Annals of Agricultural Science, Moshtohor (ASSJM)
https://assjm.journals.ekb.eg/
www.fagr.bu.edu.eg

ISSN:1110-0419

Original Article Vol. 61(1) (2023), 151 – 166 **DOI: 10.21608/ASSJM.2023.190890.1208**

Mutagenic Effect of Ultraviolet Radiation on Seeding Growth and Productivity of Summer Squash

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Received: September 2, 2022 / Revised: January 10, 2023 / Accepted: January 30, 2023

Abstract

Ultraviolet radiation affected on cellular components indirectly via oxidative mechanisms involving the formation of free radicals. Therefore, this study aimed to investigate morphological and physiological alterations in two varieties and their six hybrids of summer squash. Hybrids were extracted from hybridization between irradiated and nonirradiated plants via a half diallel crosses design. The genotype obtained from hybridization between $P_2 \times M_1{\sim}P_2$ promoted the number of leaves per plant if compared with nonirradiated parents. Meanwhile, the genotypes extracted from hybridization between $P_1{\times}M_1{\sim}P_1$, $P_1{\times}$ $M_1{\sim}P_2$ and $P_2 \times M_1{\sim}P_1$promoted the leaf area per plant. However, total chlorophyll in fruits was decreased in the genotypes affected by UV-irradiation than the parental wild types. Extracted hybrid from hybridization between $P_2 \times M_1{\sim}P_1$recorded minimum days (46.33) to start the first packings of fruits. Meanwhile, the extracted hybrid from hybridization between$P_1{\times}$ $M_1{\sim}P_2$ produced the highest number of fruits per plant, fruits weight per plant and average weight of fruit, all of which determined fruits yield per plant.

Key words: Ultraviolet radiation, summer squash, chlorophyll formation, growth traits, fruit traits, fruits productivity, hybridization.

Introduction

Summer squash (*Cucurbita pepo* L.) is a cross pollinated plant having a diploid chromosome number (2n=2x=40) which planted for its fruits. One of the humanity importance is to improve food production for a current population exceeded seven billion and project in 2050 of nine billion **(Araujo *etal*. 2016)**. Therefor, it is necessary to reduce environment impact and reduction the use of chemical products in food production **(Altieri 1994)**. Though, the research focaus on alternative physical techniques named "emerging technologies" to cover the modern world request is for save production of food and consequently the health of population, as well as, quality of life and environment **(Rifna *et al*. 2019).**

In this way, physical techniques were used by different phenological stages at the pre-sowing stage **(Aladjadjiyan and Kakanakova 2008)**. The pre-sowing technique allow the seeds to release beneficial effects in the early of growth stages **(Thomas and Pothur 2017)**. These conditions providing plants vigor leading to intensification of crop productivity **(Mariz-ponte *et al*. 2018)**. Physical techniques providing seed invigoration and leading to decreasing pollution **(Rifna *et al*. 2019)**. These techniques based on technology of laser which led to magnetic and electric fields as ionizing radiation (Gamma and X-rays), and nonionizing radiation such micro wave, ozone, magnetically treated water and ultraviolet (UV) radiation **(Rifna *et al*. 2019)**. Seed treated with UV at low levels is environmentally safe and ecologically friendly to improve plant productivity, as well induced tolerance of plants to biotic stresses **(Forges *et al*. 2018)**. Ultraviolet radiation is electromagnetic radiation having shorter wavelengths than the visible light, but longer than X - rays **(Shetta and Areaf 2009)**. UV -irradiation was divided to UV - A (320-400 nm) named black light, UV - B (280-320 nm) named medium wave and UV - C (200-280 nm) named short wave or germicidal **(Shetla and Areaf 2009)**. The damaging effect of UV - irradiation increased towards shorter wavelengths as UV - C photons which are higher magnetic and electric fields leading to quickly create higher levels of damage **(Katerova and Todorova 2009)**. The UV light have a spectrum application in food science and agriculture industry **(Gomez-lopez *et al*. 2007)**. In particular, the UV - C radiation was shown to induce positive effect on seedling healthy and vigor. It has been applied on different fruits and vegetables **(Sukthavornthum *et al*. 2018)**.

Chlorofluorocarbons induced by man activities cause depletion in ozone layers leading to attenuation of solar UV - B radiation which reached to earth's surface **(Molina and Rowland 1974)**. Solar radiation corresponds to a minor percentage of the total solar energy but it is potentially harmful caused deleterious effect in the cells. Different cellular components as nucleic acids, proteins and lipids can absorb UV - radiation directly **(Jordan 1996)**. Strong absorption of UV photons by macromolecules in the cells has a strong effect on plant and animals metabolism **(Heisler *et al*. 2003)**.

Plants affected by UV - radiation show inhibited growth, morphological alteration and stimulate the level of phenolic pigments **(Brzezinska *et al*. 2006)**. Inhibition of photosynthesis leading to the key factors of physiological disorders and decreased the weight of plants **(Ines *et al*. 2007)**. The deleterious effect of UV on photosynthesis process can be attributed to the reduction in the gene expression of photosynthesis**(Mackerness *et al*. 1997)**, as well as, changes in ion permeability of thylakoid membranes **(Doughty and Hope 1973)**, in addition changed the concentration of chlorophyll and carotenoids **(Gaberscik *et al*. 2002)**. Simultaneously, many morphological changes may accured as the reduction in plant height and leaf area **(Pukacki 2000)**. Thus, the effect of UV -irradiation on plant growth and physiology has become one of the most important trends of investigation in the past few years. Reducing photosynthesis could be a consequence of damage to different molecular mechanisms of the photosynthesis pathways**(Jansen *et al*. 1998)**. UV - radiation have an indirect damaging effect on plants. Both chlorophyll a and b concentrations were dropped in leaves of *Phaseolus vulgaris* grown under the stress of UV- B **(Michaela *et al*. 2000)**. UV -irradiation stimulated the accumulation of flavonoids , proline , copherol and ascorbate concentrations**(Carlettia *et al*. 2003)**. Furthermore, **Neelamegam and Sutha (2015)** found that pretreatment of groundnut and mung bean seeds by UV - C stimulated the weight of shoots and roots. Seeds are more susceptible to radiation if their water content was higher. The importance of water content stimulatedthe effects of physical and chemical mutagens as well **(Conger *et al*. 1968)**. Water concentration involving facilitate mobility and the effects of free radicals and oxygen with physical mutagens **(Ehrenberg 1961)**.

Therefore, in this study the seeds of both summer squash varieties were soaked before UV - irradiation to facilitate the mutagenic effect of UV. The sources of visible and UV - radiation had induced mutation that development new species to speed up generation via their action on DNA, photosynthesis orientation, metabolism and consequently growth of different plants **(Barnes and Greenebaum 2007)**. Non- ionizing radiation was insufficient to induce ionization phenomena. In this situation the radiation penetrated only the surface of samples. These radiations included ultraviolet radiation , visible light , infrared , microwaves and radio waves radiation. The results from literature appeared variations in productivity including quantitative and qualitative changes after exposure to UV - radiation **(Lazar *et al*. 2011)**. Other studies showed that exposure of whole plant to UV - B changed plant morphology as a result of inhibition the elongation of organs, while in other cases plant growth was stimulated by UV - B **(Kang *et al*. 2011)**. UV - radiation induced mutations and takes part in the production of vitamin D **(Diffey 2002)**. In this way, the present study aimed to evaluate the morphological changes, physiological quality and productivity of fruits by the seedling grown from the seeds treated with UV - radiation prior to sowing.

