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Enhancement of Drought Tolerance in *Salvia coccinea* Plants by Irradiation with Gamma and Laser Pre-Treatments

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Abstract

Gamma- and laser-irradiated seeds were grown under drought stress conditions to evaluate the irradiation effects on growth, flowering and some physiological traits of *Salvia coccinea* plants grown in pots. Pre-sowing gamma-irradiation at 5, 10, 15, 20 and 25 k.rad or laser irradiation (He-Ne) for 5, 10, 15 and 20 min. exposure time were applied. Soil moisture levels were imposed by irrigating the plants with 100 (control), 80, 60 and 40% of field capacity (F.C.). Results indicated that laser-irradiation was less effective than gamma-irradiation on drought stress. Plants grown under high water stress (40 and 60% F.C.) resulted in significant decreases in all vegetative growth and flowering parameters tested. The decrease in plant growth and flowering quality induced by water deficit was associated with a reduction in leaf relative water content and increases in total phenols, proline and abscisic acid contents in plants. Under water stress, there were significant changes in the activities of the defensive enzymatic system in leaves. The activities of peroxidase and catalase in irradiated plants with gamma or laser were higher at 60% F.C. than in other water stress treatments. In general, it can be concluded that initiated resistance of *Salvia coccinea* plants under drought stress are enhanced after pre-sowing seed irradiation with gamma at 15-25 k.rad followed by laser for 10 min. exposure time. The most effective combination was gamma-radiation (15-25 k.rad) plus soil moisture content at 80% F.C. This combined treatment protects plants from the deleterious effects of drought. It can tolerate soil water deficit and consume less irrigation water by 30%.

Keywords: *Salvia coccinea, gamma-irradiation, laser-irradiation, water stress, abscisic acid, enzymes activity*

Introduction

Scarlet sage (*Salvia coccinea* Buc'he ex Etl.) belongs to family Labiate is herb and somewhat shrubby treated as an annual growing up to 4.5 ft., with larger bright scarlet-red flowers. It is considered the most widely cultivated ornamental sages using as flower-garden, bedding plant, border subjects and the sweet-herb species.

The excess of irrigation water resulted in high water losses and low irrigation efficiencies, as well as create drainage and salinity problems; Kirkham (2005). Deficit irrigation is a strategy that allows the plants tolerant to drought stress in order to reduce costs and potentially increase income whereas water costs are high or water supplies are limited. Therefore, research on plant adaptability in arid conditions is always a focus of many investigators. Recently, some research findings have indicated that gamma- or laser-radiation can be used to pre-treat plant seeds in order to enhance the germination, the rate of seedling emergence, the promotion of growth and flowering, and especially to stimulate the drought-resistance characteristics of many plant species.

Hamideldin and Eliwa (2015) concluded that gamma-rays belongs to ionizing radiation is an energetic form of electromagnetic radiations, are known to be the most popular mutagens for their simple application, good penetration, reproducibility, high mutation frequency, and less disposal problems. They added that gamma-irradiation at 60 Gy recovers the drought stress by decreasing proline and total phenols content in maize plants. Abdel-Tawab *et al*. (2002) reported that low doses of gamma-irradiation under drought stress display better performance than that of the unirriadiated maize plants under the same conditions. Moustafa and Ali (2009) irradiated chickpea (*Cicer arietinum* L.) seeds with gamma-rays at doses of 50 and 75 Gy and planted them under drought stress conditions to obtain useful mutants. They found that induced mutation by gamma-irradiation was of great value for improving agronomic characters of economic value and enhanced tolerance to drought stress that developed in M_2 and M_3 generations. Bachiri *et al*. (2014) demonstrated that gamma-irradiation is considered as physical mutagen imposing considerable effects on physiological and biochemical processes in plants. The irradiation of wheat seeds caused genetic variability that due to select new genotype improved tolerance to drought in harsh conditions. Under water stress, the dose of 150 Gy significantly increased proline concentration and leaf relative water content composed to unirradiation plants.

