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**RESEARCH ARTICLE**

**Genetic variations induced in summer squash by ultraviolet irradiation for earliness and yield related traits**

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**Abstract**

This study aimed to increase genetic variations in summer squash via mutation breeding as a strategy among traditional plant breeding techniques, to generate novel genotypes with increased yield and earliness to be helpful the grower–consumer interaction. Soaked seeds of four summer squash genotypes were irradiated with 0, 4, 8 and 12 minutes of ultraviolet rays (UV) rays. The seeds were sown in the field to rise the M<sub>1</sub> generation which was advanced to M<sub>2</sub> generation. The results of M<sub>2</sub> generation appeared highest decrease in the time of female flowering by Gen<sub>3</sub> irradiated with eight minutes. The highest fruit length was recorded by Gen<sub>1</sub> variety irradiated with 12 minutes of UV rays. Gen<sub>3</sub> exposed to four and eight minutes of UV rays produced significant increase in the number of fruits developed per plant in relation to unirradiated plants. The highest concentration of total chlorophyll in fruits was recorded by Eskandarani and Gen<sub>1</sub> treated with four minutes and Gen<sub>1</sub> treated with 12 minutes if compared with unirradiated plants. The doses of UV irradiation were significantly affected not only on the concentration of chlorophyll a in fruits but also

on chlorophyll b in fruits. The interaction between genotypes by doses of UV irradiation were significantly affected on the concentration of chlorophyll a and total chlorophyll concentrations in fruits. Therefore, the results reflected that isolating of early maturing mutants with high earliness is possible at eight minutes of exposure time to UV irradiation.

**Keywords:** Summer squash, earliness, ultraviolet irradiation, genetic variations, yield

**Introduction**

Summer squash (*Cucurbita pepo*, L.) is one of the most important vegetable crops cultivated in Egypt. The total area cultivated in Egypt with summer squash reached about 40000 ha in 2007, produced about 699000 tonn, with the average of 18.26 ton/ha according before by the Ministry of Agriculture Statistics (Glala *et al.*, 2012). It is also grown worldwide in a total area of 1,000,000 hectares under pumpkin, squash with annual production of 19,000,000 tonnes (FAO, 2006). Squash varieties having high diversity in their size, shape and colour under Egyptian conditions (Al- Brifcany, 2015).

The United States of America and Mexico are the two main countries to which summer squash is native, as well as the largest producers. The largest producers in the Mediterranean region and Middle East are Egypt, Turkey and Italy which produced one-third of the world's production. Summer squash ranks high nutritional, as well as economic importance values among vegetable crops. The wild type forms are localized in the United States and Mexico. The term pumpkin was used for a large round fruit shape or nearly round, whereas the term squash was applied to express on edible *Cucurbita* fruit deviating greatly from roundness. Pumpkins are consumed when mature, whereas summer squash was consumed when immature (Paris, 1996).

Breeding summer squash was undertaken in most number of countries as, Egypt, United States, Mexico, France, Italy, Spain, the Netherlands, Israel, South Korea and Taiwan, to be increased productivity, earliness and disease resistance (Baggett, 1972). The economic value of fruit was related to their smaller size, commanding a higher price in nearly all cases (Paris, 1996). Breeding summer squash was more intensive now than ever times before. Squash consumption is becoming popular world wide due to its high nutritional and medicinal values as rich in vitamins, minerals with adequate fibers and carbohydrates (Adelerin *et al.*, 2022). It is a great medicinal value referred to their contents of flavonoid compounds, antioxidative substances, physiological functions like antidiabetic and anti-hypercholesterolemic activity etc. (Kostecka Gugala *et al.*, 2020). Generating of resistant transgenic genotypes against insects and viruses is a prerequisite for successful squash production. The development of new genotypes in summer squash through traditional breeding was considered because of its narrow genetic variability, as well as

assorted crossing problems with their relevant genotypes (Miguel, 2021). Summer squash is highly polymorphic in nature, shows diverse potentiality in tissue culture even in the same cultivar (Kiss-Baba *et al.*, 2006).

Chlorofluorocarbons induced by human activities caused the potential depletion in the ozone layers, leading to the attenuation of solar UV-B radiation reaching the earth's surface (Molina and Rowland, 1974). This depletion was closely related to the increase in UV-B radiation arrived to the earth's surface (Kerr and Mc Elroy, 1993). Solar radiation UV-B (280-320 nm) with a minor percentage of the total solar energy was potentially harmful because of their short wave lengths which causing deleterious effect in plant cells. Different cellular components like, nucleic acids, proteins and lipids can absorb solar UV-B radiation directly (Jordan, 1996). The depletion in stratospheric ozone layer increased the rate of ultraviolet rays arrived the biosphere, especially in the level of UV-B (280-320 nm). Strong absorption of UV-B photons by the biological macromolecule in the cell as protein and nucleic acids leading physiological changes on plant and animal metabolism (Heisler *et al.*, 2003). The harmful effects of ultraviolet rays on plants include morphological and biochemical alteration leading to increased the level of phenolic pigments (Brzezinska *et al.*, 2006). Under the effect of UV-B, chlorophyll concentration in *Fagus sylvestris* leaves was higher (Láposi *et al.*, 2002). The concentration of proline was increased in rice (*Oryza sativa*) shoots, mustard (*Brassica juncea*), and mung bean (*Vigna radiata*) after exposed to UV-B radiation (Saradhi *et al.*, 1995). This study aimed to induce genetic variations in summer squash genotypes using elevated ultraviolet irradiation to investigate their effects on the gene expression of earliness and yield related traits, as well as, fruits quality.