Materials and Methods

Varieties of summer squash

Two summer squash genotypes named Alexandarani (P_1) and Dyana (P_2) were used in this study. Both varieties were obtained from Horticulture Research Institute, Agriculture Research Center, Egypt. Both genotypes is high flesh thickness and medium sized fruit. They are used as a parental lines in crossing technique by all possible combinations adopting of half diallel cross mating technique **(Doijode and Sullamath 1983).**

Ultraviolet irradiation

Seeds of both genotypes were first soaked in water for 12 hours and then irradiated for four minutes using the laminar cabinet UV rays as an artificial source of UV. The laminar cabinet used in this study was present in Microbial Genetics Laboratory, Faculty of Agriculture, Mansoura University.

The spectrum of UV - radiation was classified into three categories; lower energy named UV - A (320 – 400 nm), high energy named UV - B (280 – 320 nm) and higher energy named UV - C (254 – 280 nm). The UV - A is less effective than UV - B and UV - C for induced mutations **(Barta *et al*. 2004)**. The spectrum of UV lamp used in this study was 300 nm, therefore it was classified as UV - B. Seeds of summer squash were exposed to UV - radiation for four minutes which equal 752.8 joules/m^2 according to **Kondrateva *et al*. (2020)**. The joules defined as the amount of energy extracted when a force of one newton is applied over a displacement of one meter which equivalent one watt of power radiated for one second.

Experimental design

Irradiated and nonirradiated seeds of both genotypes were sown in outdoor experimental plots in Completelyrandomized Block design (CRBD) with three replications. Each experimental plot consisted of 10 rows with three meter length and 0.5 meter width. Two seeds were planted in each hill with a distance 50 cm between the plants. The plants were thinned to one plant per hill after two weeks of germination. The plants were irrigated when needed. All replications were received similar treatments as irrigation, pest and disease control and other agricultural practices. Fruits were collected at two-days intervals. The average number of leaves per plant was recorded at the end of season. M_1 plants were cross - pollinated as seen in **Table (1)** to obtain M_2 seeds which planted in the same design (RCBD) to obtain M_2 plants and their hybrid fruits.

Table 1. Cross-pollination between two genotypes of summer squash including irradiated and nonirradiated plants.

Hybridization between Male plant (♂) × Female plant (♀)	Designation ♂×♀
Unirradiated Alexandarani × Unirradiated Dyana	$P_1 \times P_2$
Unirradiated Alexandarani × Irradiated Alexandarani	$P_1\times M_1{\sim}P_1$
Unirradiated Alexandarani × Irradiated Dyana	$P_1\times M_1{\sim}P_2$
Unirradiated Dyana × Irradiated Alexandarani	$P_2\times M_1{\sim}P_1$
Unirradiated Dyana × Irradiated Dyana	$P_2\times M_1{\sim}P_2$
Irradiated Alexandarani × Irradiated Dyana	$M_1{\sim}P_1\times M_1{\sim}P_2$

The fruits of M_1 plants were harvested at maturity. Seeds of M_1 were planted in the same design (RCBD) to evaluate the productivity of M_2 hybrid plants. Hybrid fruits were photographs in relation to their parents. Evolved traits were recorded in M_2 generation. Observation on days to first male and female flowering appeared was recorded on plot basis. Observations were recorded on sex randomly selected plants from each plot of each treatment.

Leaf area

It was expressed as cm^2 when the plants reached to 50 days old using fresh weight method. Ten disks were taken from the fresh leaves using corkpiercing one cm diameter and then weighted. All the plant leaves were weighted to be apply in the following formula.

$$\text{Leaf area } (cm^2) = \frac{\text{Fresh weight of total leaves per plant}\times 10\times\text{area of disk}}{\text{Fresh weight of 10 disk}}$$

Plastid pigments of chlorophyll in leaves and fruits

Plastid pigments were extracted by methanol from fresh leaves and fruits and then determined spectrophotometrically. The extraction of pigments content (µg / mg fresh weight) was done according to **Lichtenthaler and Wellburn (1983)** method. The absorption spectrum of different pigments was determined at wavelength corresponding to 663 nm and 646 nm using Eppendorf BioSpectrometer Kinetic.

$$\text{Chlorophyll a } (\mu g / mg\ FW) = \frac{12.25\ (A663) - 2.79\ (A646) \times \text{volume (ml)}}{\text{Weight of leaf tissue (mg)}}$$

$$\text{Chlorophyll b } (\mu g / mg\ FW) = \frac{21.5\ (A646) - 5.1\ (A663) \times \text{volume (ml)}}{\text{Weight of leaf tissue (mg)}}$$

Fruit volume

The volume of fruits was calculated by water displacement method using graduated cylinder according to **Gholami *et al.* (2012)**. In addition, the following traits were estimated as; plant height which measured when the plants begin to blooming, first female flowering, first male flowering, first picking date, fruit length, fruit diameter, fruit shape index, number of fruits per plant, fruits weight per plant, fruit weight, number of fruits per plot for the first seven pickings and the weight of fruits per plot during the first seven pickings.

Statistical analysis

Results are the mean values of three biological replicates. ANOVA was used to analyze the general effects of UV irradiation. The data collected were subjected to the analyses of variance to test the significance of differences between genotypic means using F- test and least significant difference (LSD) according to **Steel and Torrie (1960)**.

Results and Discussion

Different genotypes have different response to the level of UV- irradiation. **Cline and Salisbury (1966)** decided that monocots might be less affected by UV- radiation than dicots due to their vertical leaf orientation, protective basal sheath and concealed apical meristem. UV- irradiation was used in this study to increase genetic variation among two genotypes of summer squash for increasing heterosis. The results obtained from these study were divided into two main titles as follows:

Mutagenic effect of UV- irradiation

Vegetative traits

The results recorded in **Table 2** showed insignificant differences between genotypes for all vegetative traits including number of leaves per plant, leaf area, plant height, number of days to first female flowering and number of days to first male flower appeared. The genotype extracted from the selfing hybridization between $P_2 \times M_1{\sim}P_2$ promoted number of leaves / plant than unirradiated parent. In addition, the genotypes extracted from hybridization between; $P_1 \times M_1{\sim}P_1$, $P_1 \times M_1{\sim}P_2$ and $P_2 \times M_1{\sim}P_1$ promoted the leaf area / plant. On the other hand, the genotype extracted from the selfing hybridization between $P_2 \times M_1{\sim}P_2$ promoted plant height. These results agreed with **Neelamegam and Sutha (2015)**, who found that increasing the exposuretime of UV- C (up to 60 min) increased the promotery effect on the seed Germination of groundnut if compared with dry and soaked seed control. The same authors found that increasing duration period of UV- C increased the groundnut seedling (root and shoot) growth. The seedling root and shoot growth of groundnut was high in UV- C irradiated water soaked if compared with dry seeds. **Neelamegam and Sutha (2015)** found that UV- C irradiation stimulated the number of branches and leaves per plant in groundnut cultivar if compared to control. In general, UV- irradiation seed treatment progressively increased some of fresh vegetative traits if compared

Table 2. Mutagenic effect of UV - irradiation on vegetative growth and flowering of M_2 hybrids.

