

MATERIALS AND METHODS

Ten Nigerian pumpkin accessions (**Table 1**) were evaluated in 2007 and 2008 planting seasons in the the research field of the Department of Crop Science, University of Nigeria, Nsukka (Lat. 06° 52′ N; Long. 07° 24′ E; Alt. 447.2 m a.s.l.). The research field contains the “B” soil type in University of Nigeria, Nsukka soil survey map. It is a well drained ferrallitic sandy loam soil of Nkpologu series and, the monthly temperature, rainfall distribution, number of rainy days and the relative humidity are presented in **Table 2**. The experimental design used was a randomized complete block design (RCBD) with three replications. Each block had 10 plots measuring 8 × 8 m each. The planting space was 2 m × 2 m. Each plot had four tagged sample plants of one accession. The tagged plants were in the middle of the plots to avoid border effect. Ten kilogrammes of well cured pig dung (equivalent to 174 kg/ha) were applied to each plot before planting. Weeding was done manually to keep weed pressure low.

The data on some agronomic characters were collected using the standard descriptor lists developed by the International Plant Genetic Resources Institute (IPGRI) for Cucurbitacaeae (Esquinas-Alcázar and Gulick 1983). The data collected comprised; days to 50% emergence, days to 50% flowering, number of female flowers, number of male flowers, number of fruits/plant, weight of harvested fruits/plant, fruit diameter and number of seeds/fruit. The values for the agronomic characters were taken as the mean value of four measurements made on four tagged plants.

Data analysis

The data collected were subjected to analysis of variance (ANOVA) to establish the level of viability existing among the Pumpkin accessions using Genstat Discovery Edition 3 software (Genstat 2007). The phenotypic variation for each trait was partitioned into genetic and non-genetic factors and estimated according to Comstock (1952), Johanson *et al.* (1955); Uguru (2005):

$$V_p = MS_g/r;\ V_g = (MS_g\text{-}MS_e)/r;\ V_e = MS_e/r$$

where V_p, V_g and V_e are phenotypic variance, genotypic variance and environmental variance, respectively, and MS_g, MS_e and r are the mean squares of genotypes, mean squares of error and number of replications, respectively.

To compare the variations among traits, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and environmental coefficient of variation (ECV) were computed according to Allard (1960); Burton (1952):

$$PCV = \sqrt{Vp}/_X \times 100;$$

$$GCV = \sqrt{Vg}/_X \times 100;$$

$$ECV = \sqrt{Ve}/_X \times 100$$

where $\bar{X}$ is the grand mean for each of the traits measured.

Broad sense heritability (h^2) was also calculated according to Burton and DeVane (1953), Allard (1960) as the ratio of the genotypic variance (V_g) to the phenotypic variance (V_p) expressed in percentage. Correlations were calculated to examine inter-character relationships among the traits using SPSS for Windows Version 16.0 while the path coefficient analyses were done to determine the contribution of each agronomic trait to fruit yield using the analysis for moment structures (AMOS) software program.

Table 3 Mean square and genetic parameters for some quantitative traits in 10 *Cucurbita* accessions in the 2008 planting season

Traits	MS	mean	Vp	Vg	Ve	PCV	GCV	ECV	$H^2B\%$
2007 planting season									
D50%E	13.130**	4.5	4.337	4.164	0.173	46.279	45.346	9.243	96.011
D50%F	17.959**	28.7	5.986	4.781	1.205	8.525	7.619	3.825	79.870
NFF	1.911	6.27	0.637	-0.13	0.767	12.729	5.75	13.968	20.408
NMF	242.1	44.3	80.7	33.6	47.1	20.278	13.085	15.492	41.636
NFP	2.967*	6.57	0.989	0.626	0.363	15.137	12.043	9.170	63.296
WHF	11.022**	3.67	3.674	3.382	0.292	52.228	50.110	14.724	92.052
FD	349.729**	68.86	116.576	113.381	3.195	15.680	15.463	2.596	97.259
NSF	28540.0**	335.4	9513.333	9299.733	213.6	29.081	28.752	4.358	97.755
2008 planting season									
D50%E	2.463**	7.17	0.821	0.733	0.088	12.637	11.941	4.137	89.281
D50%F	24.181*	29.97	8.06	5.496	2.564	9.473	7.822	5.343	68.189
NFF	1.781	4.23	0.594	0.13	0.723	18.220	8.524	20.102	21.886
NMF	242.1	41.34	78.7	30.66	48.04	21.459	13.394	16.601	38.958
NFP	1.496	3.87	0.499	0.044	0.454	18.253	5.420	17.411	8.818
WHF	87.90	4.9	29.3	5.91	23.39	110.468	49.613	98.700	20.171
FD	320.159**	58.79	106.72	106.591	0.1288	17.572	17.561	0.610	99.879
NSF	28540.0**	315.4	9513.333	9299.733	213.6	30.925	30.575	4.634	97.755