## Material and methods

This study was carried out in the Agri-farm of Genetic Department, Faculty of Agriculture, during summer seasons of 2021 and 2022, the farm was located inside the campus of Mansoura University. This area has temperatures ranging between 22° C in April reached the maximum temperature up to 42° C in August. The crop was raised under field conditions following the recommended package of practices. Four summer squash genotypes used in this study were kindly obtained from the National Gene Bank, Agriculture Research Center, Egypt. These genotypes include Eskandarani (Gen<sub>1</sub>), barcoding number 1116228 (Gen<sub>2</sub>), barcoding number 1116232 (Gen<sub>3</sub>) and barcoding number 1116237 (Gen<sub>4</sub>). Seeds of four genotypes were first soaked in water for five hours before exposed to UV-B irradiation to increase the mobility and the effect of free radicals and oxygen associated with physical mutagenic agents (Ehrenberg 1961). Soaked seeds were exposed to UV rays in the laminar cabinet as an artificial source of UV irradiation for periods; 0, 4, 8 and 12 minutes. The laminar chamber of UV was located in the Laboratory of Microbial Genetics, Faculty of Agriculture, Mansoura University. The spectrum of UV lamp used in this study was 300 nm, therefore it was classified as UV-B (280-320 nm). One minute of exposure to UV-irradiation was equal 188.2 joules/m<sup>2</sup> 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 one meter which is equivalent to one watt of power radiated for one second. The seeds were sown on rows with four seeds per hole for each genotype at a distance of 50 cm between holes and 80 cm between the rows (Al-Obaidi, 1986). The seedlings were reduced to one seedling per stand at two weeks after planting. The size of each plot was 21 x 5 m. Each experimental plot consisted of 16 rows with five meter length and 0.5 meter width. The

seeds were planted in a randomized factorial experiment including two plots with three replicates. The main plot including genotypes and sub-plot including the doses of UV rays. All the agronomic recommendations were applied as such and the plants were irrigated when needed. All replications received similar treatments as irrigation, pest and disease control and other agricultural practices. Fruits were collected at two-days intervals. M<sub>1</sub> plants were self cross-pollinated to obtain M<sub>1</sub> seeds which advanced to M<sub>2</sub> plants after germination. The fruits of M<sub>1</sub> plants were harvested at maturity. The M<sub>1</sub> seeds were grown in the field of summer season 2022 to obtain M<sub>2</sub> plants and their fruits. The seeds harvested from individual M<sub>1</sub> plants were grown in 2022 as M<sub>2</sub> generation in a randomized complete sectors design. Evolved traits were recorded in M<sub>2</sub> generation. Observations on days to first male and female flowering appeared were recorded on plot basis. In addition, chlorophyll pigments concentration in fruits was measured. The yield components including fruit length and total number of fruits per plant were recorded. First female flowering was recorded as the number of days from sowing to initiating the first female flowering in each plot. In addition, first male flowering was recorded as the number of days needed to first male flower initiating from the date of sowing for each experimental plot. These including chlorophyll a, chlorophyll b and total chlorophyll which are measured in fruits according to the technique explained by Arnon (1949). Fruit length was estimated by centimeters as the average length of selected fruits at random (Gholami *et al.*, 2012). The data were subjected to analyses of variance to test the significance of differences between genotypic or doses means using F-test. In addition, least significant difference (LSD) was used to test the differences between the means at 0.05 and 0.01 levels of probability. In addition, the data were subjected to factorial analyses of variance according to Steel and Torrie (1960).

## Results and discussion

As shown from the results tabulated in table 1 that four minutes exposure time to UV

irradiation decreased the time of female flowering to 51 day instead of 53 day in unirradiated Eskandarani plants.

**Table 1: Effect of UV irradiation on the number of days needed to first female flowering**

Doses of UV radiation	Number of days to first female flowering				F-test	LSD	
	Eskandarani	Gen <sub>1</sub>	Gen <sub>2</sub>	Gen <sub>3</sub>		0.05	0.01
00	53.20	51.19	57.96	55.47	Is	8.47	12.83
4 min	51.12	49.55	60.00	46.96	**	5.45	8.25
8 min	59.70	47.26	50.20	45.47	**	2.52	3.82
12 min	51.45	53.14	53.57	55.45	Is	3.70	5.61
F-test	**	Is	*	**			
LSD <sub>0.05</sub>	3.83	4.53	6.75	3.49			
LSD <sub>0.01</sub>	5.79	6.87	10.23	5.29			

Is: Insignificant differences; \*: Significance at 0.05 level of probability; \*\*: Significance at 0.01 level of probability