Genotypes ♂ × ♀		Number of leaves/plant	Leaf area (m^2)/ plant	Plant height (cm)	Number of days to first female flowering	Number of days to first male flowering
Unirradiated P_1		34.01	20.62	38.41	46.94	48.86
Unirradiated P_2		31.73	23.16	30.18	51.51	51.29
$M_1{\sim}P_1$		28.99	15.98	35.24	50.54	49.48
$M_1{\sim}P_2$		30.00	24.37	31.45	53.03	52.36
$P_1 \times P_2$		28.88	22.99	36.38	47.29	49.64
$P_1 \times M_1{\sim}P_1$		31.41	49.28	39.50	49.91	48.75
$P_1 \times M_1{\sim}P_2$		29.95	33.72	39.42	47.49	48.67
$P_2 \times M_1{\sim}P_1$		33.14	42.32	41.66	44.51	47.96
$P_2 \times M_1{\sim}P_2$		38.13	19.67	43.56	49.77	50.06
$M_1{\sim}P_1 \times M_1{\sim}P_2$		33.04	20.66	37.82	50.67	50.78
F-test		Is	Is	Is	Is	Is
LSD	0.05	8.07	25.81	8.18	6.25	2.57
	0.01	11.06	35.36	11.20	8.57	3.52

Notes

M_1 = First irradiated generation.

M_2 = Second irradiated generation.

$M_1{\sim}P_1$ = First irradiated generation derived from P_1.

$M_1{\sim}P_2$ = First irradiated generation derived from P_2.

Is = Insignificant differences.

to control without significant differences between genotypes affected and nonaffected by UV- irradiation. In contrast,**Flint *et al*. (2003)** stated that UV irradiation resulted alterations in plant growth, development and morphology. However,**Siddiqui *et al*. (2011)** decided that groundnut seeds treated with UV- irradiation showed increment in shoot weight, root length, root weight, leaf area and number of nodules per plant. According to **Ulukapi and Ozmen (2018)**, gamma applications had an enhancing effect on stem diameter of common bean (*Phaseolus vulgaris* l.) than control plants and there was a relationship between body thickening and dwarfing of plant affected by gamma rays. **Kayan and Eser (2004)** found that chlorophyll mutations were increased in M_3 generation in small - grained beans line due to increased dose of gamma irradiation. **Preuss and Britt (2003)** stated that at the high dose of gamma rays, DNA damage and mutation rates are higher, but most of plants die or sterility. Besides, it was stated that the reduction shown in this study for some vegetative traits in the plants affected by UV- irradiation may resulted from reduction in the amount of internal growth regulators depending on the radiation **(Kiong *et al*. 2008)**. This agreed with **Bajaj (1970)**, who reported that gamma rays caused problems in RNA and protein biosynthesis and then inhibits plant growth *in vitro*. Note that the control plants presented the highest values of vegetative traits when compared with most genotypes obtained from the UV- irradiated seeds. In this respect,**Gani *et al*. (2012)** showed that when applying UV- radiation, the bean starches and the cell wall of the cotyledon undergo changes, these changes could modify their functional properties which would benefit the food industry as an additive. Furthermore,**Lazim and Nasur (2017)** treated sorghum seeds with UV- radiation without find significant effects on germination percentage and the length of seedling roots, while showing significant negative impact on seed germination, seedling length and the number of leaves. The present study agreed with **Hernandez-Aguilar *et al*. (2021)**, who found that there were insignificant differences between UV- irradiated seeds of *Phaseolus vulgaris*. According to **Solecka (1997)**, exposure of plant tissues to UV increased the concentration of reactive oxygen species which induced seed germination. The results are also in harmony with**Zuk-Golaszewska*et al*. (2003)**, who found that applied UV- radiation on *Avena fatua* and *Setaria viridis* induced changes in leaf and plant morphology. It was decrease plant height, fresh mass of leaves, shoots and roots, as well as leaf area. The same authors decided that the subsequent levels of increased UV- B radiation delayed plant growth and reduced the number of leaves leading to decreased the leaves fresh weight per plant.

Chlorophyll formation

The results presented in **Table 3** appeared significant differences between different genotypes in total chlorophyll of leaves and fruits. Total chlorophyll in leaves was decreased insignificantly than unirradiated P_1 and P_2. The negative effects of UV- radiation resulted in deformed chlorophyll formation. This reflected the mutagenic effect of UV- radiation on the genes formed chlorophyll. Total chlorophyll in fruits was also decreased in the genotypes affected by UV- irradiation than the parental wide types. Some genotypes appeared significant decrease in fruits chlorophyll formation as irradiated P_1 genotype, while some other genotypes showed insignificant decrease chlorophyll formation in fruits. Furthermore, the formation of chlorophyll a and b in leaves and fruits showed insignificant differences between different genotypes. Some hybrids showed intermediate values of total chlorophyll formation in leaves as $P_1 \times P_2$ and $P_1 \times M_1$~P_2. However, the same trend was also appeared in fruits produced by the following hybrids; $P_1 \times P_2$ and $P_1 \times M_1$~P_2.

These results reflected the effect of UV- irradiation on some physiological traits in two different genotypes of summer squash. The results obtained herein agreed with **Zuk-Golaszewska *et al*. (2003)**, who found that the different doses of UV- B radiation applied on two species *Avenafatua* and *Setariaviridis* induced changes in chlorophyll pigments which varied considerably. In this respect **Hoffman (1999)** stated on ornamental plants that the high level of radiation caused chlorophyll degradation but has no impact on quality of the plants. The UV- radiation acts on cellular constituents indirectly through oxidative mechanisms involving the radicals formation. The exposure to UV- radiation determined changes in the metabolism within the growth and development processes leading to positive or negative influences on plant health and vitality **(Lazar *et al*. 2011).**

Table 3. Mutagenic effect of UV- irradiation on chlorophyll formation in leaves and fruits of M_2 hybrids**.**

