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Estimates of genetic variability in ultraviolet irradiated populations of summer squash

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Summer squash is an important member of the family Cucurbitaceae. It is one of the most popular vegetable crops cultivated in Egypt. Increasing yield and improving fruits quality are the targets for growers. Therefore, this study aimed to evaluate the extent of genetic variations, heritability, as well as expected genetic advance for growth and yield related traits in four genotypes of summer squash subjected to three doses of ultraviolet irradiation. Data were subjected to the analysis of variance for the important components of yield and agronomic traits. The results showed relatively small differences between phenotypic and genotypic variance for the number of leaves per plant, chlorophyll concentrations in leaves, and fruits. Larger magnitude of difference was obtained between phenotypic and genotypic coefficient of variations in the expression of leaf area, female flowers, male flowers developed per plant, and carotenoids concentration in fruits, indicating that environmental factors played predominance role in the expression of these traits. Moderate heritability value was obtained for fruits weight per plant coupled with high genetic advance as a percentage of mean. Therefore, selection based on the phenotypes will improve the mean performance of fruits weight per plant in the selected progenies.

Key words: Summer squash, ultraviolet irradiation, genetic components, genetic advance, heritability.

INTRODUCTION

Summer squash is the edible immature fruit which belongs to the economically important family Cucurbitaceae. Summer squash, *Cucurbita pepo* L. generally displays more male flowers and few female flowers. This leads to lowering its fruit yield. The sex expression of *C. pepo* L. is resolved by genetics and ambience as photoperiods, temperature, etc. This crop was cultivated in Egypt for local consumption, as well as for foreign exporting market. It contains a huge amount of vitamins A, C, E, B6, niacin, thiamin, and minerals (Bose et al., 2000). Increasing squash yield and fruit quality are the main targets for breeders. *C. pepo* L. is native to North America and the wild types can be found in northeastern Mexico and central USA (Paris, 2008). Kooistra (1967) found a clear effect of temperature and day length on cucurbits sex expression. Furthermore, long days and high night temperatures induced shift towards increased male flowers and decreased female flowers. Whereas, low temperatures and short photoperiod increased female flowers and decreased male flowers. This may affect pollination and fruit setting. This will cause decrease of its fruit yield in summer

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season compared to the early spring season. *C. pepo* L. is a cross pollinated vegetable crop having a diploid number of chromosomes (2n = 2X = 40) which is cultivated for its fruits to be used in human nutrition (Jasim and Esho, 2021). The sexual development in summer squash is monoecious, occurring in separate locations on the same plant, as well as isolated in the leaf axils. Furthermore, female flowers are usually less numerous than male flowers perhaps they have an impact on the carrying of elongated ovary (Filgueira, 2008).

Induced mutations in *C. pepo* via UV irradiation have been used to generate genetic variability which successfully utilized to improve yield and its components in summer squash. Mutagenesis is a potential tool to be employed for summer squash improvement (Khan et al., 2006). To create high-yielding genotype in summer squash requires the existing genetic variations for yield and its components. The phenotypic variability observed included genetic and environmental causes. The estimates of heritability alone do not indicate a knowledge about the expected genetic gain in the next generation, but have need to estimates of genetic advance, the change in mean value between generations (Wani and Khan, 2006). The relative performance of different genotypes differed in different environments because of genotype by environment interaction. The reliability of genotype expression across different environmental conditions was an important consideration in plant breeding program. A successfully developed new genotypes may have a stable genetic expression and broad adaptation over a wide range of environmental conditions, as well as to high yielding potential (Azad et al., 2009).

Summer squash prevails high degree of genetic variability due to the presence of high percentage of out crossing (Hanelt and Mettin, 1989). A large genetic variability identified in summer squash including floral biology, fruit size, fruit colour, fruit composition, tolerance to biotic and abiotic stresses, and yield potential efficiency (Duc et al., 2010). It is obvious that genetic gain from selection depending on the genetic variations and the magnitude of the heritable protein of these genetic variations. Thus, the information about the degree of genetic variations exist in summer squash is critical to design a suitable breeding program (Fikreselassie and Seboka, 2012).