Meanwhile, the dose of eight minutes decreased the time of female flowering to 47.26 day instead of 51.19 day in unirradiated plants of Gen<sub>1</sub> variety. The dose of eight minutes decreased the time of female flowering to 50.20 day instead of 57.96 day in unirradiated plants of Gen<sub>2</sub> variety. The dose of eight minutes showed the highest decrease in the time of female flowering (45.47 day) compared with unirradiated plants of Gen<sub>3</sub> variety (55.45 day). The results showed significant differences between the doses of UV irradiated Eskandarani, Gen<sub>2</sub> and Gen<sub>3</sub>. Meanwhile, the doses of four and eight minutes of exposure time to UV irradiation induced significant differences between the different genotypes if compared with insignificant differences obtained between unirradiated plants from all genotypes. The results indicated that eight minutes of exposure time to UV irradiation is the best dose decreased the time of female flowering in Gen<sub>1</sub>, Gen<sub>2</sub> and Gen<sub>3</sub>. Meanwhile the doses

of four and 12 minutes of exposure time to UV irradiation were the best doses decreased the time of female flowering in the Eskandarani variety.

The results obtained herein agreed with Adeyanju and Ishiyaku (2006), who stated that earliness related traits were controlled by duplicate dominant epistatic genes with late maturity leading partially dominant over earliness. In addition, Owusu *et al.*, (2022) demonstrated that the gene action of earliness related traits in cowpea (*Vigna unguiculata*, L.) could be due to the differences in the genotype materials or to the statistical methods used by various researchers. Hence, the genetic basis of early maturing summer squash genotypes would assist plant breeders in the choice of breeding techniques to exhibit the generation of high yielding early maturing genotypes to improve the production and productivity of summer squash. Gupta *et al.*, (2017) found a duplicate type of epistasis for earliness related traits in cowpea.

However, Owusu *et al.*, (2022) suggested that duplicate types of non-allelic gene interaction were controlled the inheritance of earliness related traits in cowpea. This implies that the magnitudes of epistasis (non-fixable gene action types) were higher than the additive or dominance gene effects in the inheritance of earliness related traits in summer squash. Thus, trigenic or high-order epistatic actions may be controlling the inheritance of earliness related traits in summer squash. Therefore, Santos *et al.*, (2020) found four and five genes are responsible in the genetic control of first flower appearance and the number of days needed to 95% pod maturity in cowpea,

respectively. The results presented in table 2 appeared significant differences in the time of male flowering between the doses irradiated Eskandarani variety. From the doses used in this study, the dose of four minutes is the best dose decreased the time of male flowering from 50 day in unirradiated plants to 46 day in Eskandarani variety exposed to four minutes of UV rays. In addition, the doses of four and eight minutes of exposure time induced significant differences between different genotypes for the time of male flowering if compared with insignificant differences obtained in this trait from unirradiated plants.

**Table 2: Effect of UV irradiation on the number of days needed to first male flowering**

Doses of UV radiation	Number of days to first male flowering				F-test	LSD	
	Eskandarani	Gen <sub>1</sub>	Gen <sub>2</sub>	Gen <sub>3</sub>		0.05	0.01
00	49.97	47.51	50.13	35.09	Is	26.01	39.40
4 min	45.66	47.06	60.61	46.17	**	5.27	7.99
8 min	56.34	45.68	46.13	44.36	**	0.96	1.45
12 min	46.67	47.76	35.87	49.50	Is	25.67	38.88
F-test	**	Is	Is	Is			
LSD <sub>0.05</sub>	2.09	2.94	26.38	25.25			
LSD <sub>0.01</sub>	3.16	4.46	39.96	38.26			

Is: Insignificant differences; \*: Significance at 0.05 level of probability; \*\*: Significance at 0.01 level of probability

The results obtained in this study are in harmony with Kaniti (2015), who stated that non-additive gene effects were played a main role than additive gene action in the inheritance of earliness. The results are also in conformity with the findings of Verma *et al.*, (2023), reported the days needed to first staminate flower an thesis were ranged from 39.20 to 50.36 if compared with the general mean (43.66 days) of the population. The same authors found among 28 genotypes, only one genotype was significantly lowering the days needed to first staminate flower an thesis than the general mean of population (43.66 days).

Information on the genetic control of earliness related traits in cowpea was still limited (Owusu *et al.*, 2022). Ishiyaku *et al.*, (2005) found that seven genes controlling DFFA. Meanwhile, Ribeiro *et al.*, (2014) found three genes were responsible for DNPM. However, Santos *et al.* (2020) decided that four and five genes were contributed the genetic control of DFFA and MNPM in cowpea, respectively. Therefore, earliness related traits may be due to the contribution of duplicate epistatic gene effect in the inheritance of the key earliness related traits (Abdelsatar *et al.*, 2021).

As shown in table 3, there were significant differences between the doses of UV irradiated Gen1 variety for fruit length. In addition, there were significant differences between unirradiated genotypes, as well as between the genotypes irradiated with four and 12 minutes. All the doses of UV irradiation significantly increased fruit length of Gen1 above that produced by unirradiated plants. The highest fruit length (16 cm) was produced by Gen1 variety exposed to 12 minutes of UV irradiation if compared with the control (14 cm). Stimulating effect of UV irradiation

obtained in on fruit length may be due to increasing of cell division or cell elongation of fruits, alteration of metabolic processes affected on the synthesis of phytohormones or nucleic acids (Pitiramovae, 1979). These results were agreed with Ambavane *et al.*, (2015), who found that the effect of gamma rays doses on finger millet were varied from genotype to genotype, as well as all the mutagenic doses exhibited the weight of panicle per plant if compared with unirradiated control plants.