As for laser-rays which belong to unionizing radiation is a type of gas laser that gain medium consists of a mixture of helium and neon (10:1) in side of a small bore capillary tube. Absten (1992) declared that the interaction between laser light and plant tissue can be described in terms of reflection, scattering, transmission and absorption. El-Tobgy *et al*.(2009) stated that laser-rays can promote the complex cycle of GA formation, while the polychromatic light (sunlight) cannot induce this effect. Wu *et al*. (2007) found that laser pretreatments of Chinese pine seeds have important application prospect in order to increase the biological effects on seed germination under water stress and increasing drought resistance of seedlings. They added that laser-irradiation showed significant changes in the activities of the defensive enzymatic system such as peroxidase in plants under water stress conditions. Metwally *et al*. (2014) exposed caster bean (*Ricinus communis* L.) seeds to laser-rays for 5 min., and they found this treatment stimulated plant growth parameters and helped it to complete its life cycle under drought conditions.

The majority of Egyptian plant-growers usually irrigate by flooding irrigation method that consume more water. Improving drought tolerance by using pre-sowing irradiation of ornamental-herb seeds such as *Salvia coccinea* (as a good example) consume less water that could be solved water deficit problem and the cultivation in the dry regions has been well documented.

Although there have been many studies on the effects of pre-sowing irradiation and water deficit treatments separately on growth, flowering and active biochemical constituents, comparatively few researches investigate the relationship between these treatments, especially for ornamental-herbs under drought stress conditions. For the areas having drought problem, the selection of plant species has high water use efficiency that would be valuable to be cultivated. *Salvia coccinea* plant can be the choice since it is very important potted flowering and there is a good marked demand for it in Egypt.

The main objective of the present work was to develop new *S. coccinea* genotypes (putative mutants) of high quality under water stress conditions. Also, to understand the physiological basis for the new mutants and how that might impact drought tolerance.

Materials and Methods

The experiment was carried out at the Nursery of ornamental plants, Faculty of Agriculture, South Valley University during two successive seasons of 2016/2017 and 2017/2018.

A lot of 1500 healthy scarlet sage seeds were obtained from Agriculture Faculty, South Valley University, Qena, Egypt. Seeds were randomly divided into ten lots selected; each 150 seeds, for irradiation treatments.

In October 10th 2016, ten lots; each lot considered is considered as an individual treatment, five lots were exposed to five gamma-radiation doses of 5, 10, 15, 20 and 25 k.rad through cesium source (at a rate of 2.2 kGy/sec) done at National Center for Radiation Research and Technology, Cairo, Egypt. Other four lots were exposed to laser-rays for 5, 10, 15 and 20 min. exposure time at the wavelength of 632.8 nm with helium-neon laser (especially prepared for irradiation of biological materials) in National Institute of Laser Enhanced Sciences, Cairo University, Egypt. The light power of the laser was 10 mW and the intensity of light falling on the seeds was about 1 mW cm^{-2}. The rest lot was considered as unirradiated control (without exposure to rays).

After complete emergence of the irradiated seedlings (40-day-old), uniform seedlings developed four leaves (10 cm in height) were carefully and randomly selected from each treatment and singly transplanted into plastic pots filled with clay soil (pH 7.65), each pot (2.2 *l*) contained 3.5 kg air-dried soil to follow up the growth and development of the newly generated plants subjected to different soil moisture levels.

Soil moisture treatments were initiated directly after transplanting at four levels; 100 (control), 80, 60 and 40% of the field capacity in the first season (M_1 generation), meanwhile, at the end of it the treatment of 40% F.C. failed to produce seeds. Soil moisture levels of the field capacity were determined according to Veihmeyer and Hendrickson (1931). An approximate value of the plant weight was taken into consideration. The amounts of water needed for 100, 80, 60 and 40% F.C were 300, 210, 130 and 50 ml/pot/day. The pots were covered with black plastic to exclude light from the roots and prevent evaporation. All horticulture practices as weeding and others were similarly done whenever needed. No fertilizers were added to the soil.

The experiment included 40 treatments (10 pre-sowing irradiation x 4 moisture levels) consisting of a split-plot design; the main plot was field capacity levels and the sub-plot was pre-sowing irradiations. Each experimental unit contained four plants (pot) and replicated three times. The experiment was placed in polyethylene house clear sheets under partial shade conditions (50% shade), ambient temperatures ranging from 20 to 35°C and relative humidity 70-75% until the end of experiment.

Data recorded

1. Vegetative growth and flowering parameters

Data of plant height, number of branches and leaves, leaf area, and dry weight of aerial parts and root system (dried in an electric oven at 70°C for 48 hours) were recorded in June 2017 and in May 2018 for M_1 and M_2, respectively. Days to anthesis were calculated from sowing date till the first inflorescence opened. Number of inflorescences per plant, number of florets per inflorescence and inflorescence length were measured.