Variability is the presence of genetic variations among individuals due to the differences in their genetic background and/or the environment in which they live (Falconer and Mackay, 1996). Effective selection needs information about the nature and magnitude of genetic variations across populations (Yagdi, 2009). The selection of promising genotypes from large genetic base in the population to be subjected with a sequence utilization for hybridization is a good tool for improving the productivity of summer squash (Mulugeta et al., 2013). The highest production of summer squash was referred to Turkey, Italy, Egypt, Spain, USA, and Mexico (Paris, 2008). It is so considered that Egypt is the most famous *C. pepo* producer. Egypt imports seeds of some squash genotypes that need agricultural production. The main objectives for squash breeders are earliness, productivity, tolerance or resistance to biotic and abiotic stress, and fruit quality (Loy, 2004).

UV-B irradiation (280-315 nm) when applied on plants can cause damage in the DNA structure of the plants. It induced reduction in stem length and number of floral (Kumari et al., 2021). Squash cultivars varied among genotypes in the number of male flowers per plant, number of fruits developed per plant, average weight of fruit, fruit diameter, number of seeds per fruit, and the content of chlorophyll a. Exposure period of 30 min irradiated squash cultivars with ultraviolet rays (UV-C) significantly increased the number of male flowers and chlorophyll content. The few exposure time to UV rays may cause the plant to be resistant to oxidative stress generated by UV rays by increasing antioxidants as phenols and proline, leading the plant more resistant to environmental stress (Hammok and Esho, 2022). In addition, Singh et al. (2022) found early flowering and early edible fruit maturity in brinjal under 5 KR of gamma irradiation. Under these doses of gamma rays, the fruit yield per plant was increased but under the increasing concentration of mutagen; the plants showed an adverse effect for all growth and yield traits among genotypes. Agronomic traits in potatoes treated with low doses of UV observed yield increased slightly. Similarly, photosynthetic and physiological traits were significantly increased. In addition, the synthesis of tuber nutrient as flavonoids, anthocyanins, vitamin C, phenols and chlorogenic acids were increased due to the expression of their structural genes. Meanwhile, the higher doses of UV-B irradiation caused greater damage in the pigmentation traits making the plants reduce the yield and tuber nutrients (Wu et al., 2023). In Balsam apple, Bammanakatti et al. (2023) observed high heritability for the number of fruits per plant in M_1 and M_2 generations, whereas fruit yield per plant showed positive association with fruit length and days to flowering. Meanwhile, the number of fruits per plant, fruit weight, fruit length, and fruit girth showed highest positive effect on fruit yield per plant.

Therefore, this study attempts to partition the variance components for morphological, physiological, and yield components in M_1 generation of summer squash released from UV-irradiated genotypes. These estimates are very important in developing reliable selection indices.

MATERIALS AND METHODS

The experiment was conducted at the experimental Agri Farm of Genetic Department inside the campus of Mansoura University

Table 1. Summer squash genotypes used in this study.

Genotype	Designation
Alexandarani	Genotype 1
1116228	Genotype 2
1116232	Genotype 3
1116237	Genotype 4

Table 2. Expectation mean squares derived from the analysis of variance.

Source of variations	Degrees of freedom	Mean squares	Expectation mean squares
Replications	r-1	MSr	$\sigma^2e + r\,\sigma^2g + g\,\sigma^2r\,\sigma$
Genotypes	g-1	MSg	$\sigma^2e + r\,\sigma^2g$
Error	(r-1) (g-1)	MSe	σ^2e

r = Number of replications, g = Number of genotypes, MSe = Error mean square, MSg = Genotypic mean square, MSr = Replications mean square, σ^2e = Error variance, σ^2g = Genotypic variance, σ^2r = Replication variance.

during the successive season of 2022, to study the effect of UV irradiation on the genetic variability of vegetative growth, sex expression, pigment concentration in leaves and fruits, as well as yield and its components. All agricultural practices of *C. pepo* L. were carried out as recommended by Egyptian Ministry of Agriculture.

Genetic material

Four genotypes of summer squash were used in this study (Table 1). Seeds of these genotypes were kindly provided by the gene bank of Agricultural Research Center, Giza, Egypt.