**Table 3: Effect of UV irradiation on fruit length (cm) of four irradiated genotypes**

Doses of UV radiation	Fruit length (cm)				F-test	LSD	
	Eskandarani	Gen <sub>1</sub>	Gen <sub>2</sub>	Gen <sub>3</sub>		0.05	0.01
00	15.04	14.33	13.75	15.61	*	1.08	1.63
4 min	14.02	14.51	15.82	15.58	*	1.26	1.91
8 min	14.90	14.64	15.38	14.55	Is	1.33	2.01
12 min	15.47	16.36	14.55	15.99	*	0.89	1.35
F-test	Is	**	Is	Is			
LSD <sub>0.05</sub>	0.99	0.53	1.48	1.23			
LSD <sub>0.01</sub>	1.51	0.80	2.24	1.87			

Is: Insignificant differences; \*: Significance at 0.05 level of probability; \*\*: Significance at 0.01 level of probability

The data regarding the number of fruits yield per plant which revealed significant differences between the doses of UV irradiated Gen<sub>1</sub> and Gen<sub>3</sub> (Table 4). Meanwhile, there were a significant differences between the different genotypes irradiated with eight minutes of UV exposure time. The doses of four (17.88 fruits) and eight (18.33 fruits) minutes of UV exposed Gen<sub>3</sub> induced significant increase in the number of fruits formed per plant in relation to unirradiated control plants (9.63 fruits). These results indicated that the highest number of fruits formed per plant was produced by Gen<sub>3</sub> exposed to eight minutes of UV irradiation. The results reflected that Gen<sub>3</sub> variety was positively responsive to eight minutes of UV

irradiation for the number of fruits developed per plant. This reflected that the dose of eight minutes induced high number of female flowers per plants from Gen<sub>3</sub>. This agreed with Ati (2016), who found that the lower doses of gamma rays were most effective in exhibited the yield of fruits from okra crop than the higher doses. The results obtained in this study demonstrated that the lower doses of UV irradiation as eight minutes exposed Gen<sub>3</sub> initiated more number of female flowers developed per plant. In addition, the different genotypes were differed in their response to the same dose of UV irradiation, indicating significant differences were obtained between the genotypes irradiated with eight minutes of UV rays.

**Table 4: Effect of UV irradiation on the number of fruits formed per plant**

Doses of UV radiation	Number of fruits per plant				F-test	LSD	
	Eskandarani	Gen <sub>1</sub>	Gen <sub>2</sub>	Gen <sub>3</sub>		0.05	0.01
00	12.10	17.49	13.17	9.63	Is	7.92	12.00
4 min	12.39	15.12	11.50	17.88	Is	5.99	9.09
8 min	8.54	16.20	14.27	18.33	**	3.56	5.39
12 min	12.13	7.95	8.51	10.30	Is	7.46	11.30
F-test	Is	*	Is	**			
LSD <sub>0.05</sub>	5.88	6.34	8.98	4.09			
LSD <sub>0.01</sub>	8.91	9.60	13.61	6.21			

Is: Insignificant differences; \*: Significance at 0.05 level of probability; \*\*: Significance at 0.01 level of probability

This reflected that mutation breeding with UV rays can improve the yield and yield related traits in summer squash. Therefore, female flowers developed in Gen<sub>3</sub> variety showed a positive response to eight minutes of UV irradiation. All genotypes were highly wider in fruits yielding per plant at different doses of UV irradiation than that obtained by the control plants. This indicated that the effect of UV doses varied from genotype to genotype, as well as from dose to dose within the same genotype. The variations obtained in the number of fruits developed per plant may happened due to several reasons as adverse or stimulatory effect on cytochrome oxidase content that reducing or stimulated the respiration rate (Swaminathan *et al.*, 1962), drastic distortion of exhibited the activity of dividing cells initiated female flowering (Singh and Singh, 1989), damage or damage associated with repair of cell constituents at molecular level (Khan and Goyal, 2009), interference or stimulating the synthesis of enzyme activity and acceleration in the degradation of existing enzyme (Yusuf and Nair, 1974). The results obtained herein agreed with Omilabu *et al.*, (2022), reported differences between cowpea genotypes for all the studied traits which suggested that genetic variations were present between cowpea

genotypes. Mehata *et al.*, (2022) evaluated seven genotypes of okra and found that two of them gave the highest average yield per plant. Furthermore, Mohammed *et al.*, (2023) obtained significant differences between eight varieties of Faba bean for the number of pods developed per plant, hundred seed weight, grain yield and biomass yield per hectare. As shown from the results tabulated in Table 05 that there were a significant differences between UV doses irradiated Eskandarani and Gen<sub>3</sub> genotypes for the concentration of chlorophyll a pigment in fruits. The highest concentration in this pigment (0.11 mg/g Fw) was recorded by Eskandarani genotype irradiated with four minutes of UV rays if compared with the control which recoded 0.06 mg/g FW. This reflected stimulation induced in the concentration of chlorophyll a in Eskandarani fruits by the dose of four minutes exposure time to UV rays. Fruit color mutation obtained herein was often used as an indicator for mutagenic effect and efficiency of UV rays. Mutants that increased green pigment in their fruits regarded as better mutants because the consumers prefer higher green fruits of summer squash. Therefore, positive chlorina mutants were predominant in marketing summer squash if compared with different abnormalities.