Genotypes ♂ × ♀		**Leaves (mg/g)**			**Fruits (mg/g)**		
		Chl a	Chl b	Total	Chl a	Chl b	Total
Unirradiated P_1		12.34	23.34	35.68	0.93	2.33	3.26
Unirradiated P_2		10.58	8.81	19.40	0.55	0.94	1.49
M_1~P_1		12.06	12.23	24.30	0.48	0.92	1.40
M_1~P_2		6.94	4.46	11.41	0.27	0.97	1.25
P_1× P_2		13.65	7.36	21.01	0.44	1.07	1.51
P_1× M_1~P_1		11.76	4.55	16.32	1.00	1.00	2.00
P_1× M_1~P_2		13.59	7.58	21.18	1.29	0.75	2.04
P_2× M_1~P_1		9.58	5.18	14.76	0.52	0.26	0.78
P_2× M_1~P_2		9.96	8.96	18.92	1.30	0.55	1.86
M_1~P_1× M_1~P_2		10.18	4.78	14.96	0.26	0.60	0.86
F-test		Is	Is	*	Is	Is	*
LSD	0.05	8.35	10.91	12.64	0.97	1.04	1.17
	0.01	11.44	14.94	17.32	1.32	1.42	1.61

Notes

Chl = Chlorophyll.
M_1 = First irradiated generation.
M_2 = Second irradiated generation.
M_1~P_1 = First irradiated generation derived from P_1.
M_1~P_2 = First irradiated generation derived from P_2.
Is = Insignificant differences.
* = Significance at 0.05 level of probability.

These results agreed with **Barnes and Greenebaum (2007),** who demonstrated that UV- radiation induced mutations to speed up generation and development the new species by its action on DNA, photosynthesis, orientation and mobility, metabolism and growth of different plants. In this situation non-ionizing radiation which characterized by small wavelengths and energies which means insufficient to produce ionization phenomena. These category includes UV, visible light, infrared, microwaves, radio waves radiation **(Moan 2001)**. Furthermore,**Lazar *et al.* (2011)** stated that UV- radiation is absorbed by proteins and nucleic acids in which photochemical changes are produced, cell death may be occurred and physiological changes may be happen as the result of inhibition in the elongation or expansion of organ. On the other hand, responses may be causes by direct effects of UV- radiation on essential components and cellular membranes under the action of free radicals leading to reducing mRNA transcription and effects on protein synthesis and enzymatic activity **(Lazar *et al.* 2011)**. The UV- light activates aromatic amino acids (Tyr, Trp, Phe) and thiols on the outside of protein leading to coupling the slide surface, as well as cross linking between proteins **(Rogers *et al.* 2004)**. The seeds of summer squash used in this study were soaked in water for 12 hours before UV- irradiation to facilitate the mobility and action of free radicals and oxygen with physical mutagens **(Ehrenberg 1961)**.

Quality of fruits

Summer squash is a cross pollinated crop exhibits considerable variations for the traits of fruits quality among different genotypes as shown in **Table**

4. Therefore, fruit length, fruit diameter and shape fruit index showed significant differences between different genotypes. On the other hand, none of the hybrid genotypes showed significant increase above the parental varieties. Furthermore, the number of days needed to begin the first collection of fruits and fruit volume did not show any significant differences between different genotypes. The results revealed that the estimates for number of days needed to start the first collection of fruits showed a range of days between 46.33 ($P_2 \times M_1\sim P_1$) to 52.33 ($P_1 \times M_1\sim P_1$). Meanwhile, fruit volume was ranged between 56.4 ($P_1 \times M_1\sim P_2$)to 73.73 centimeter ($M_1\sim P_1 \times M_1\sim P_2$).

Table 4. Effect of UV- irradiation on fruit quality of M_2 hybrids.

Genotypes ♂ × ♀		Number of days to first fruits collection	Fruit length (cm)	Fruit diameter (cm)	Fruit volume (cm)	Shape index of fruit
Unirradiated P_1		48.33	14.23	3.22	58.96	4.41
Unirradiated P_2		49.66	11.79	3.88	58.83	3.05
$M_1\sim P_1$		49.66	14.89	3.30	68.23	4.50
$M_1\sim P_2$		50.33	12.73	3.76	61.96	3.37
$P_1\times P_2$		48.33	13.22	3.44	58.16	3.85
$P_1\times M_1\sim P_1$		52.33	14.19	3.27	65.23	4.33
$P_1\times M_1\sim P_2$		47.00	13.25	3.26	56.40	4.11
$P_2\times M_1\sim P_1$		46.33	12.78	3.44	65.26	3.74
$P_2\times M_1\sim P_2$		50.33	12.43	3.70	66.93	3.35
$M_1\sim P_1\times M_1\sim P_2$		49.00	13.28	3.68	73.73	3.59
F-test		Is	**	*	Is	**
LSD	0.05	4.92	1.02	0.42	15.81	0.55
	0.01	6.74	1.40	0.57	21.66	0.76

Notes

M_1 = First irradiated generation.
M_2 = Second irradiated generation.
$M_1\sim P_1$ = First irradiated generation derived from P_1.
$M_1\sim P_2$ = First irradiated generation derived from P_2.
Is = Insignificant differences.
*, ** = Significance at 0.05 and 0.01 levels of probability, respectively.

The fruit length showed a range of 11.79 (P_2) to 14.89 ($M_1\sim P_1$), while fruit diameter was ranged between 3.22 (P_1) to 3.88 (P_2). Meanwhile, the shape index of fruit was ranged between 3.05 (P_2) to 4.50 ($M_1\sim P_1$). These results agreed with **Marxmathi *et al*. (2018)**, who found that fruit length heterosis showed a range from -37.02 to 32.91, while fruit diameter heterosis showed a range of -31.75 to 6.41. It has been seen that the dose of UV- irradiation applied in this study do not affect significantly on the quality of fruit traits of summer squash because the dose used in this study may be lowest to stimulated fruit traits. In future studies on summer squash, it is thought that the determination of the effects of low ultraviolet doses on summer squash fruit traits will contribute to abiotic stress studies in particular.

This has proved that it is absolutely necessary to carry out a dose determination study before largescale studies are carried out. Insignificant effects shown in fruit traits may be due to insignificant effect of UV on flavonoids production thereby protect the primary metabolism and furthermore they have antioxidant properties. Therefore, flavonoid accumulation in plant tissues can improve their tolerance to abiotic stresses as UV- radiation via reducing the damage may be happen due to photosynthetic apparatus **(Estiarte *et al*. 1999)**. Similarly flavonoid accumulation proved to be a useful indicator to potential plant sensitivity to increased ultraviolet radiation **(Wand 1995)**. Furthermore, **Kovács and Keresztes (2002)** stated that UV- C (100-280 nm) photons have higher energy than visible light (> 400 nm) photons, therefore affected plantcells more strongly. Insignificant effect shown by the lowest dose of UV used in this study may be due to insufficient temperature increased which do not reached to the optimum temperature required to seed respiration and mitochondrial activities **(Sadeghianfar *et al*. 2019)**.

In contrast, UV- irradiation on winter wheat for 10 minutes (1882 j/m^2) positively affected germination energy by 2.8 % **(Kondrateva *et al*. 2019)**. Therefore, ultraviolet irradiation used for treated the seeds is a promising environmentally friendly and a cheap technique to be used for increasing the energy of seed germination.