2. Active biochemical constituents

* The content of soluble phenols in dried leaves were estimated colorimetrically at 750 nm using a modified Folin method as described by Vasco *et al*. (2008).

*Proline content in dried leaves and roots were determined colorimetrically at 520 nm wave length according to Bachiri *et al*. (2014).

*Endogenous abscisic acid content in fresh leaves and roots was isolated by extraction with volatile organic solvents, and quantification the hormone on C_{18} reversed-phase high performance liquid chromatography (RP-HPLC) column. Detection was with absorbance monitor operating at 254 nm according to Zhang *et al.* (1998).

3. Determination of enzymatic activities

The enzyme extraction was prepared by grinding 0.5 g of fresh young leaves in 10 ml 0.1 M Na-phosphate buffer at 7.1 in mortar. The mixture was filtered then the filtrate centrifuged at 1500 rmp for 20 min at 6°C. The supernatant was used for peroxidase and catalase assays.

* The activity of peroxidase was determined spectrophotometrically at 425 nm according to the method described by Macadam *et al.* (1992). This method depends on measuring the oxidation of pyrogallol to pyrogallin in the presence of hydrogen peroxide. The activity was estimated as the change in absorbance. Data of peroxidase activity were converted to µmol pyrogallin/1 g fresh tissues/1 min.

*Catalase activity was determined according to Aebi (1984). The activity in the crude extract was quantified base on the activity of bovine liver catalase. Absorbance changes were recorded at 240 nm. On unit of catalase activity was defined as the decomposition of 1 µmol H_2O_2/min. at pH 7 and 25°C.

4. Leaf relative water content (LRWC)

The LRWC was calculated based on the methods of Yamasaki and Dillenburg (1999).

Statistical analysis

Data were statistically analyzed using Statistix 8.1 analytical software, and the means were compared using a least significant difference (L.S.D.) test according to Dowdy and Wearden (1983).

Results and Discussion

Vegetative growth characteristics

Plant height

It is cleared that plant height was significantly decreased with decreasing soil moisture level in M_1 and M_2 generations (Table 1). Obviously, high water stress (40% F.C) reduced plant height by 72% compared to 100% F.C. These results are in accordance with the findings of Shams El-Din (1976) on chrysanthemum, Abd El-Samad and Sief (2002) on apricot seedlings, and Dichio *et al*. (2004) on peach seedlings. They concluded that vegetative growth is very sensitive to water deficit. An early stress will not allow an adequate shoot elongation.

Concerning irradiation treatments effect, gamma-rays ranged from 5 to 20 k.rad (G_1- G_4) significantly increased plant height by 11-24% over unirradiated plants in M_1 generation, as well as the doses of 15 and 20 k.rad (G_3 and G_4) increased it by 14-16% in M_2. Meanwhile, laser treatments showed no significant effect in most cases (Table 1). These results are in conformity with those reported by Momin *et al*. (2012) on chrysanthemum, and el-Khateeb *et al*.(2017) on *Helichrysum bracteatum* that irradiated with gamma-rays. The effect of laser on plant height has previously been shown for *Celosia argentea* var. *cristata* by Metwally *et al*. (2013).

In this way, according to the opinions of a number of authors, one of the first reasons for the stimulation of plant growth and development with low irradiation doses is attributed to the stimulation of cell division which accelerated by the division of the nucleus, in all probabilities, with the acceleration of DNA synthesis; Fonshtein and Cheltsova (1969), and Khudadatov (1969).

Branch number

It was observed that the difference between water-stressed plants (80% F.C) and well-watered ones (100% F.C) was not significant in both generations. Meanwhile, the irrigated plants at 60 or 40% F.C produced the least branch formation (Table 2). Clearly, soil moisture content at 100% F.C was almost 7-times higher than 40% in M_1. Similar results were obtained by Suzuki (1979) on some annual flowers (*Callistephus chinensis, Bellis perennis, Calendula officinalis, Impatiens balsamina* and *Salvia splendens*), El-Keltawi *et al.* (1984) on *Ageratum conyzoides* and Bettaieb *et al.* (2009) on *Salvia officinalis*. They reported that plant growth characteristics were sensitive to moisture stress levels and this depends mainly on the developmental phases and growth stages. In this regard, Dichio *et al*. (2004) declared that application of deficit irrigation at 50 and 25% F.C. decreased vegetative vigour resulting in a significant reduction in growth and lateral shoots of peach seedlings.