**Table 5: Effect of UV irradiation on the concentration of chlorophyll a in fruits**

Doses of UV radiation	Chlorophyll a in fruits (mg/g FW)				F-test	LSD	
	Eskandarani	Gen <sub>1</sub>	Gen <sub>2</sub>	Gen <sub>3</sub>			
						0.05	0.01
00	0.06	0.07	0.08	0.07	Is	0.09	0.14
4 min	0.11	0.11	0.11	0.06	Is	0.06	0.09
8 min	0.05	0.07	0.06	0.08	Is	0.45	0.68
12 min	0.04	0.11	0.06	0.08	Is	0.21	0.32
F-test	*	Is	Is	*			
LSD <sub>0.05</sub>	0.03	0.09	0.09	0.04			
LSD <sub>0.01</sub>	0.05	0.13	0.14	0.06			

Is: Insignificant differences; \*: Significance at 0.05 level of probability; \*\*: Significance at 0.01 level of probability

There were a significant differences in the concentration of chlorophyll b in fruits, not only between the doses irradiated Eskandarani genotype but also between the different genotypes exposed to the same dose of four minutes exposure time (Table 6 ). The dose of four minutes not only induced significant increase in the concentration of chlorophyll b pigment in fruits produced by Eskandarani genotypes, but also produced the highest concentration in the same pigment of fruits produced by Gen<sub>2</sub>. Chlorophyll b formation

increased in fruits may be resulted from the activation of cycle components forming chlorophyll b (Long *et al.*, 1994). The lower dose of four minutes exposure time to UV exhibited higher concentration in chlorophyll b containing fruits of Eskandarani, Gen<sub>1</sub> and Gen<sub>2</sub> genotypes, suggesting that this dose caused stimulation of essential enzymatic reactions thereby leading to increase in the uptake and partitioning of nutrients, needed for chlorophyll b formation.

**Table 6: Effect of UV irradiation on the concentration of chlorophyll b in fruits of M<sub>2</sub> generation**

Doses of UV radiation	Chlorophyll b in fruits (mg/g FW)				F-test	LSD	
	Eskandarani	Gen <sub>1</sub>	Gen <sub>2</sub>	Gen <sub>3</sub>			
						0.05	0.01
00	0.04	0.04	0.03	0.05	Is	0.04	0.06
4 min	0.07	0.08	0.09	0.04	*	0.03	0.04
8 min	0.04	0.05	0.05	0.06	Is	0.05	0.07
12 min	0.03	0.07	0.04	0.06	Is	0.09	0.15
F-test	*	Is	Is	Is			
LSD <sub>0.05</sub>	0.02	0.60	0.04	0.02			
LSD <sub>0.01</sub>	0.03	0.09	0.06	0.30			

Is: Insignificant differences; \*: Significance at 0.05 level of probability; \*\*: Significance at 0.01 level of probability

The results presented in table 7 revealed significant differences for total chlorophyll in fruits not only between genotypes irradiated with 12 minutes of exposure time but also between the doses irradiated Eskandarani variety. The concentration of total chlorophyll was ranged between 0.07 (Eskandarani treated with 12 min) to 0.18 (Eskandarani and Gen<sub>1</sub> treated with four min and Gen<sub>1</sub> treated with 12 min). The highest concentration of total chlorophyll was 0.18 mg/g FW recorded by

Alex and Gen<sub>1</sub> treated with four min and Gen<sub>1</sub> treated with 12 minutes if compared with the control which recorded 0.09 and 0.11, respectively. Photosynthesis is the most important metabolic process of plants which essential for the production of biomass (Kumari *et al.*, 2009). Campbell (1975) stated that chloroplast is the first cell organelle to show injury response, hence there is always a sharp increase or decrease in fruits concentration chlorophyll in UV treated plants.

**Table 7: Effect of UV irradiation on the total chlorophylls concentration in fruits of M<sub>2</sub> generation**

Doses of UV radiation	Total chlorophylls in fruits (mg/g FW)				F-test	LSD	
	Eskandarani	Gen <sub>1</sub>	Gen <sub>2</sub>	Gen <sub>3</sub>		0.05	0.01
00	0.09	0.11	0.12	0.11	Is	0.13	0.19
4 min	0.18	0.18	0.20	0.09	Is	0.09	0.14
8 min	0.08	0.11	0.11	0.14	Is	0.11	0.17
12 min	0.07	0.18	0.09	0.14	*	0.06	0.09
F-test	**	Is	Is	Is			
LSD <sub>0.05</sub>	0.05	0.14	0.13	0.06			
LSD <sub>0.01</sub>	0.07	0.21	0.19	0.09			