Ultraviolet irradiation

Seeds of all genotypes were soaked for 12 h before UV-irradiation according to Ehrenberg (1961). Irradiation was done in the laminar cabinet supported with UV lamp as an artificial source of UV rays which is present in the Laboratory of Microbial Genetics, Faculty of Agriculture, Mansoura University. The spectrum of UV-radiation usually used in mutation is high energy named UV-B (280-320 nm) (Barta et al., 2004). The spectrum of UV lamp used in this study was 300 nm, therefore it was classified as UV-B. Each minute of exposure to UV-radiation generated 188.2 joules/m^2 according to Kondrateva et al. (2020). The joules are defined as the amount of energy extracted when a force of one newton is applied over a displacement of 1 m which is equivalent to 1 W of power radiated for 1 s.

Experimental design

The seeds of all genotypes were irradiated with the laminar UV lamp at room temperature of 20 ± 3 for 0, 4, 8 and 12 min. By the end of treatment, seeds were sown directly into the soil in a randomized complete block design with three replicates. Each plot consisted of 16 ridges with 80 cm width and 3 m length. The seeds were sown on one side of ridge with 50 cm apart. The plants in each experimental plots were fertilized with the chemical fertilization of urea nitrogen at a rate of 320 kg of nitrogen/ha, as well as all agricultural service were applied from hoeing, weeding, controlling diseases, and insect infestations as recommended by the Egyptian Ministry of Agriculture in productive fields (Hammok and Esho, 2022).

Experimental measurements

After 45 days from sowing date, six plants were randomly chosen from each plot to measure the number of leaves per plant, number of male and female flowers per plant all over the flowering and fruiting period, chlorophylls pigments in leaves and fruits. Sex ratio was recorded by dividing the average number of female by male flowers. Fruits were harvested at two days intervals. During the fruiting period, the average fruit weight was recorded. Fruit yield was calculated as the number of fruits and the weight of fruits per plant. Sex ratio was measured according to Shafeek et al. (2016). Flowering traits and fruits yield were measured according to Abou El-Salehein et al. (2019). Photosynthetic pigments content in leaves and fruits were measured according to Arnon (1949). Plant height was measured at the end of plant life when the plants became to blooming according to Hassan et al. (2016).

Statistical analysis

The data were subjected to statistical analysis of variance procedure (Table 2), according to Snedecor and Cochran (1980).

Estimation of genetic parameters

The genetic parameters included genotypic variance (σ^2g), phenotypic variance (σ^2P), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), as well as environmental coefficient of variation (ECV) estimated according to Burton (1952) and Singh and Chaudhury (1985). Meanwhile, heritability (H) in broad sense and expected genetic advance (EGA) were estimated according to Allard (1960). The genetic advance assumed selection intensity of superior plants up to 0.05 of population. Meanwhile, the genetic advance as the percentage of

Table 3. Assessment of genetic parameters related to the number of leaves per plant in summer squash.

Doses of UV irradiation (kGy)	GV	PV	EV	H (%)	GCV (%)	PCV (%)	ECV (%)	EGA	GAM (%)
Control	038.41	042.55	004.14	90.27	031.87	059.42	27.55	12.12	40.24
4 min	350.94	481.51	130.57	72.88	160.64	188.16	27.52	32.93	96.90
8 min	028.47	054.58	026.11	52.16	048.43	067.05	18.62	08.35	27.51
12 min	023.98	135.89	111.91	17.64	037.94	090.32	52.38	04.24	10.18
Mean	110.45	178.63	068.18	58.24	069.72	101.23	31.51	14.41	43.71

GV, Genotypic variance; PV, phenotypic variance; EV, environmental variance; H (%), heritability in broad sense in percent; GCV (%), genotypic coefficient of variation in percent; PCV (%), phenotypic coefficient of variation in percent; ECV (%), environment coefficient of variation in percent; EGA, expected genetic advance; GAM, genetic advance as percent of mean at 5% selection intensity; kGy, kilo Gray of rays.

population mean (GAM) in which selection apples was assessment according to Johnson et al. (1955).

RESULTS AND DISCUSSION

Variability is the phenotypic differences among individuals within the population due to variations in their genetic composition. The magnitude of variation in populations was important for effective selection. The knowledge about nature and magnitude of diversity in plant breeding materials are very significant for the improvement of summer squash. The crop shows high degree of genetic variations due to the high percentage of out crossing. The genetic gain from selection depends upon the genetic variations, as well as on the magnitude of the heritable portion of these variabilities. Induced mutations as carried out in this study have been used to generate genetic variations in summer squash populations to be used in improving yield and its components in this crop. The variability observed in summer squash populations resulted from genetic and environmental causes, of which only the genetic component is heritable. Furthermore, assessment of heritability alone do not indicate information about the expected gain of genetic advance in the next generation, but needs in conjunction to measure the genetic advance, the change in mean value between generations.