In respect of pre-sowing irradiation treatments, it was observed that gamma dose at 5 k.rad (G_1) was the most effective treatment in increasing number of branches per plant showing significant increases by 21 and 31% compared to 15 k.rad (G_3) and control in M_1 generation, respectively. Similar results were reported by Gad (1988) on violet, and El-Khateeb *et al*. (2017) on *Helichrysum bracteatum*.

Among laser treatments, the exposure time for 10 min. (L_2) was the best dose in branch formation; it achieved 24, 35 and 43% over L_1, L_3 and L_4 in M_1, respectively. These results are in harmony with those obtained by El-Kereti *et al*. (2013) on sweet basil. In this connection, Kuzin (1962) was inclined to consider the stimulation as a result of defensive reaction of plants to the action of any irritant, including the ionizing radiations. Primary changes emerging in plants at the moment of irradiation cause numerous secondary changes to which the plants react with a complex. In the process of vegetative growth, depending on the irradiation dose, these changes exert a depressing or stimulating effect.

Table 1. Plant height (cm) as affected by soil moisture levels and pre-sowing irradiation treatments of *Salvia coccinea* seeds in M_1 and M_2 generations.

Irradiation treatments	Generation								
	M_1 (2016/2017)					M_2 (2017/2018)			
	Soil moisture at irrigation (% F.C)								
	100 (control)	80	60	40	Mean	100	80	60	Mean
Control (without exposure) 0	54.7	51.7	35.7	10.0	**38.0**	60.3	60.0	51.3	**57.2**
Gamma (K. rad)									
5 (G_1)	67.5	60.0	41.2	17.8	**46.6**	76.7	57.7	47.7	**60.7**
10 (G_2)	65.3	50.8	37.4	15.0	**42.1**	76.3	65.0	50.7	**64.0**
15 (G_3)	60.5	57.0	42.2	22.0	**45.4**	75.0	73.0	50.3	**66.1**
20 (G_4)	66.8	58.0	40.7	23.0	**47.1**	75.3	73.0	47.7	**65.3**
25 (G_5)	60.0	59.0	25.0	15.0	**39.8**	68.3	59.7	40.7	**56.2**
Laser (min.)									
5 (L_1)	44.0	45.7	35.5	19.0	**36.1**	69.3	42.7	44.7	**52.2**
10 (L_2)	64.0	46.3	27.0	13.5	**37.7**	79.0	65.7	47.0	**63.9**
15 (L_3)	62.3	48.5	27.0	14.0	**38.0**	76.3	71.3	50.7	**66.1**
20 (L_4)	41.0	48.0	20.0	12.0	**30.3**	74.3	70.0	44.7	**63.0**
Mean	**58.6**	**52.5**	**33.2**	**16.1**		**73.1**	**63.8**	**47.6**	
L.S.D. 0.05	Soil moist. 2.2		Irrad. 3.6		Inter. 7.2	Soil moist. 8.9		Irrad. 7.6	Inter. 13.2

Table 2. Number of branches per plant as affected by soil moisture levels and pre-sowing irradiation treatments of *Salvia coccinea* seeds in M_1 and M_2 generations.

Irradiation treatments	Generation								
	M_1 (2016/2017)					M_2 (2017/2018)			
	Soil moisture at irrigation (% F.C)								
	100 (control)	80	60	40	Mean	100	80	60	Mean
Control (without exposure) 0	18.7	18.0	12.0	3.3	**13.0**	23.3	29.7	19.7	**24.2**
Gamma (K. rad)									
5 (G_1)	23.0	24.3	19.0	1.7	**17.0**	30.7	31.0	18.3	**26.7**
10 (G_2)	21.0	18.3	15.7	2.0	**14.3**	27.7	30.7	22.3	**26.9**
15 (G_3)	14.0	17.8	19.0	5.0	**14.0**	27.7	34.7	24.7	**29.0**
20 (G_4)	22.0	19.7	17.3	3.0	**15.5**	29.7	32.0	17.3	**26.3**
25 (G_5)	19.0	26.0	14.0	1.0	**15.0**	29.0	17.3	17.0	**21.1**
Laser (min.)									
5 (L_1)	16.7	20.0	16.0	3.0	**13.9**	27.0	16.0	9.0	**17.3**
10 (L_2)	24.7	20.3	17.0	7.0	**17.3**	25.0	27.0	20.3	**24.1**
15 (L_3)	23.0	15.3	11.7	1.3	**12.8**	25.7	16.3	20.3	**20.8**
20 (L_4)	14.0	16.0	16.7	1.7	**12.1**	25.7	23.7	11.0	**20.1**
Mean	**19.6**	**19.6**	**15.8**	**2.9**		**27.2**	**25.8**	**18.0**	
L.S.D. 0.05	Soil moist. 1.5		Irrad. 2.9		Inter. 5.9	Soil moist. 3.9		Irrad. 3.6	Inter. 6.2