Generally, the subsequent levels of increased UV- B radiation delayed plant growth **(Zuk-Golaszewska *et al*. 2003)**. **Greenberg *et al*. (1997)** confirmed the distinguished changes in morphological traits as plant height and leaf area reduction and curling the leaves. In this way, UV- irradiated seeds produce their degradation as a function of radiation time. It is possible that ultraviolet light interacts with different structural levels in the seed leading to photostimulate chromophores that intervene in seeds metabolic processes.

Among the genotypes, the hybrid between ($P_2 \times M_1{\sim}P_1$) recorded minimum days (46.33) to start the first collection of fruits followed by the hybrid ($P_1 \times M_1{\sim}P_2$) (47.0), while the maximum days (52.33) was recorded by the selfing hybrid ($P_1 \times M_1{\sim}P_1$). The higher length of fruit (14.89) was appeared in $M_1{\sim}P_1$ followed by P_1 (14.23), while the lowest fruit length (11.79) was shown in P_2 genotype (3.88) followed by $M_1{\sim}P_2$ (3.76), while the lowest fruit diameter (3.22) was achieved by P_1 genotype. On the other hand, the highest fruit volume (73.73) was recorded by the hybrid genotype ($M_1{\sim}P_1 \times M_1{\sim}P_2$) followed by the selfing genotype (66.93) extracted from ($P_2 \times M_1{\sim}P_2$). Furthermore, the lowest fruit volume (56.40) was appeared by the hybrid genotype extracted from the hybrid $P_1 \times M_1{\sim}P_2$. These results agreed with **Behera *et al.* (2006)**, who found variations in yield and yield components of bitter gourd genotypes depending on the fact that genotypes differ in their morphological and physiological traits and thereby translocation of carbohydrates from source to sink.

Fruits color

The results appeared in **Figures 1, 4 and 6** reflected that the hybrid fruits showed intense green color than their parents. These results revealed that additive gene effects may played an important role in the contribution of chlorophyll concentrations. This agreed with **Huang and Hsieh (2016)**, who found that fruits color in bitter gourd was controlled by quantitative genes, as well as, the magnitudes of additive and additive × additive gene effects were larger than those of dominance and dominance × dominance gene effects. In cucumber, **Li *et al.* (2013)** decided that a single dominant gene, *B*, controlled both black spine color and orange mature fruit color. The *B* locus was located in the short arm of cucumber chromosome four.

As shown in **Figures 2, 3 and 5** which appeared that the hybrid fruits color showed the same green color of both parents. These results indicated that no dominance was expressed between green color genes from the both parents. This may be due to homozygosity of green color genes in both parents. **Shifriss (1947)** found that the ratio between green and yellow fruits in summer squash changed from the time of flowering to the ripe fruit. The same authors investigated that F_2 plants resulted from the cross between yellow and green fruits were classified after anthesis to 3 green : 1 yellow. But at ripe fruit stage the ratio was 3 yellow : 1 green. **Shifriss (1947)** explained this phenomena is due to the induced of heterozygous plants. Therefore, homozygous plants were stable from anthesis to the ripe fruit stage as seen in these Figures. **Nath and Hall (1963)** found that green fruit at immature stage was monogenetically dominant over the yellow color and green striped fruit exhibited simple dominance over the plain green. **Globerson (1969)** found that the green striped fruit appeared a simple dominance over the plain white fruits in summer squash. The same author stated that the green fruit is controlled by two genes *C* and *R* and that one *C* has a dominant epistatic control. The white fruit was decided as ccrr. The white fruit color in the same study appeared in F_2, F_3 and BC_1 was changed to green during development. The genotype of these fruits was suggested to be ccR-**(Globerson 1969)**. The same author stated that the green color was found to be controlled by epistatic gene, *C*gene have green fruits,

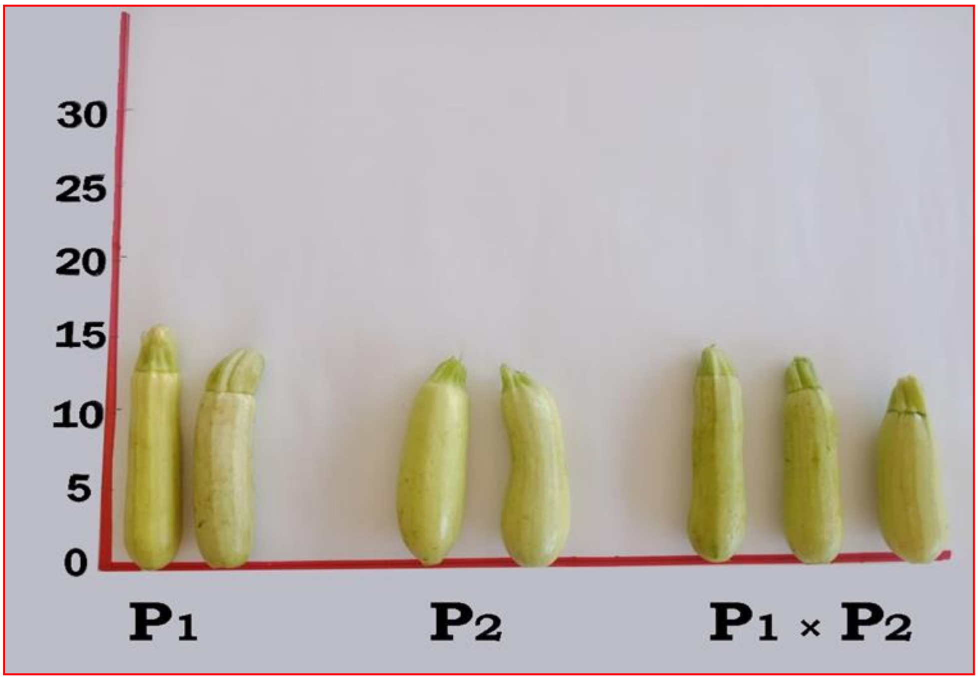

Figure 1. Photograph of parental and hybrid fruits extracted from hybridization between unirradiated variety (P_1) as a male parent with unirradiated variety (P_2) as a female parent.