Number of leaves

As shown in Table 3, estimated range of genotypic variance for the number of leaves per plant ranged between 23.98 and 350.94. The genotypic variance is relatively much higher than the environmental variance, indicating the greater share of genotypic variance in the total variability. Greater genotypic variance than environmental variance indicated that the genotypic effect was high for the expression of genes controlled the number leaves developed per plant. Among the number of leaves per plant, genotypic variance values exceed 20%, regarded as high effects of genotypes on the gene expression of this trait. These results indicated that this trait offered high scope of selection, as this under the influence of genotypes. These results agreed with Ahmed et al. (2008), who found high level of genotypic variance for days to maturity, spikelets per spike, grains per spike, grain-filling period, and harvest index in barley. Meanwhile, the mean of phenotypic variance (178.63) was greater than the genotypic variance (110.45) with relatively small difference which indicated that the environmental effect was lower than genotypic effect for the gene expressed the number of leaves developed per plant. Therefore, the mean of genotypic coefficient of variation was greater than the mean of environmental coefficient of variation. This indicates lower influence of environmental factors than genetic factors on the expression of leaves number developed per plant. This disagreed with Nechifor et al. (2011), who decided that high difference between genotypic coefficient of variation and phenotypic coefficient of variation is due to great influence of the environment on this trait. In this respect, Deshmukh et al. (1986) categorized phenotypic coefficient of variations as low (10%), medium ranged from 10 to 20%, and high exceeds 20%.

Heritability estimates gives insight about the extent of genetic control on the expression of trait under investigation, as well as phenotypic reliability in predicting the related breeding value (Nahar et al., 2016). Estimated heritability in broad sense ranged from 17.64 to 90.27. As decided by Robinson et al. (1949), heritability was characterized as low (0-30%), moderate ranged from 30 to 60% and high exceeds 60%. The mean of heritability obtained in this study for number of leaves per plant was equal 58.24% categorized as moderate heritability, based on the aforementioned classification. The genetic advance as percentage of means in combined analysis ranged from 10.18% at the dose of 12 min exposure to UV to 96.90% at the dose of 4 min exposure to UV. Johnson et al. (1955) reported that genetic advance as percentage of mean can be categorized as low ranging from 0 to 10%, moderate ranging from 10 to 20%, and high above 20%. The mean of genetic advance as percentage of means in combined analysis for the

Table 4. Assessment of genetic parameters for leaf area per plant in summer squash.

Doses of UV irradiation (kGy)	GV	PV	EV	H (%)	GCV (%)	PCV (%)	ECV (%)	EGA	GAM (%)
Control	0.21	1.64	1.43	12.80	15.31	42.78	27.47	0.34	43.83
4 min	0.01	0.25	0.24	4.43	03.48	16.51	13.03	0.05	01.98
8 min	0.51	1.22	0.71	41.80	05.99	14.34	08.35	0.94	44.47
12 min	0.61	0.92	0.31	66.30	24.41	29.98	05.57	1.31	51.42
Mean	0.34	1.01	0.89	31.33	12.29	25.90	13.61	0.66	35.43

GV, Genotypic variance; PV, phenotypic variance; EV, environmental variance; H (%), heritability in broad sense in percent; GCV (%), genotypic coefficient of variation in percent; PCV (%), phenotypic coefficient of variation in percent; ECV (%), environment coefficient of variation in percent; EGA, expected genetic advance; GAM, genetic advance as percent of mean at 5% selection intensity; kGy, kilo Gray of rays.

number of leaves per plant equal 43.71%, classified as high value depending on the classification of Johnson et al. (1955). These results indicated that moderate value of heritability was coupled with the high value of genetic advance as a percentage of means. Therefore, selection depending on the phenotypic performance of genotypes leads to increase in the mean performance of the selected individual plants for the number of leaves per plant. The results obtained herein agreed with Nechifor et al. (2011), who demonstrated moderate values of heritability and genetic advance for the number of seeds per pod in common bean. In addition, the low values of heritability reflected the influence of environmental factors on the trait under investigation that limit the scope of improvement through selection.