Leaf parameters

Clearly, the treatments of 80 and 100% F.C were the greatest in leaf production without significant difference between them. Since both levels increased number of leaves compared to 40% F.C in M_1 and 60% in M_2 generations (Table 3). These results are parallel to the results of Shams El-Din (1976) on chrysanthemum, Bettaieb *et al*. (2009) and Mansori *et al*. (2016) on *Salvia officinalis*. As for leaf area, it is quite clear that soil moisture at 80% F.C produced the largest leaf area followed by 100% F.C resulting significant difference (Table 4). However, both levels appeared significant differences compared to 60 or 40% F.C. Whilst, at 40% F.C showed a great reduction in M_1. Since 80 and 100% F.C alternated their effects on leaf area in M_2. These results are in partial agreement with those obtained by Shams El-Din (1976) on chrysanthemum, and Mansori *et al*. (2016) on *Salvia officinalis*.

Referring to irradiation treatments, it was noticed that G_1, G_3, G_4 and L_2 formed more leaves than unirradiated plants with significant differences in M_1 generation. Since G_3 was the most effective in this regard. There were no significant differences between other treatments and control in M_2 (Table 3). These results are in agreement with those reported by Gad (1988) on violet. The effect of laser on leaf number has previously been shown for *Celosia argentia* var. *cristata* by Metwally *et al*. (2013).

In concern of leaf area, it was observed that the widest leaves were obtained from G_2 resulting in significant increases compared to other treatments on control (Table 4). In contrast, L_3 produced the smallest leaves, showing significant decreases compared to G_1, G_2 and control in M_1. Meanwhile, there were not significant differences in M_2. Similar trend of these results were obtained by Gupta and Datta (1978) on chrysanthemum and Gad (1988) on violet.

Whole-plant dry weight (PDW)

Average of PDW are shown in Figure 1 indicated that both shoots and roots were positively reflected on the PDW. In general, water deficit in the container grown *S. coccinea* produced a considerable significant reduction in PDW which was gradually decreased with decreasing soil water content. This was considered due to inhibit stem and leaf growth at high water stress. More recent studies, however showed that stem and leaf growth may be inhibited at low water potential despite complete maintenance of turgor in the growing regions as a result of osmotic adjustment. This suggests that the growth inhibition may be metabolically regulated possibly serving an adoptive role by restricting the development of transpiring leaf area in the water-stressed plants; Hopkins (1995) and Kirkham (2005). In addition, the mechanisms involved in drought-stress-induced metabolic disruption resulted in reduction in plant growth.

Table 3. Number of leaves per plant as affected by soil moisture levels and pre-sowing irradiation treatments of *Salvia coccinea* seeds in M_1 and M_2 generations.

Irradiation treatments	Generation								
	M_1 (2016/2017)					M_2 (2017/2018)			
	Soil moisture at irrigation (% F.C)								
	100 (control)	80	60	40	Mean	100	80	60	Mean
Control (without exposure) 0	85	80	55	14	**59**	85	108	79	**91**
Gamma (K. rad)									
5 (G_1)	109	105	72	27	**78**	117	111	69	**99**
10 (G_2)	88	76	58	16	**60**	113	109	85	**102**
15 (G_3)	78	101	70	22	**68**	109	128	85	**107**
20 (G_4)	97	93	66	28	**71**	115	120	61	**99**
25 (G_5)	85	116	44	16	**65**	99	75	64	**79**
Laser (min.)									
5 (L_1)	71	82	56	28	**59**	104	73	58	**78**
10 (L_2)	107	85	63	31	**72**	108	104	71	**94**
15 (L_3)	92	76	40	28	**59**	93	77	65	**78**
20 (L_4)	64	82	45	26	**54**	91	92	50	**78**
Mean	**88**	**90**	**57**	**24**		**103**	**100**	**69**	
L.S.D. 0.05	Soil moist. 5		Irrad. 9		Inter. 19	Soil moist. 15		Irrad. 14	Inter. 23

Table 4. Leaf area (cm^2) as affected by soil moisture levels and pre-sowing irradiation treatments of *Salvia coccinea* seeds in M_1 and M_2 generations.