D50%E: days to 50% emergence, D50%F: days to 50% flowering, NFF: number of female flowers, NMF: number of male flowers, NFP: number of fruits per plant, WHF: weight of harvested fruits per plant, FD: fruit diameter per plant, NSF: number of seeds per fruit.

RESULTS AND DISCUSSION

Genetic variability

The mean squares and genetic parameter estimates of 10 Nigerian pumpkin accessions in the 2007 and 2008 planting seasons are presented in **Table 3**. The analysis of variance showed that the mean squares for the accessions were significant ($P < 0.05$) for number of fruits/plant and highly significant ($P < 0.01$) for days to 50% emergence, days to 50% flowering, weight of harvested fruits/plant, fruit diameter/plant and number of seeds/fruit in the 2007 planting. In the 2008 planting, days to 50% emergence, fruit diameter and number of seeds/fruit were found significant at $P < 0.01$ while days to 50% flowering was significant among the accessions only at 5% probability level. The significant differences observed among the accessions in most of the traits at both planting seasons suggest the existence of an inherent genetic variability among the accessions. The observed variability among the accessions were mostly contributed by the days to 50% emergence, fruit diameter and number of seeds/fruit. Knan *et al*. (2009) have earlier reported the existence of a wide genetic variation among the Pointed gourd (*Trichosanthes dioica* Roxb) accessions with respect to the number of leaves, flowers, and fruits/plant and seed characters. Significant differences have also been reported in all the vegetative and reproductive parameters evaluated in crops like Cucumber, (Afangideh and Uyoh 2007) and okra, *Abelmoschus esculantus* (Singh *et al.* 2004). Enormous genetic variations among the accessions are needed for effective and successful selection programme (Nausherwan *et al.* 2008).

The phynotypic variance was partitioned into heritable (genotypic variance) and non-heritable (environmental variance) components in both 2007 and 2008 planting seasons (**Table 3**). In the 2007 planting, the magnitude of genotypic variance for days to 50% emergence, days to 50% flowering, weight of harvested fruits/plant, fruit diameter/plant, number of seeds/fruit and number of fruits/plant were higher than the environmental variance and, the phenotypic and genotypic variances were observed to be similar. This is an indication that the genotypic component of variation was the major contributor to the total variation during the 2007 planting. The environmental variance of the above traits were observed to be very low indicating that the environment had very little effect on the observed phenotypic variations of the traits. This would therefore suggest that days to 50% emergence, days to 50% flowering, weight of harvested fruits/plant, fruit diameter/plant, number of seeds/fruit and number of fruits/plant have broad variation and, hence improvement can be achieved through the imposition of selection on the traits. The phenotypic coefficient of variation (PCV) was highest (52.228%) in weight of harvested fruits/plant followed by days to 50% emergence (46.279%), number of seeds/fruit (28.752%), number of male flowers (20.278%) in that order. High PCV is an indication of the existence of wide scope of selection for the improvement of the traits from a considerable amount of variability present (Knan *et al*. 2009). Thus, a greater potential is expected in the selection for these characters. A comparatively low PCV observed for fruit diameter (15.680%), number of fruits/plant (15.137%), number of female flowers (12.729%) and days to 50% flowering (8.525%) is indicative of less scope for improvement (Okoye and Ene-Obong 1992). The genotypic coefficient of variation provides a measure to of genetic variability present in various quantitative characters. The highest estimates of GCV were observed for weight of harvested fruits/plant (50.11%), followed by days to 50% emergence (45.346%) and number of seeds/fruit (28.752 %) while number of fruits/plant (12.043%), days to 50% flowering (7.619%), and number of female flowers (5.75%) recorded low GCV. High GCV indicates the prescence of exploitable genetic variability for these traits which may facilitate selection (Yadav 2000). The environmental coefficient of variation varied from 2.596% for fruit diameter to 15.492% for number of male flowers. Nausherwan *et al.* (2008) reported that polygenic variation may be phenotypic, genotypic or environmental and the relative values of the three coefficients give an idea about magnitude of the variability.