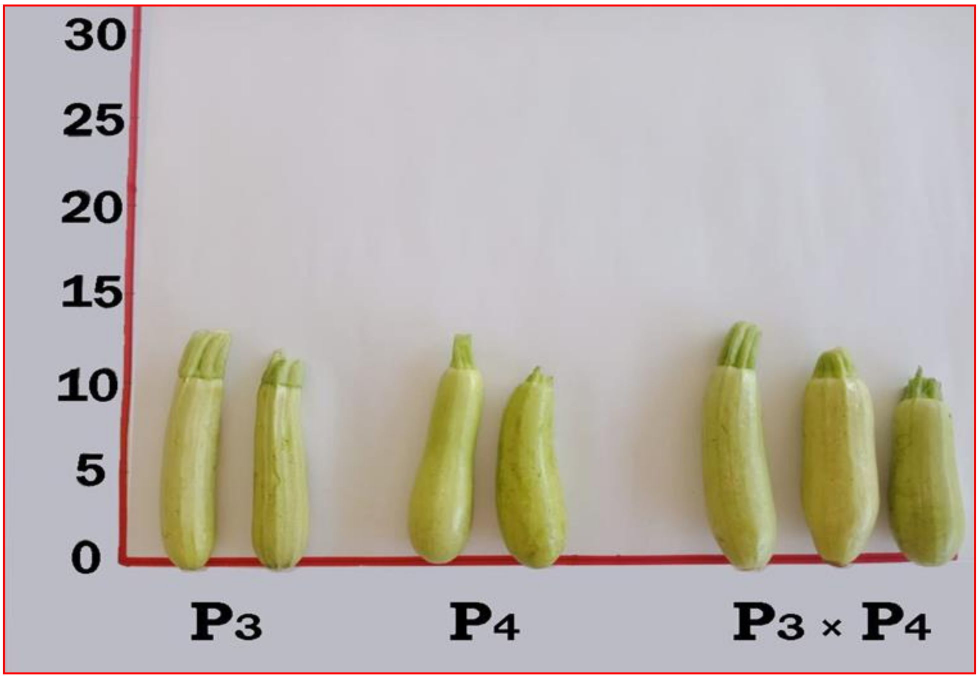

Figure 2. Photograph of parental and hybrid fruits extracted from hybridization between irradiated variety P_1 (named P_3) as a male parent with irradiated variety P_2 (named P_4) as a female parent.

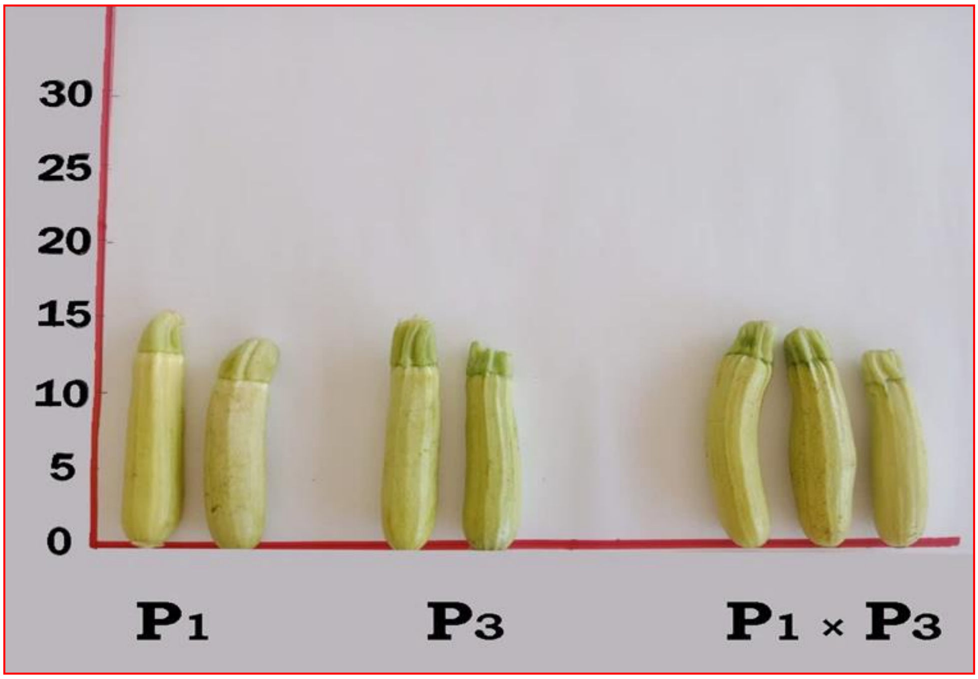

Figure 3. Photograph of parental and hybrid fruits extracted from hybridization between unirradiated variety (P_1) as a male parent with irradiated variety P_1 (named P_3) as a female parent.

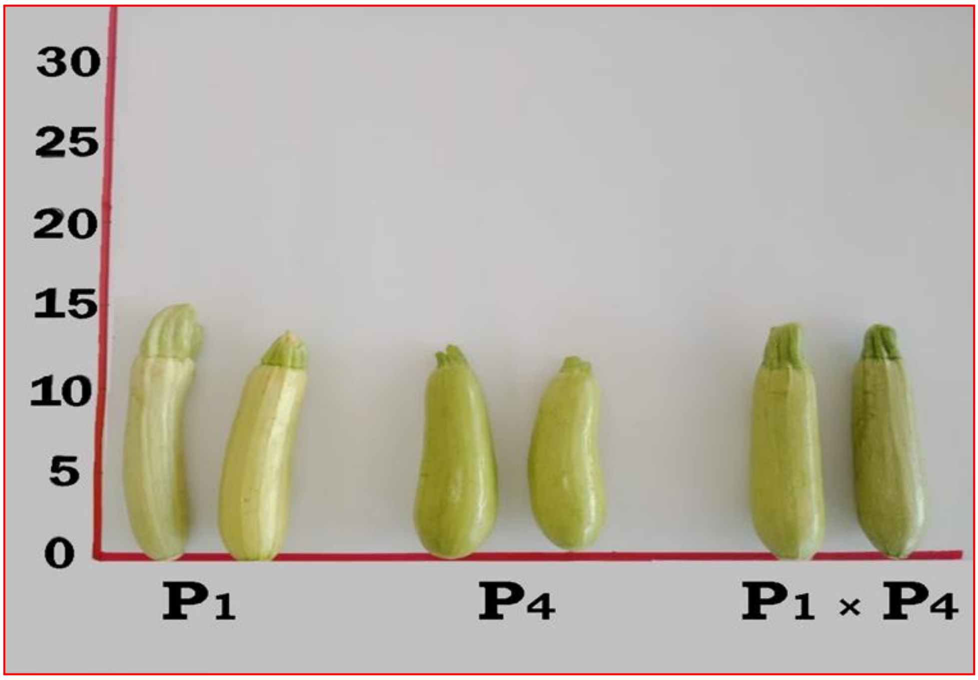

Figure 4. Photograph of parental and hybrid fruits extracted from hybridization between unirradiated variety (P_1) as a male parent with irradiated variety P_2 (named P_4) as a female parent.