Leaf area

The results presented in Table 4 revealed that the genotypic coefficient of variation ranged between 0.01 and 0.61. Meanwhile, the phenotypic coefficient of variation ranged from 0.25 to 1.64. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation. The larger magnitude of difference between the two parameters indicates higher influence of environmental factors than the genetic elements in the expression of leaf area per plant. Therefore, selection depending on the phenotypic performance may not be appropriate for the leaf area. This indicated that the environmental factors played a considerable role on the gene expression of leaf area. Heritability percentage ranging from 4.43 to 66.30% produced the mean of heritability equals 31.33%, categorized in general as moderate heritability. Meanwhile, the phenotypic coefficient of variations is greater than the genotypic coefficient of variations for the leaf area per plant. Though, the environmental effects are predominance on the expression of genes controlled the leaf area per plant. In addition, the results showed that high difference between genotypic and phenotypic coefficient of variations reflected higher influence of environmental effects on the gene expression of leaf area. The mean of phenotypic coefficient of variations concerning leaf area is categorized as high (25.90%) because its value exceeds 20%. The estimated genetic advance as percentage of mean ranged from 1.98 to 51.42% which produced the mean value equals 35.43%.

Based on the aforementioned classification, the estimated genetic advance for leaf area per plant was high because its value exceeds 20%. Moderate heritability obtained in leaf area was coupled with high genetic advance suggesting that improvement would be partially effective through phenotypic selection. According to Blanco and Folegatti (2005), leaf area is a key variable for plant growth, photosynthetic efficiency, yield indicator, and irrigation responses. The results obtained herein are in line with Raju et al. (2002), who stated that high heritability coupled with high genetic advance in percentage of mean found in parents and hybrids of summer squash suggested that improvement would be effective through phenotypic selection.

Genetic components of female and male flowers

The results presented in Table 5 showed that the genotypic coefficient of variation for the number of female flowers per plant was higher than the environmental coefficient of variations.

Therefore, the differences between genotypic coefficient of variations and phenotypic coefficient of variations were relatively large in magnitude of female flowers developed per plant, indicating high influence of environmental effects in the expression of this trait. These results agreed with Fekry (2016), who found that ethephon recorded the best results in floral characteristics via decreasing the number of male flowers, as well as increased the number of female flowers, femaleness and yield components in summer squash. Moreover, Shafeek et al. (2016) stated that foliar application of etheral on summer squash with high level concentration (150 mg/L) induced greater number of female flowers developed per plant when compared with the control. In addition, Costa-Silva et al. (2020) found that ethylene can change the flowering pattern in zucchini

Table 5. Assessment of genetic parameters for female flowers developed per plant in summer squash.

Doses of UV irradiation (kGy)	GV	PV	EV	H (%)	GCV (%)	PCV (%)	ECV (%)	EGA	GAM (%)
Control	05.52	21.24	15.72	25.99	32.45	63.67	31.22	2.47	18.85
4 min	05.31	14.32	9.01	37.08	30.55	50.17	19.62	2.89	20.31
8 min	16.60	19.79	3.19	83.88	53.80	58.74	04.94	7.67	53.51
12 min	08.16	29.19	21.03	27.95	45.19	85.47	40.28	3.11	31.12
Mean	08.89	21.14	12.24	43.73	40.49	64.51	24.02	4.04	30.95

GV, Genotypic variance; PV, phenotypic variance; EV, environmental variance; H (%), heritability in broad sense in percent; GCV (%), genotypic coefficient of variation in percent; PCV (%), phenotypic coefficient of variation in percent; ECV (%), environment coefficient of variation in percent; EGA, expected genetic advance; GAM, genetic advance as percent of mean at 5% selection intensity; kGy, kilo Gray of rays.

Table 6. Assessment of genetic parameters for male flowers developed per plant in summer squash.