Is: Insignificant differences; \*: Significance at 0.05 level of probability; \*\*: Significance at 0.01 level of probability

Several mechanisms were suggested for the decline in chlorophyll contents of UV irradiated plants. In addition, Strid *et al.*, (1994) linked between reduced chlorophyll concentrations to reduced synthesis resulting from the decrease in gene expression encoding chlorophyll binding proteins. Meanwhile, Strid and Porra (1992) suggested that accumulation of chlorophyllide a and b resulted in decreased chlorophylls contents under UV-B stress. The results obtained in this study agreed with Zhao and Mabl (2007), who reported that hypergravity may affect on chlorophyll concentration through inhibition of chlorophyll biosynthesis or an acceleration of

its degradation. Therefore, photosynthesis is the most important metabolic process in plants which, essential for biomass production. The inhibition of net photosynthesis resulted to significant change in biomass production. The increased biomass production under the effect UV irradiation may be attributable to the higher rate of carbon assimilation capacity via the substantial increase in photosynthetic pathway. The higher accumulation of UV-B absorbing compounds in the epidermal vacuolar region, decrease the penetration of harmful UV irradiation to photosensitive tissues (Tevini *et al.*, 1991).

The results tabularized in table 8 appeared that genotypes, doses of UV irradiation and the interaction between genotypes by doses of UV irradiation reflected insignificant effect on female flowering, first male flowering, fruit length and the number of fruits developed per plant. Insignificant effect obtained by yield contributed factors on the yield of summer squash may be due to similar response of different genotypes to the same dose of UV irradiation, as well as the same genotype do not varied in response to different doses of UV irradiation. All the sources of variation exhibited significant effect on the concentration of chlorophyll a pigment in fruits. This indicated that the concentration of

chlorophyll b in fruits was dependent upon the genotype, genetic variations leading to stimulate the formation of chlorophyll b in some genotypes, as well as the interaction between genotypes by genetic variations induced in the population. Genotypes, as well as the interaction between genotypes by doses appeared significant effect on the concentration of total chlorophyll in fruits. The results indicated that enhanced photosynthetic activity in fruits increased fruits quality of summer squash and consequently better plant growth. Further, chlorophylls have a positive effect on yields as they are reported before by Singh *et al.*, (2011).

**Table 8: Mean squares of simply inherited traits contributing fruits yielding in summer squash**

Source of variation	Df	Number of days to first female flowering	Number of days needed to first male flowering	Fruit length	Number of fruits/plant	Chlorophyll a in fruits	Chlorophyll b in fruits	Total Chlorophyll in fruits
Replicates	2	20.98	325.2	0.51	18.65	$1.72 \times 10^{-3}$	$2.37 \times 10^{-3}$	$5 \times 10^{-3}$
Genotypes	3	72.38 <sup>1s</sup>	74.10 <sup>1s</sup>	1.05 <sup>1s</sup>	26.42 <sup>1s</sup>	$1.98 \times 10^{-3}$ <sup>**</sup>	$5.17 \times 10^{-4}$ <sup>**</sup>	$4 \times 10^{-3}$ <sup>**</sup>
Doses of UV	3	33.36 <sup>1s</sup>	61.54 <sup>1s</sup>	0.86 <sup>1s</sup>	55.75 <sup>1s</sup>	$5.33 \times 10^{-3}$ <sup>**</sup>	$4.03 \times 10^{-4}$ <sup>**</sup>	0.01 <sup>1s</sup>
Genotypes X Doses	9	59.20 <sup>1s</sup>	146.29 <sup>1s</sup>	2.15 <sup>1s</sup>	31.52 <sup>1s</sup>	$1.22 \times 10^{-3}$ <sup>**</sup>	$8.04 \times 10^{-4}$ <sup>**</sup>	$3.44 \times 10^{-3}$ <sup>**</sup>
Error	30	35.25	142.83	1.17	26.81	$2 \times 10^{-3}$	$8.33 \times 10^{-4}$	$5.33 \times 10^{-3}$
Total	47							

In conclusion, UV irradiation induced new limited genetic variations in summer squash leads to generate new varieties that have favorable traits for earliness and yield-related traits. Irradiation was considered as promising environmentally friendly and cheap tool to induce genetic variations in summer squash. Radiation periods used in this study did not

cause plant death but they also significantly affected on physiological traits, as well as yield components. All the doses used in this study stimulated earliness of female flowering depending upon the genotype. The isolation of early maturing mutants with high earliness is possible at eight minutes of exposure time to UV irradiation.