A narrow range of difference between PCV and GCV was recorded for days to 50% emergence (46.279 and 45.346), days to 50% flowering (8.525 and 7.619), number of fruits/plant (15.137 and 12.043), weight of harvested fruits/plant (52.228 and 50.110), fruit diameter/plant (15.680 and 15.463) and number of seeds/fruit (29.081 and 28.752) indicating that the traits are mostly governed by genetic factors with minimal environmental influence on the phenotypic expression of the traits. Thus, selection of these traits on the basis of their phenotypic values may be effective. However, our results showed that wide variation existed between the PCV and GCV in the number of female flowers (12.729 and 5.75) and number of male flowers (20.278 and 13.085) indicating high influence of environment on the traits thereby reducing the response to selection on phenotypic basis. The GCV values only are not enough to determine the the level of genetic variability among genotypes (Ibrahim and Hussein 2006; Shukla *et al.* 2006). Thus, GCV can further be investigated with the help of heritability estimates. While coefficients of variation measure the magnitude of variability present in a population, heritability indicates the reliability with which the genotype will be recognized by its phenotypic expression (Chandraba and Sharma 1999). The high heritability (broad sense) estimates observed for days to 50% emergence (97.259%), number of seeds/fruit (97.755%), fruit diameter/plant (97.259%), weight of harvested fruits/plant (92.052%), days to 50% flowering (79.870%) and number of fruits/plant (63.296%) are indicators of minimal environmental influence in the expressions of these characters. These characters can be accorded significant attention in selections aimed at pumpkin improvement. Shadakshari *et al.* (1995); Shan and Mishra (1995), reported that high heritability estimates provides a clue that the characters would exhibit high response to selection. Moderate (41.636%) and low (20.408%) heritability estimates were observed in number of male and female flowers, respectively. The low GCV and heritabibilty obtained for number of male and female flowers in the 2007 planting implies that direct selection on the basis of number of male and female flowers/plant may not produce the desired results for improvement in a pumpkin breeding programme.

The mean squares, genotype and phenotypic variance, GCV, PCV and broad sense heritability for eight agronomic traits in 2008 planting season are shown in **Table 3**. The mean squares values showed significant genotype effects at $P < 0.05$ in days to 50% flowering and, at $P < 0.01$ in fruit diameter/plant and number of seeds/fruit. This result is in tandem with the results obtained for the traits in the 2007 planting. These observations validate the existence of considerable and exploitable variations in the accessions evaluated. The magnitude of genotypic variance of fruit diameter per plant and number of seeds/fruit was higher than the environmental variance. The differences between the phenotypic and genotypic variances of days to 50% emergence (0.821 and 0.733), days to 50% flowering (8.06 and 5.496), fruit diameter/plant (106.72 and 106.591) and number of seeds/fruit (9513.333 and 9299.733) were very narrow during the 2008 planting seasons. This result was also in line with the results obtained during the 2007 planting suggesting that the genotypic component of the above traits should be considered as the major contributor to the phenotypic expresions observed among the accessions. Thus, the traits would respond to selection. However, the wide variations was observed between the magnitude of phenotypic and genotypic variance for number of female flowers, number of male flowers, number of fruits/plant and weight of harvested fruits/plant are indications of little contributions of the genotypic variances with respect to traits. The results also indicated that the environmental variance of the above traits had a stronger influence on the phenotypic expressions.