Doses of UV irradiation (kGy)	GV	PV	EV	H (%)	GCV (%)	PCV (%)	ECV (%)	EGA	GAM (%)
Control	11.23	23.19	11.96	048.43	15.30	56.21	40.91	04.80	26.20
4 min	13.08	67.33	54.25	019.43	43.24	98.10	54.86	03.28	18.76
8 min	12.03	29.69	17.66	040.51	43.07	67.67	24.60	04.55	28.06
12 min	13.62	17.63	04.02	129.44	35.98	40.94	04.96	11.17	42.49
Mean	12.49	34.46	21.94	059.45	34.39	65.73	31.34	05.95	28.88

GV, Genotypic variance; PV, phenotypic variance; EV, environmental variance; H (%), heritability in broad sense in percent; GCV (%), genotypic coefficient of variation in percent; PCV (%), phenotypic coefficient of variation in percent; ECV (%), environment coefficient of variation in percent; EGA, expected genetic advance; GAM, genetic advance as percent of mean at 5% selection intensity; kGy, kilo Gray of rays.

squash via influencing the sexual expression but not enough to show complete sex reversal.

Moderate heritability (43.73%) was obtained for the number of female flowers developed per plant coupled with high genetic advance in percent of mean (30.95%), suggesting that environmental factors play a considerable role in expressing female flowers developed per plant. These results indicated that moderate heritability of female flowers developed per plant is due to the influence of environmental factors that limits the scope of improvement by selection based on phenotypic performance of genotypes. Increasing female flowers leading to increasing squash yield which is the main target for growers. In this respect, Baruah and Sarma (2018) found that application of ethrel on *Cucumis sativus* L. improved flowering behavior via increasing the number of female flowers.

Estimated genetic components of male flowers developed per plant shown in Table 6 showed that the differences between genotypic and phenotypic coefficient of variations exhibited large values in magnitude of male flowers developed per plant. The estimated environmental coefficient of variation ranged between 4.96 and 54.86% indicating the higher effects of environmental factors than genetic factors in the gene expression developed male flowers. The heritability of this trait has a moderate value (59.45%) depending on the classification of Robinson et al. (1949). The mean of genetic advance as a percentage of means in combined analysis was high (28.88%) depending on the classification of Johnson et al. (1955). The results indicated moderate values of heritability coupled with relative increase in genetic advance for the number of male flowers developed per plant. Therefore, the results stated that moderate heritability estimates reflected high effect of environmental factors than genetic factors on the phenotypic expression of male flowers developed per plant, as well as the effectiveness of selection in improving this trait. Heritability demonstrated whether differences observed on the level of individuals arose as inducement by differences in the genotypes or due to the environmental factors.

Thus, Singh (2001) stated that a close correspondence between the genotypic and phenotypic performance is due to small contribution of environmental factors on the phenotype. In addition, traits with lower heritability leading to selection may be considerably difficult due to the masking effect of the environmental factors.

Chlorophylls in leaves

As shown from the results presented in Table 7, the differences between the mean of genotypic coefficient of variation (12.04%) and phenotypic coefficient of variation (22.12%) were relatively small, indicating that the

Table 7. Estimates of genetic parameters for chlorophyll concentrations in leaves of summer squash genotypes.

Doses of UV irradiation (kGy)	GV	PV	EV	H (%)	GCV (%)	PCV (%)	ECV (%)	EGA	GAM (%)
Control	0.05	0.196	0.150	25.51	11.83	23.43	11.60	0.23	025.98
4 min	0.03	0.110	0.080	29.09	10.39	19.28	8.89	0.19	026.72
8 min	0.15	0.155	0.008	94.94	06.02	25.19	19.17	0.76	123.02
12 min	0.07	0.073	0.005	96.84	19.94	20.59	0.65	0.54	124.79
Mean	0.07	0.133	0.060	61.59	12.04	22.12	10.08	0.43	075.13

GV, Genotypic variance; PV, phenotypic variance; EV, environmental variance; H (%), heritability in broad sense in percent; GCV (%), genotypic coefficient of variation in percent; PCV (%), phenotypic coefficient of variation in percent; ECV (%), environment coefficient of variation in percent; EGA, expected genetic advance; GAM, genetic advance as percent of mean at 5% selection intensity; kGy, kilo Gray of rays.

Table 8. Estimates of genetic parameters for fruit chlorophylls concentration in summer squash genotypes.