## References

1. Abdelsatar, M. A., Hassan, T. H., Ahmed, A. A. and Aboelkassem, K. M. 2021. Generation means analysis of seed yield and its components in canola. *Egypt. J. Sgric. Res.*, 99 (1): 37-48.
2. Adelerin, R., Ifesan, B. and Awolu, O. 2022. Physicochemical, nutritional, phytoconstituents and antioxidant properties of three different processing techniques of pumpkin (*Cucurbita pepo*, L.) pulp flour. *Ceylon J. Sci.*, 51 (1): 43-50.
3. Al-Brifcany, M. T. 2015. Estimation of heterosis and nature of gene action for some economical traits in squash (*Cucurbita pepo*, L.). M.Sc. Thesis, Faculty of Agriculture Mansoura University, Egypt.
4. Al-Obaidi, O. K. A. 1986. Effect of nitrogen fertilization levels and planting distances on growth and yield of squash. M. Sc. Thesis, College of Agriculture and Forestry, University of Mosul, Republic of Iraq.
5. Ambavane, A. R., Sawardekar, S. V., Sawantdesai, S. A. and Gokhale, N. B. 2015. Studies on mutagenic effectiveness and efficiency of gamma rays and its effect on quantitative traits in finger millet (*Eleusine coracana* L. Gaertn). *J. Radiat. Res. Appl. Sci.*, 8 (1):120-125.
6. Arnon, D. I. 1949. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. *Plant Physiol. J.*, 24 (1): 1-15.
7. Ati, H. M. 2016. Effect of gamma ray and sodium azide on the germination, survival and morphology of varieties of okro (*Abelmoschus esculantus* L. moench). *Int. J. Horti. Agricul.*, 2 (1): 1-4.
8. Baggett, J. R. 1972. Open growth habit in summer squash. *Hort. Sci.*, 7 (3): 287-288.
9. Brzezinska, E., Kozłowska, M. and Stachowiak, J. 2006. Response of three conifer species to enhanced UV-B radiation; consequences for photosynthesis. *Polish. J. Environ. Stud.*, 15 (4): 531-536.
10. Campbell, W. S. 1975. Impacts of climatic changes on the biosphere. In: D. W. Nachtwey, M. M., Caldwell, R. H. Biggs (eds.), *Ultraviolet radiation effects*, Monograph 5 Climatic impact assessment program, US Dept, 167-176. Transportation Rep No. DOT-TST-75-55. Nat. Tech. Info. Serv., Spring Field, VA.
11. Ehrenberg, A. 1961. Research on free radicals in enzyme chemistry and irradiation biology. In: *Free radicals in biological system*. Academic Press, New York. Pp., 337– 350
12. FAO. 2006. Genetic divergence and cluster analysis in summer squash (*Cucurbita pepo*, L.) *The Pharma Innovat. J.*, 11(7): 1811-1814.
13. Gholami, R., Lorestani, A. N. and Jaliliantabar, F. 2012. Determination of physical and mechanical properties of Zucchini (summer squash). *Agric. Eng. Int: CIGR Journal*, 14 (1): 136–140.
14. Glala, A. A., Abd El-Samad, E. E. H. and El-Abd, S. O. 2012. Increasing organic production of summer squash by modulating plant. *National Research Center Egypt. Acta. Hortic.* 933 (933): 137-143.
15. Gupta, R. P., Patel, S. R., Modha, K. G. and Wadekar, P. B. 2017. Generation mean analysis for yield and yield components in cowpea (*Vigna unguiculata* L. Walp). *Int. J. Curr. Microbiol. Appl. Sci.*, 6: 2231-2240.
16. Heisler, G. M., Grant, R. H., Gao, W. and Slusser, J. R. 2003. Ultraviolet radiation and its impacts on agriculture and forests. *Agric. For. Meteorol*, 120 (3): 120-133.