The level of variability during the 2008 planting season revealed that the estimates of phenotypic and genotypic coefficient of variations were high for weight of harvested fruits/plant (110.468 and 49.613, respectively) and number of seeds/fruit (30.925 and 30.575, respectively). In the contrary, the remaining traits were found to have a low PCV and GCV estimates. The differences between PCV and GCV were very small for days to 50% emergence (12.637 and 11.941), days to 50% flowering (9.473 and 7.822), fruit diameter (17.572 and 17.561) and number of seeds/fruit (30.925 and 30.575) which is an indication of minimal effect of the environment on the above mentioned agronomic traits. However, the wide range between PCV and GCV values observed for number of female flowers, number of male flowers, number of fruits/plant and weight of harvested fruits/plant suggest large influence of environment on the traits. Thus, selection based on the number of female flowers, number of male flowers, number of fruits/plant and weight of harvested fruits/plant may not be an effective means of improving the fruit yield. High heritahbility values were recorded for fruit diameter (99.88%), number of seeds/fruit (97.76%), days to 50% emergence (89.28%) and days to 50% flowering (68.19%) while number of male flowers had low heritability (38.958%). Also, low heritability estimates of 21.886%, 20.171% and 8.818% were obtained for number of female flowers, weight of harvested fruits/plant and number of fruits/plant, respectively. The high heritability estimates obtained in some of the traits are indications that selection could be effective for improving such traits. Afangideh and Uyoh (2007) reported high heritability value of 94% for days to flower initiation in cucumber (*Cucumis sativus* L). The moderate to low heritability estimates make selection considerably difficult or virtually impossible due to the masking effect of the environment on the genotypic effects (Singh 1993). The low heritability values obtained for weight of harvested fruits per plant, is not surprising since fruit yield is a product of many complex traits. This means that the direct selection of pumpkin based on fruit yield may not produce the desired result but wholistic approach involving the yield determining traits may be more reliable. Akinwale *et al.* (2011) have reported low broad sense heritability for the number of tillers per plant, 1000-grain weight and seed yield (t/ha) in rice (*Oryza sativa* L.) which indicates the influence of the environment on these traits. Weight of harvested fruits per plant and number of fruits per plant showed lower GCV and heritability in 2008 planting when compared with the 2007 planting. These values were also lower and at variance with the GCV and Hs values reported for fruit yield and number of fruits in cucumber by Afangideh and Uyoh (2007). Days to 50% emergence, days to 50% flowering, fruit diameter per plant and number of seeds per fruit showed less variation between PCV and GCV and was accompanied by a high heritability at both planting seasons. These traits should be considered for selection because it is most likely that the traits is controlled by additive gene effects.

Correlation

The results of the correlation coefficient among some agronomic traits of *Cucurbita* spp. studied during 2007 and 2008 planting season are shown in **Table 4**. At both plantings, number of seeds/fruit correlated positively and significantly ($P < 0.01$) with number of male flowers (r = 0.480** and 0.481** for 2007 and 2008, respectively) and fruit diameter (r = 0.631** and 0.619** for 2007 and 2008, respectively). This suggests that increase in the number of male flowers and fruit diameter would lead to an increase in the number of seeds that will be produced. The number of seeds/fruit increased with increase in the number of male flowers, indicating that the number of seeds produced in the crop is influenced by the number of male flowers. This means that increase in the number of male flowers would result in higher pollen production and therefore, enhance fertilization and seed production. Picken (1984) reported similar results in tomato fruits. The positive and significant correlation obtained between the number of seeds/plant and fruit diameter is in line with the previous report by Stephenson *et al.* (1988) that fruits with low seed numbers would be about 17% smaller than fruits with high seed numbers. It is therefore probable that Cucurbita genotypes that have the ability to produce higher number of male flowers and large fruit size would produced higher number of seeds. Therefore a breeder interested in the improvement of pumpkin seed yield could select plants with large fruit and/or higher number of male flowers, and be fairly certain of obtaining high seed yielding plants. The selection to increase seed yield would invariably result in increased fruit yield in pumpkin (Afangideh *et al.* 2005). A significant positive correlation was also obtained between number of male flowers and number of female flowers (r = 0.358* and 0.358*, for 2007 and 2008, respectively) at both planting dates. This suggests that the number of male and female flowers increases or decreased simultaneously and thus could be linked to enhanced pollination efficiency in the plant. Positive genetic correlation was reported between the number of male and female flowers in crops like monoecious herb, *Begonia semiovata* (Agren and Schemske 1995) and wild rose, *Rosa canina* (Bilir 2011). A similar trend was also reported in an earlier study on the number of male and female flowers in

Table 4 Correlation coefficients among yield traits and weight of harvested fruit per plant of 10 accessions of cucurbita under 2008 planting season.