Doses of UV irradiation (kGy)	GV	PV	EV	H (%)	GCV (%)	PCV (%)	ECV (%)	EGA	GAM (%)
Control	0.0012	0.0018	0.0006	81.21	04.94	06.08	1.14	0.071	057.54
4 min	0.0013	0.0033	0.0022	39.39	05.55	06.79	1.24	0.047	029.41
8 min	0.0042	0.0055	0.0013	76.36	10.58	12.11	1.53	0.116	123.83
12 min	0.0020	0.0030	0.0010	66.66	06.45	07.90	1.45	0.074	061.80
Mean	0.0002	0.0007	0.0013	65.90	06.88	08.22	1.34	0.077	068.14

GV, Genotypic variance; PV, phenotypic variance; EV, environmental variance; H (%), heritability in broad sense in percent; GCV (%), genotypic coefficient of variation in percent; PCV (%), phenotypic coefficient of variation in percent; ECV (%), environment coefficient of variation in percent; EGA, expected genetic advance; GAM, genetic advance as percent of mean at 5% selection intensity; kGy, kilo Gray of rays.

observed differences in this trait were mostly due to the genotypes, but the environmental factors played a limited role in the gene expression of chlorophyll formation. Similar results were noticed earlier by Abebe et al. (2017), who observed the narrow magnitude of variation between phenotypic and genotypic coefficient of variance in rice cultivar for days to maturity, culm length, plant height, panicle length and biomass production, reflected limited influence of environmental factors in the expression of these traits. Thus, selection based upon phenotypic performance of chlorophylls concentration in leaves would be effective to bring about considerable genetic improvement.

Therefore, the mean of heritability estimates of chlorophyll concentration in leaves was relatively greater than 60% (61.59%) categorized as high heritability percentage depending on the classification of Robinson et al. (1949). High values of heritability estimates were coupled with high genetic advance (75.13%) as a percentage of mean. This indicated that selection depending on phenotypic performance of the genotypes leads to increase in the mean performance of selected progenies for photosynthesis.

Chlorophylls and carotenoids in fruits

As shown from the results tabulated in Table 8, the differences between phenotypic and genotypic coefficient of variations concerning chlorophylls concentrations in fruits were relatively small, indicating that the observed variations of this trait were mostly due to genetic elements but environmental factors were also showed a decreased role in the expression of this trait. Therefore, the heritability of this trait categorized a high value (65.90%) based on the classification of Robinson et al. (1949), who categorized heritability as high when its value reached 60% and above. High heritability obtained in this study for chlorophylls concentrations in fruits coupled with high genetic advance (68.14%) as a percent of mean.

Therefore, selection based on phenotypic expression of genotypes leads to the exhibition of the mean expression of selected progenies. The results obtained herein are in line with Manju and Sreelathakumary (2002), who decided the effectiveness of selection based on genetic advance of the selected trait along with heritability. In addition, Hailu et al. (2016) found high heritability coupled with moderate high genetic advance based on the percentage of mean for the number of productive tillers/m^2 in barley length of spike, number of kernels/spike, as well as harvest index among locations. The results obtained in this study indicated the involvement of additive gene action in the inheritance of chlorophylls concentrations in fruits.

The results tabulated in Table 9 showed that the

Table 9. Estimates of genetic parameters for carotenoids concentration in fruits of summer squash genotypes.

Doses of UV irradiation (kGy)	GV	PV	EV	H (%)	GCV (%)	PCV (%)	ECV (%)	EGA	GAM (%)
Control	0.006	0.370	0.360	01.63	04.39	11.76	07.37	0.020	02.66
4 min	0.040	0.120	0.080	30.00	09.57	17.47	07.90	0.210	21.44
8 min	0.008	0.039	0.031	45.29	06.23	13.76	07.53	0.180	35.35
12 min	0.030	0.136	0.110	19.11	10.19	23.32	13.13	0.145	23.13
Mean	0.021	0.166	0.145	23.94	07.59	16.58	08.98	0.138	20.64

GV, Genotypic variance; PV, phenotypic variance; EV, environmental variance; H (%), heritability in broad sense in percent; GCV (%), genotypic coefficient of variation in percent; PCV (%), phenotypic coefficient of variation in percent; ECV (%), environment coefficient of variation in percent; EGA, expected genetic advance; GAM, genetic advance as percent of mean at 5% selection intensity; kGy, kilo Gray of rays.