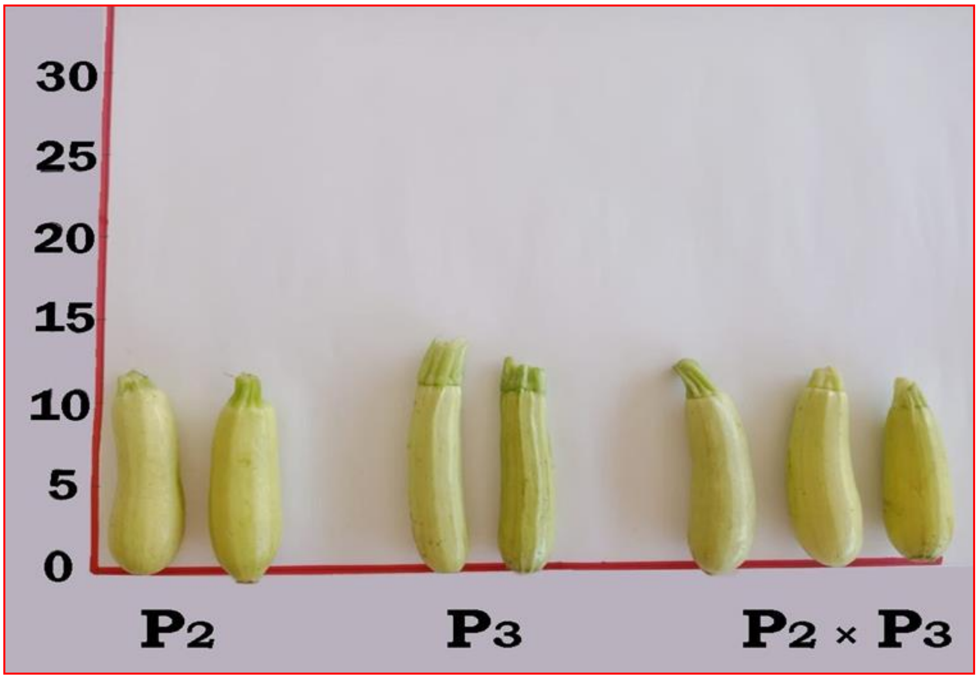

Figure 5. Photograph of parental and hybrid fruits extracted from hybridization between unirradiated variety (P_2) as a male parent with irradiated variety P_1 (named P_3) as a female parent.

Figure 6. Photograph of parental and hybrid fruits extracted from hybridization between unirradiated variety (P_2) as a male parent with irradiated variety P_2 (named P_4) as a female parent.

while the white fruits was controlled by ccrr. **Globerson (1969)** found that the green fruits vs. white was controlled by two genes (*C* and *R*) of which *C* has an epistatic control.**Sinnott and Durham (1922)** recorded an epistatic control of fruit color in *C. pepo* which appeared that white is epistatic to yellow and yellow was simply dominant over green. In addition, **Holowinsky *et al.* (1965)** decided that the size of chloroplasts was associated with the leaf area and morphological age. The change of fruit color from white to green was involved with chlorophyll production. It is possible that in summer squash more than one type of genetic control exists for each fruit color.

Yield components

As shown from the results in **Table 5**, insignificant differences were obtained between different genotypes for number of fruits / plant, fruits weight / plant, average fruit weight, number of fruits per first seven collections,fruits weight per first seven collections, number of total fruits per ten plants and total weight of fruits per ten plants. Thenumber of fruits per plant was varied from 21 ($P_1 \times M_1\sim P_2$ and $P_2 \times M_1\sim P_1$) to 11 ($M_1\sim P_1$). This indicated that the highest number of fruits per plant was obtained from the hybrids extracted from hybridization between $P_1 \times M_1\sim P_2$ and $P_2 \times M_1\sim P_1$. This means that the hybrid between wild type from one variety with irradiated genotype from another variety produced the highest number of fruits per plant because of heterozygosity induced in female parent which contribute the second generation by chloroplast and mitochondria affected by UV- irradiation. In the same time

Table 5. Effect of UV- irradiation on fruits productivity of M_2 hybrids.

Genotypes ♂ × ♀		**Number of fruits per plant**	**Fruits weight /plant (g)**	**Average of fruit weight (g)**
Unirradiated P_1		16	1198	71
Unirradiated P_2		14	948	65
$M_1\sim P_1$		11	962	77
$M_1\sim P_2$		13	907	66
$P_1\times P_2$		17	1384	73
$P_1\times M_1\sim P_1$		18	1540	77
$P_1\times M_1\sim P_2$		21	1675	77
$P_2\times M_1\sim P_1$		21	1656	74
$P_2\times M_1\sim P_2$		18	1467	76
$M_1\sim P_1\times M_1\sim P_2$		17	1348	75
F- test		Is	Is	Is
LSD	0.05	9	797	10
	0.01	12	1091	13

Table 5. Continued.

Genotypes ♂ × ♀		Number of fruits per first seven collections	Fruits weight per first seven collections (g)	Number of total fruits /10 plants	Total fruits weight /10 plants (g)
Unirradiated P_1		20	1242	165	11986
Unirradiated P_2		8	504	140	9480
$M_1\sim P_1$		7	536	119	9624
$M_1\sim P_2$		5	317	134	9077
$P_1 \times P_2$		30	2550	179	13844
$P_1 \times M_1\sim P_1$		30	2307	183	15400
$P_1 \times M_1\sim P_2$		44	2727	211	16758
$P_2 \times M_1\sim P_1$		47	3357	219	16562
$P_2 \times M_1\sim P_2$		8	726	188	14674
$M_1\sim P_1 \times M_1\sim P_2$		9	715	173	13489
F -test		Is	Is	Is	Is
LSD	0.05	43	3069	91	7971
	0.01	59	4204	125	10919

Notes

M_1 = First irradiated generation.
M_2 = Second irradiated generation.
$M_1\sim P_1$ = First irradiated generation derived from P_1.
$M_1\sim P_2$ = First irradiated generation derived from P_2.
Is = Insignificant differences.

less viability mutants were deleterious from the population because they are subjected to natural selection. Thus the remaining plants were better performance in their viability and fertility.

The weight of fruits per plant was varied between 1675 gram ($P_1 \times M_1\sim P_2$) to 907 gram ($M_1\sim P_2$). This indicated that the highest weight of fruits per plant was produced by the hybrid genotype $P_1 \times M_1\sim P_2$ followed by $P_2 \times M_1\sim P_1$ and selfing genotype $P_2 \times M_1\sim P_2$. The weight of fruits per plant affected by the number of fruits per plant and the average weight of fruit.The average weight of fruit was varied between 77 ($M_1\sim P_1$, $P_1 \times M_1\sim P_1$ and $P_1 \times M_1\sim P_2$) to 65 (P_2). The results stated that the superior genotype extracted from the cross between ($P_1 \times M_1\sim P_2$) produced the highest number of fruits per plant, as well as fruits weight per plant and average weight of fruit. These three components determined fruits yield per plant. This reflected that cross pollination between two different genotypes one of them affected by a mutagenic agent may be leading to produce superior genotypes in fruits productivity.

The number of fruits per first seven collections varied from 47 ($P_2 \times M_1\sim P_1$) to 5 ($M_1\sim P_2$). The highest genotypes produced higher number of fruits per first seven collections were $P_2 \times M_1\sim P_1$ followed by $P_1 \times M_1\sim P_2$ and $P_1 \times M_1\sim P_1$. This indicated that hybrid genotypes continued to formed female flowers which turned to fruits after fertilization during all the time of first seven collections. Fruitsweight perfirstsevencollectionswasvaried between 3357gram ($P_2 \times M_1\sim P_1$) to 317 gram ($M_1\sim P_2$). The highest genotypes produced higher fruits weight per first seven collections were $P_2 \times M_1\sim P_1$ (3357 g) followed by $P_1 \times M_1\sim P_2$ (2727 g), $P_1 \times P_2$ (2550 g) and $P_1 \times M_1\sim P_1$ (2370 g). These results indicated that the highest productivity genotypes were obtained from hybridization between wild type variety with a mutant genotype due to heterozygosity between both parents.