Traits	D50%E	D50%F	NMF	NFF	NFP	FD	NSF	WHF
2007 planting season								
D50%E	1							
D50%F	-.479**	1						
NMF	-.037	.160	1					
NFF	-.180	.078	**.358***	1				
NFP	-.264	.134	.179	.378*	1			
FD	-.325	.368*	.293	.154	.426*	1		
NSF	.003	.222	**.480****	.085	.281	**.631****	1	
WHF	-.198	**.435***	.342	**.427***	.530**	.544**	.505**	1
2008 planting season								
D50%E	1							
D50%F	.271	1						
NMF	-.054	-.131	1					
NFF	.232	-.052	**.358***	1				
NFP	.273	-.033	.226	**.946****	1			
FD	.286	**.507****	.315	.179	.177	1		
NSF	-.222	.145	**.481****	.108	.112	**.619****	1	
WHF	.015	**.556****	.131	.205	.165	.354	**.396***	1

D50%E: days to 50% emergence, D50%F: days to 50% flowering, NMF: number of male flowers, NFF: number of female flowers, NFP: number of fruits per plant, FD: fruit diameter per plant, NSF: number of seeds per fruit, WHF: weight of harvested fruits per plant

different plant species by Bilir *et al.* (2005); Varghese *et al.* (2008); Nicodemus *et al.* (2009). The significant positive correlation observed between number of female flowers and the number of fruits/plant at both planting seasons is an indication that both traits increase or decrease simultaneously and thus, genotypes that produced higher number of female flowers/plant would as well produced higher number of fruits/plant. However, days to 50% emergence had non significant correlations with most of the agronomic traits evaluated indicating that it had minimal and non-significant contributions to the crop's fruit yield and development.

In 2007 planting season, significant positive correlation of weight for harvested fruits with days to 50% flowering (r = 0.435*), number of female flowers (r = 0. 427*), number of fruits/plant (r = 0.530**) and fruit diameter/plant (r = 0.544**), number of seed/fruit (r = 0.505**) were observed. This indicates that weight of harvested fruit increased with the increase in the number of days to flowering, number of female flowers, number of fruits/plant, fruit diameter/plant and number of seeds/fruit. The positive significant correlation obtained between fresh fruit weight and days to 50% flowering is in line with the earlier result by Cramer and Wehner (2000). Thus, accessions that flowered too early had higher rates of flower abscission resulting in low fruit yields, as did those that flowered late or reached 50% flowering after the heavy rains. Saha *et al.* (1992) and Khan *et al.* (2009) have also reported similar results in pumpkin and pointed gourd, respectively. The positive significant correlation obtained between weight of fruits/plant and number of fruits/plant indicates that yield per plant will be increased with the increase in the number of fruits. These results are in consonance with the findings of Singh (1983) and Singh *et al.* (1993) in pointed gourd, Panwar *et al.* (1977) in sponge gourd and Rana (1982) in pumpkin. The positive correlation obtained between the weight of harvested fruit and the number of seeds/fruit is in agreement with the results obtained in sweet pepper (*C. annuum* L.) (Rylski 1973) and in tomato (*Lycopersicon esculentum* Mill.) (Picken 1984). These positive and strong associations of the above characters with weight for harvested fruits revealed the importance of the characters in determining fruit yield and show that selection for these traits would result in superior fruit yield. However, the negative significant correlation between days to 50% emergence and days to 50% flowering is an indication of an inverse relationship existing between the above two traits. Thus, early seedling emergence in the pumpkin would lead to the extension of the crops vegetative stage. During the 2008 planting season, weight of healthy fruits had a positive and significant relationship with days to 50% flowering (r = 0.556**) and number of seeds/fruits (r = 0.396*). This is an indication that weight of healthy fruits increases with increase in the days to flowering and number of seeds per plant. This result was not in an agreement with Mohanty (2002) who reported that early flowering at lower nodes and higher number of flowers/plant, particularly the female flower, increased fruiting. There were also significant positive correlation between days to 50% flowering and fruit diameter (r = 0.507**) suggesting that the increase in the vegetative growth phase of the plant would result in a simultaneous increase in the fruit diameter.

Path coefficient analysis

Yield is a complex character and is associated with a number of component characters which may be interrelated among them. Such inter-dependence of the contributing factors often affects their direct relationship with yield, thereby making correlation coefficients unreliable as selection indices. Path coefficient analysis permits the separation of direct effects from the indirect effects through other related characters by partitioning the correlation coefficients. It helps not only to identify the cause and effect relationship between yield and component characters but also the relative importance of each, as they affect the yield both directly and indirectly. Partitioning of the total correlation into direct and indirect effects would provide actual information on the contribution of traits and thus form the basis for selection to improve the yield.