Table 10. Estimates of genetic parameters for fruits weight per plant in summer squash genotypes

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Doses of UV irradiation (kGy)	GV	PV	EV	H (%)	GCV (%)	PCV (%)	ECV (%)	EGA	GAM (%)
Control	0.083	0.163	0.080	50.92	12.00	16.00	4.00	0.419	29.64
4 min	0.090	0.180	0.090	50.00	12.13	17.14	5.01	0.459	30.02
8 min	0.210	0.260	0.050	80.76	18.21	20.27	2.06	0.850	53.71
12 min	0.190	0.350	0.160	54.28	21.29	28.90	7.61	0.850	90.52
Mean	0.140	0.240	0.095	58.99	15.91	20.58	4.67	0.640	50.97

GV, Genotypic variance; PV, phenotypic variance; EV, environmental variance; H (%), heritability in broad sense in percent; GCV (%), genotypic coefficient of variation in percent; PCV (%), phenotypic coefficient of variation in percent; ECV (%), environment coefficient of variation in percent; EGA, expected genetic advance; GAM, genetic advance as percent of mean at 5% selection intensity; kGy, kilo Gray of rays.

differences between genotypic and phenotypic coefficient of variations were relatively high in magnitude of carotenoid concentrations in fruits, indicating higher effects of environmental factors than genetic background in the expression of this trait. The considerable difference obtained between phenotypic and genotypic coefficient of variation for carotenoids concentration in fruits indicates a greater effect of environmental conditions on the phenotypic expression of these traits. Therefore, selection based on the phenotypic expression of this trait would be ineffective to bring genetic improvement in the genotypes considered in this study. In addition, heritability values (23.94%) categorized as low (0-30%) based on the classification of Robinson et al. (1949).

In contrast, the mean of genetic advance as a percent of means reached 20.64% which is categorized as high (20% and above) depending on the classification of Johnson et al. (1955). Therefore, the low heritability obtained for carotenoids concentrations in fruits is due to the influence of environmental factors that limits the scope of improvement via selection. These results are in harmony with Dursun (2007), who obtained low board-sense heritability estimates for grain yield in *Phaseolus vulgaris* L. In addition, Alemayehu (2010) found moderate estimates of heritability and genetic advance for the number of seeds per pod in *Phaseolus vulgaris* L. Therefore, selection depending on the phenotypic expression of carotenoid concentrations in fruits limits the scope of improvement in the progenies because this trait is mainly influenced by the environment than genetic factors.

Fruits weight

The results presented in Table 10 showed that the differences between genotypic and phenotypic coefficient of variations were relatively moderate in magnitude of fruits weight per plant.

This indicated high influence of the environmental factors than genotypes in the expression of fruits weight per plant. The estimates of heritability (58.99%) categorized as moderate (30-60%) depending on the classification of Robinson et al. (1949). Moderate estimates of heritability obtained in magnitude of fruits weight per plant coupled with high genetic advance (50.97%) as a percentage of mean in combined analysis. Therefore, selection depending on the phenotypes leading to increase in fruits weight per plant in the offspring of selected progenies. These results agreed with Ejara et al. (2018), who found that plant height, as well as, seeds number per pod in common bean (*Phaseolus vulgaris* L.) showed moderate heritability coupled with relatively high genetic advance based on the percentage of mean.

As opposite to the results obtained herein, Hailu et al.

(2016) found that days to maturity in barley, as well as days to heading depicted high heritability values with lower genetic advance. These traits possessing high heritability with low genetic advance indicating the influence of non-additive gene action. Therefore, selection technique in early segregating generations will not be effective for improving these traits. Further studies by Sardana et al. (2007) found that high values of heritability might not be necessary to increase genetic advance gain through selection, unless sufficient genetic variations existed in the genome. In addition, Chand et al. (2008) stated that high values of heritability with low genetic gain were obtained for days needed to ear emergence in barley.

In conclusion, heritability reflected whether differences shown within individuals arose as a result of variations in the genotypes or due to the environmental factors. High heritability values coupled with high genetic advance indicated that selection is effective based on the phenotypic performance. High heritability coupled together with relatively greater genetic advance as a percentage of the mean indicated the involvement of additive gene action in the inheritance of this trait leading to selection will be effective. However, low genetic advance with high heritability estimates indicated the involvement of non-additive gene action leading to selection will not be effective. The reason for low heritability arose from some variance constituting the environmental variance indicating slow progress based on selection for this trait.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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