Current evidence points to the number of total fruits per ten plants which ranged between 219 ($P_2 \times M_1\sim P_1$) to 134 ($M_1\sim P_2$). The highest productivity genotypes were $P_2 \times M_1\sim P_1$ (219) followed by $P_1 \times M_1\sim P_2$ (211), $P_2 \times M_1\sim P_2$ (188) and $P_1 \times P_2$ (179). These results revealed that cross pollination was better than selfing in cross pollination crops as summer squash. Furthermore, crosses between wild type variety and mutant genotype from another variety may produced superior genotypes recommended to be used in productivity sector.

The results of total fruits weight per ten plants varied from 9480 gram ($M_1\sim P_1$) to 16758 gram ($P_1 \times M_1\sim P_2$). Among ten genotypes sex of them recorded the higher productivity of total fruits per 10 plants as $P_1 \times M_1\sim P_2$ (16758 g) followed by $P_2 \times M_1\sim P_1$ (16562 g), $P_1 \times M_1\sim P_1$ (15400 g), $P_2 \times M_1\sim P_2$ (14674 g), $P_1 \times P_2$ (13844 g) and $M_1\sim P_1 \times M_1\sim P_2$ (13489 g). The results revealed that the superior genotype which recorded better performance for all yield components was obtained from the hybrid extracted from hybridization between $P_1 \times M_1\sim P_2$. This indicated that the divergent parents exhibited better performance of fruits productivity.

The results obtained in this study agreed with **Marxmathi *et al*. (2018)**, who found that out of thirty hybrids one hybrid recorded significant standard heterosis, which may be due to additive gene action. Similar results were obtained by the hybrid genotype P_1 $\times M_1\sim P_2$ which expressed higher yield components reflected the importance of heterozygosity stage that remove the action of recessive alleles. Also, **Marxmathi *et al*. (2018)** stated that fruit size was controlled by partial dominance of additive gene effect. The same authors also found that crossed between smaller sized fruits with higher sized fruits induced decrease in hybrid fruit size which is consonance with the finding of **Muthaiah *et al*. (2017)** in ridge gourd. Generally, the highest heterotic expression of yield components was recorded in P_1 $\times M_1\sim P_2$ followed by P_2 $\times M_1\sim P_1$. This leading to a prime need for improvement and develop superior hybrids in summer squash exhibiting higher productivity of fruits in relation to its importance to be serve as the most potent material for exploitation of heterosis on commercial scale. Hence, in this study new genotypes exhibited heterosis for higher productivity were produced to improve the yield of this crop. Therefore, the superior genotypes appeared may be selected as parents in further breeding programme to improve this crop in terms of yield and earliness.

Yield is greatly influenced by number of fruits, average fruit weight, fruit length and fruit girth. From these results it can be concluded that the variations in yield components among the genotypes explained that the genotypes differ in their expressing genes. Irradiated variety P_2 intered the cross as irradiated female parent with wild type variety P_1 as a male parent produced the highest yield components. The adverse factor UV affected on P_2 may affect metabolic and physiological changes due to mutation in nuclear and cytoplasmic genes. On the other hand, UV- radiation stimulated the biosynthesis of UV- absorbing contents performed a photoprotective function. Ultraviolet radiation reduced protein, nucleic acids and other macro molecules, which caused conformational changes in their structure **(Bassman 2004)**.

Genetic improvement of crop depending on the amount of genetic variability carrying population. Mutation in gene level caused alterations in gene structure named point mutation. Changes in chromosome structure either by loss or addition of any chromosome set caused appearance or disappearance of new traits. Once the mutation occurred in the gene or chromosomal level and then stable in populations, they are subjected to natural or artificial selection. Mutation breeding as shown in this study is a tool in the hand of breeder to create variations in crop populations to make selection to bring further improvement in crop **(Ambavane *et al*. 2015)**.

In conclusion, ultraviolet treatment of plant seeds is a promising environment friendly and a cheap way to increase genetic variations in the varieties of summer squash to be used as a tools for increasing genetic diversity. Morphological and physiological changes occurring in both varieties of summer squash exposed to UV are a tools in mutation breeding studies. It is thought that the determination of UV effects will contribute to abiotic stress studies in particular. On the another aspect, mutations induced by UV - irradiation may generate novel genetic variations which may be better suited in constructed heterozygosity. Though, the cross combination between wild type variety with UV - irradiated variety from another genotype exhibited superior performance in fruits productivity. Hence, these genotypes may be selected as a parents in future breeding programme to improve crop yield and earliness. Isolation of better genotypes defined as high yield of fruits is possible in UV - irradiated plants. The role of mutation in plant breeding programs has been established. UV - radiation absorbed by proteins and nucleic acids induced morphological and physiological changes in plants as seen in this study.

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التأثير المطفر للأشعة فوق البنفسجية على نمو البذور وإنتاجية قرع الكوسة

ميرفت إبراهيم كمال ، أشرف حسين عبد الهادي ، خليفه عبد المقصود زايد ، أسماء سمير أحمد
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تؤثر الأشعة فوق البنفسجية بشكل غير مباشر على التراكيب الخلوية من خلال آلية الأكسدة التى تتضمن تكوين الشوارد الحرة. لذلك كان الهدف من هذه الدراسة هو مشاهدة التغيرات الوراثية المورفولوجية والفسيولوجية فى صنفين بالإضافة إلى ست هجن من قرع الكوسة. تم الحصول على الهجن من خلال تصميم التهجينات نصف الدوارة بين النباتات المعاملة والغير معاملة بالإشعاع.

نتج عن التركيب الوراثي المستخلص من التهجين بين $P_2 \times M_1\sim P_2$ أعلى عدد من الأوراق للنبات إذا ما قورن بالأب الغير معامل بالإشعاع. كما تميزت التراكيب الوراثية التالية $P_1 \times M_1\sim P_1$ $P_1 \times M_1\sim P_2$, $P_2 \times M_1\sim P_1$ بزيادة قيمة المساحة الورقية للنبات. بينما انخفض تركيز الكلوروفيل الكلي فى الثمار للتراكيب الوراثية المتأثرة بالأشعة فوق البنفسجية مقارنة بالأصناف البرية الأبوية. سجل الهجين المستخلص من التهجين بين $P_2 \times M_1\sim P_1$ أقل عدد من الأيام اللازم لبدء أول جمعة للثمار (46,33). كما أنتج الهجين $P_1 \times M_1\sim P_2$ أعلى عدد من الثمار للنبات، وزن الثمار للنبات، متوسط وزن الثمرة وكلها من الصفات المحددة لإنتاج الثمار للنبات.