The direct and indirect effects for weight of harvested fruits/plant using the seven agronomic traits during the 2007 and 2008 plantings are presented in **Table 5**. The path diagrams showing the cause and effect relationships of weight of harvested fruits and its components are presented in **Figs. 1** (2007 planting) and **2** (2008 planting). At the two planting seasons, the path coefficient analysis revealed that all the direct effects were positive except for the number of male flowers. In the 2007 planting, the days to 50% flowering showed highest positive direct effect (0.33) towards weight of harvested fruits followed by number of female flowers (0.28), number of fruits/plant (0.28), number of seeds/friut (0.24) and fruit diameter (0.16) while days to 50% emergence recorded the lowest positive direct effect of 0.14. The positive and significant correlation (r = 0.5451**) obtained between the weight of harvested fruits and fruit diameter was because of the contribution of both the direct and indirect effects of fruit diameter to fruit weight. Thus, the direct selection of fruit diameter and the indirect selections of fruit diameter via number of seeds/fruit, number of fruits/plant and days to 50% flowering can be emphasised in every breeding programme aimed at the improvement of the crop. Rashwan (2011) reported a very strong positive

Table 5 Path analysis showing direct [diagonal (in **bold**)] and indirect influence of quantitative traits on weight of harvested fruit per plant on *Cucurbita* accessions under 2007 planting seasons.

	Indirect effects via							Total indirect effect	Correlation
	NSF	**FD**	**NFP**	**NFF**	**NMF**	**D50F**	**D50E**		
2007 planting season									
NSF	**0.2400**	0.1008	0.0784	0.0252	-0.0096	0.0726	0.0000	**0.2674**	**0.5074****
FD	0.1512	**0.1600**	0.1204	0.0420	-0.0058	0.1221	-.0448	**0.3851**	0.5451**
NFP	0.0672	0.0688	**0.2800**	0.1064	-0.0036	0.0429	-.0364	**0.2453**	**0.5253****
NFF	0.0216	0.0240	0.1064	**0.2800**	-0.0072	0.0264	-.0266	**0.1446**	0.4246*
NMF	0.1152	0.0464	0.0504	0.1008	**-0.0200**	0.0528	-.0056	**0.3600**	0.3400
D50F	0.0528	0.0592	0.0364	0.0224	-0.0032	**0.3300**	-.0672	**0.1004**	0.4304*
D50E	0.0000	-0.0512	-0.0728	-0.0532	0.0008	-0.1584	**0.1400**	**-0.3348**	0.1948
2008 planting season									
NSF	**0.5000**	-0.1922	-0.0528	0.0792	-0.0384	0.0975	0	-0.1067	0.3933*
FD	0.3100	**-0.3100**	-0.0864	0.1296	-0.0256	0.3315	0	**0.6591**	0.3491
NFP	0.0550	-0.0558	**-0.4800**	0.6840	-0.0184	-0.0195	0	**0.6453**	0.1653
NFF	0.0550	-0.0558	-0.4560	**0.7200**	-0.0288	-0.0325	0	-0.5181	0.2019
NMF	0.2400	-0.0992	-0.1104	0.2592	**-0.0800**	-0.0845	0	0.2051	0.1251
D50F	0.0750	-0.1581	0.0144	-0.0360	0.0104	**0.6500**	0	-0.0943	0.5557**
D50E	-0.1100	-0.0899	-0.1296	0.1656	0.0040	0.1755	**0**	0.0156	0.0156

D50%E: days to 50% emergence, D50%F: days to 50% flowering, NMF: number of male flowers, NFF: number of female flowers, NFP: number of fruits per plant, FD: fruit diameter per plant, NSF: number of seeds per fruit, WHF: weight of harvested fruits per plant

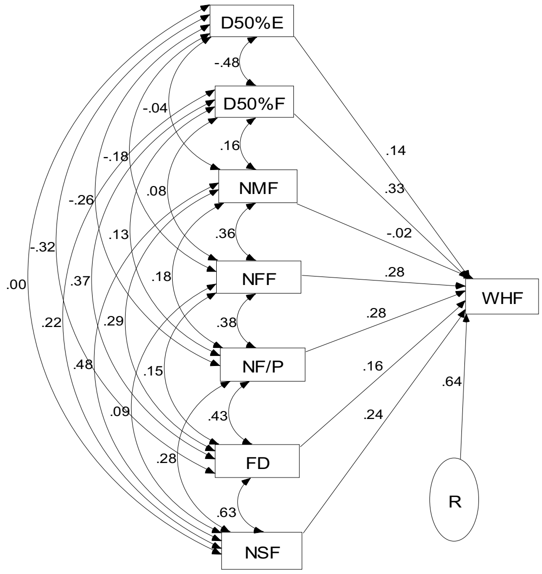

Fig. 1 Path diagram representing cause and effect relationships among yield traits and yield in *Cucurbita* spp. during the 2007 planting season.