17. Ishiyaku, M. F., Singh, B. B. and Craufurd, P. Q. 2005. Inheritance of time to flowering in cowpea (*Vigna unguiculata* L. Walp). *Euphytica*, 142: 291-300.
18. Jordan, B. R. 1996. The effects of ultraviolet-B radiation on plants: a molecular perspective. *Adv. Bot. Res.*, 22: 97-162.
19. Kaniti, K. R. 2015. Combining ability for yield related traits, earliness and yield in Bitter gourd (*Momordicacharantia*). *Electr. J. Plant Breed.*, 7 (2): 267-274.
20. Kerr, J. B. and Mc Elroy, C. K. 1993. Evidence for large upward trend of ultraviolet-B radiation linked to ozone depletion. *Sci.*, 262: 1032-1034.
21. Khan, S. and Goyal, S. 2009. Improvement of mungbean varieties through induced mutation. *African. J. Plant Sci.*, 3: 174 - 180.
22. Kiss-Baba, E., Simonyi, K., Zaraka, V., Tobias, I., Velich, I. and Bisztray, G. 2006. Investigations on the regeneration ability of squash cultivars. *Acta Horti.*, 109 (10): 791-794.
23. Kondrateva, N. P., Kasatkina, N. I., Kuryleva, A. G., Baturina, K. A., Iiyasov, I. R. and Korepanov, R. I. 2020. Effect of treatment seeds of grain crops by ultraviolet radiation before sowing. *IOP Conference Series: Earth Environ. Sci.*, 433 (1): 1-8.
24. Kostecka-Gugala, A., Kruczek, M., ledwozyw-Smolenand, I. and Kaszycki, P. 2020. Antioxidants and health-beneficial nutrient in fruits of eighteen cucurbita cultivars: Analysis of diversity and dietary implications, *Molecules*, 25 (8): 1-20.
25. Láposi, R., Veres, S., Mile, O. and Mészáros, I. 2002. Photosynthesis-ecophysiological properties of beech (*Fagus sylvatica* L.) under the exclusion of ambient UV B radiation. *Acta. Biol., Szegediensis.* 46(3-4): 243-245.
26. Long, S. P., Humphries, S. and Falkowski, P. G. 1994. Photoinhibition of photosynthesis in nature. *Ann. Rev. Plant Physiol. Plant Mol. Biol.*, 45: 633-662.
27. Mehata, D. K., Kattel, I., Yadav, S. P. S., Bhujel, S., Bhattarai, S., Yadav, P., Sapkota, P., Timsina, S., and Lahutiya, V. 2022. Varietal trial of okra (*Abelmoschus esculentus* L.) for evaluation of yield and yield parameters. *Journal of Genetics, Genomics & Plant Breeding* 6(4) 111-116.
28. Miguel, J. F. 2021. Effect of light conditions on in vitro adventitious organogenesis of cucumber cultivars. *Fortune J.*, 12 (4): 138-144.
29. Mohammed, A., Endris, A., Haile, A., Kassaw, A., Getu, D., Seyoum, N., Tefera, M., Kebede, G., Assefie, S., and Tefera, A. 2023. Participatory variety selection of faba bean varieties based on farmers preferences for producing areas of South Wollo Ethiopia. *J. Genet., Genom. Plant Breed.*, 7(4): 84 – 88.
30. Molina, M. J. and Rowland, F. S. 1974. Stratospheric sink for chlorofluoromethanes chlorine atomic-catalysed destruction of ozone. *Nat.*, 249: 810-812.
31. Omilabu, S.K., Ayo-Vaughan, M.A., Akintobi, D.C., Lawal, I.T., and Alake, C.O. 2022. G x E interactions and stability analysis in cowpea genotypes (*Vigna unguiculata* (L.) Walp). *J. Genet., Genom. Plant Breed.*, 6(4) 93-101.
32. Owusu, E. Y., Kusi, F., Kena, A. W., Akromah, R., Attamah, P., Awuku, F. J., Mensah, G., Lamini, S. and Zakaria, M. 2022. Genetic control of earliness in cowpea (*Vigna unguiculata* L. Walp). *Heliyon*, 8 (7): 1-12.

33. Paris, H. S. 1996. Summer Squash: history, diversity and distribution. Horti. Techno., 6: 6-13.
34. Pitiramovae, M. A. 1979. Effect of gamma rays and mutagens on barley seeds. Fiziol Res., 6: 127-131.
35. Ribeiro, H. L., Boiteux, L. S. and Santos, C. 2014. Genetic parameters of earliness and plant architecture traits suitable for mechanical harvesting of cowpea *Vigna unguiculata*. Australian J. Crop Sci., 8 (8): 1232-1238.
36. Santos, R., Carvalho, M., Rosa, E., Carnide, V. and Castro, I. 2020. Root and agro-morphological traits performance in cowpea under drought stress. Agronomy, 10 (10): 1604-1623
37. Saradhi, P. P., Arora, A. S. and Prasad, K. V. 1995. Proline accumulates in plants exposed to UV radiation and protects them against UV induced peroxidation. Biochem. Biophys. Res. Commun., 209 (1): 1-5.
38. Singh, M., Sardana, S. and Sharma, S. K. 2011. Genetic resources of lentil and its utilization in India. Plant Genetic Res., 9 (1): 30-37.
39. Singh, R. P. and Singh, B. D. 1989. Recovery of rare interspecific hybrids of gram *Cicer arietinum* x *C. cuneatum* L. through tissue culture, Jstor., 58 (15): 874-876.
40. Steel, R. G. D. and Torrie, J. H. 1960. Principles and procedures of statistics. the biological sciences. McGraw Hill, New York, 187-287.
41. Strid, A. and Porra, R. J. 1992. Alterations in pigment content in leaves of *Pisum sativum* after exposure to supplementary UV-B. Plant Cell Physiol., 33: 1015-1023.
42. Strid, A., Chow, W. S. and Anderson, J. M. 1994. UV-B damage and protection at the molecular level in plants. Photosynth. Res., 39: 475-489.
43. Swaminathan, M., Chopra, V. and Bhaskaran, S. 1962. Chromosome aberration frequency and spectrum of mutations induced by EMS in barley. Indian J. Genet. Plant Breed., 22: 192-207.
44. Tevini, M., Braun, J. and Fieser, G. 1991. The protective function of the epidermal layer of rye seedlings against ultraviolet-B radiation. Photochem. Photobiol., 53 (3): 329-333.
45. Verma, A. K., Singh, P., Singh, A. K., Prajapati, J., Gangwer, V., Singh, H., Singh, V. B. and Mishra, A. C. 2023. Performance of pumpkin (*Cucurbita moschata* Duchex. Poir) genotypes for earliness and yield parameters. Biolo. Forum – An Int. J., 15 (8): 18-21.
46. Yusuf, K. K. and Nair, P. M. 1974. Effect of gamma irradiation on the indole acetic acid synthesizing system and its significance in sprout inhibition of potatoes, Rad. Bot., 14: 251-256.
47. Zhao G. Q. and Mabl .2007. Effect of UV-C radiation and hypergravity on germination, growth and content of chlorophyll of wheat seedlings. Crop Sci., 47:123-131.