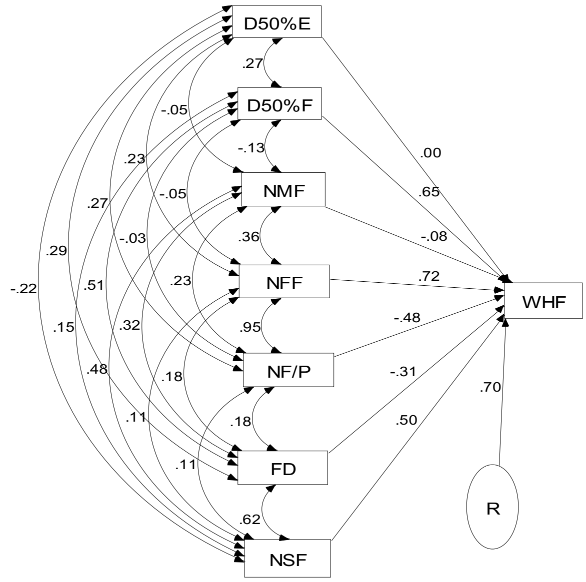

Fig. 2 Path diagram representing cause and effect relationships among yield traits and yield in *Cucurbita* spp during the 2008 planting season.

relationship between fruit diameter and total fruit yield in okra, *Abelmoschus esculentus* (L.) Similarly, fruit diameter is one of the traits that recorded highest direct and indirect effect towards total fruit yield and thus, a dependable trait for the improvement of pumpkins. The number of seeds per fruit and number of fruits/plant showed highly significant positive correlation with the weight of harvested fruits/plant due to the combined contributions of the direct and indirect effects of the two traits to fruit weight. Although, the direct selection of number of seeds/fruit had a high contribution to fruit yield in 2007 planting, the indirect selections of number of seeds/fruit via fruit diameter and number of fruits/plant via number of seeds/fruit and fruit diameter could also be adopted for improving the fruit yield. Thus increase in the fruit weight were not only influenced by the direct effects of the number of seeds/fruit but also by the indirect selection of accessions with high number of seeds/plant and large fruits could be effective in increasing the fruit weight. In 2008 planting, days to 50% flowering had the maximum direct effect on weight of healthy fruit. This result confirms the previous result obtained in the 2007 planting. The result indicated that the positive and significant correlation obtained between the weight of harvested fruits and days to 50% flowering at both planting season was due to the high direct contribution of the days to 50% flowering to their total correlation. Considering the high direct contributions of days to 50% flowering to the weight of harvested fruits and its association with fruit yield, it would appear that the most reliable selection criteria for fruit yield improvement. Similar result has been reported by Vijay (1987) in muskmelon. The number of seeds/fruit had a high direct effect on the weight of harvested fruit in the 2008 planting and this resulted to the positive significant corration obtained between the two traits. Number of seeds/fruit has been previously reported to have a direct and positive contribution on the green fruit yield of chilli (*Capsicum annuum* L.) (Karnataka 2008). The result suggested that due emphasis should be given to the genotypes that are having more number of seeds in the selection process, due to its high positive direct effect on fruit yield. The fruit diameter (-0.66) and number of fruits/plant (-0.65) were observed to have high negative direct effects on fruit weight. However, the high indirect effects of fruit diameter and number of fruits/plant on fruit weight obtained did not produce significant correlations betwen the fruit weight and the above traits due to the masking effect and supresing action of their direct effects. Number of female flowers (0.72) was observed to have high positive direct effects on weight of fruits/plant but its influence was nulified by the negative indirect effects through number of fruits per plant (-0.46) which resulted in the non significant negative correlation observed between the weight of fruits/plant and number of female flowers. This showed that the indirect selection via number of female flowers is efficient than the direct selection of number of female flowers. Although, the correlations of weight of harvested fruits with number of male flowers were not significant, highest positive indirect effect was recorded in number of male flowers via number of seeds/fruit (0.24) and number of female flowers (0.26) suggesting that increase in the fruit yield were to some extent, influenced by the above traits. Therefore, the indirect selection of genotypes with higher number of seeds and female flowers could be effective in increasing the fruit yield.

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