Irradiation treatments	Generation								
	M_1 (2016/2017)					M_2 (2017/2018)			
	Soil moisture at irrigation (% F.C)								
	100 (control)	80	60	40	Mean	100	80	60	Mean
Control (without exposure) 0	34.1	39.9	30.1	8.7	**28.2**	21.5	21.7	20.1	**21.1**
Gamma (K. rad)									
5 (G_1)	36.2	40.7	33.0	13.7	**30.9**	32.1	20.9	17.8	**23.6**
10 (G_2)	34.1	58.5	45.7	9.5	**37.0**	25.4	21.3	20.5	**22.4**
15 (G_3)	30.7	38.9	30.2	8.4	**27.1**	25.3	19.7	24.2	**23.1**
20 (G_4)	28.2	28.8	31.0	9.8	**24.5**	25.2	29.3	23.7	**26.1**
25 (G_5)	23.8	33.7	23.8	11.5	**23.2**	23.9	27.9	19.9	**23.9**
Laser (min.)									
5 (L_1)	33.9	32.0	26.8	16.4	**27.3**	19.8	22.1	21.6	**21.2**
10 (L_2)	28.3	37.5	28.3	8.3	**25.6**	27.0	22.6	20.8	**23.5**
15 (L_3)	35.0	31.1	17.3	6.7	**22.5**	28.7	21.7	19.9	**23.4**
20 (L_4)	39.5	24.5	25.1	7.3	**24.1**	35.3	21.4	17.8	**24.8**
Mean	**32.4**	**36.6**	**29.1**	**10.0**		**26.4**	**22.9**	**20.6**	
L.S.D. 0.05	Soil moist. 2.2		Irrad. 5.4		Inter. 10.8	Soil moist. 3.4		Irrad. N.S	Inter. 7.8

Drought inhibits cell elongation, breaks down RNA and DNA, reduces photosynthesis, increases respiration, interferes with nutrient uptake and others plant hormone levels; Thomas *et al*. (2003) and Taiz and Zeiger (2010). Furthermore, it is noticed that root growth was less inhibited than shoot growth under water stress. This observation is in agreement with studies conducted by Kirnak *et al.* (2001) who reported that some roots continue to elongate at low soil water potentials that completely inhibited shoot growth. In water-stressed plants may also be related to decrease transpiration rate and Leaf relative water content (LRWC) values. Important increases in PDW of well-watered plants might be possible if irrigation water was applied at the most appropriate time to prevent excessive and nutrient leaching.

A number of other workers have reported similar effects of water stress on PDW such as Suzuki (1979) on some annual flowers, El-Keltawi *et al*. (1984) on *Ageratum conyzoids*, Sanam *et al*. (2012) on *Salvia sclarea* and Corell *et al*. (2012) on *Salvia officinalis*. They demonstrated that a decline in vegetative growth was linearly correlated with the increase of water stress. Also dry matter production were adversely affected by drought.

Considering irradiation effects, it was observed that the heaviest PDW was obtained from G_1 followed by G_4 in M1 (Fg.1). On the contrary, the lightest PDW was occurred by L_4. However, the rest irradiated-plants showed inconsiderable effect on PDW in M_1. Concerning M_2 generation, the greatest growth was closely associated with G_4. Since the other doses significantly increased PDW compared to unirradiated control (Fig. 1).

These results are in agreement with those obtained by Soedjono (1979) on chrysanthemum and Gad (1988) on violet treated with gamma-radiation. Besides, laser effect showed a similar trend to those reported by Perveen *et al*. (2011) and Sivaci *et al.* (2018) on sunflower and El-Kereti *et al*. (2013) on sweet basil.

In this regard, Batygin (1963) showed light effect on the action mechanism of the stimulating doses of irradiation, enhancing plant growth and improving its quality. He explained the initial reaction of living organism to the action of ionizing irradiation as a change in the physical and chemical properties of protoplasm which results in the intensification or depression of some physiological processes and metabolic reactions associated with them. As different plant tissues and organs have different sensitivity to the ionizing irradiations, physiological changes of different levels emerge which lead to a physiological qualitative variation in the organ. As a result of interaction with environmental conditions, such qualitative variations can be the reasons for the stimulation or depression of the plant development.

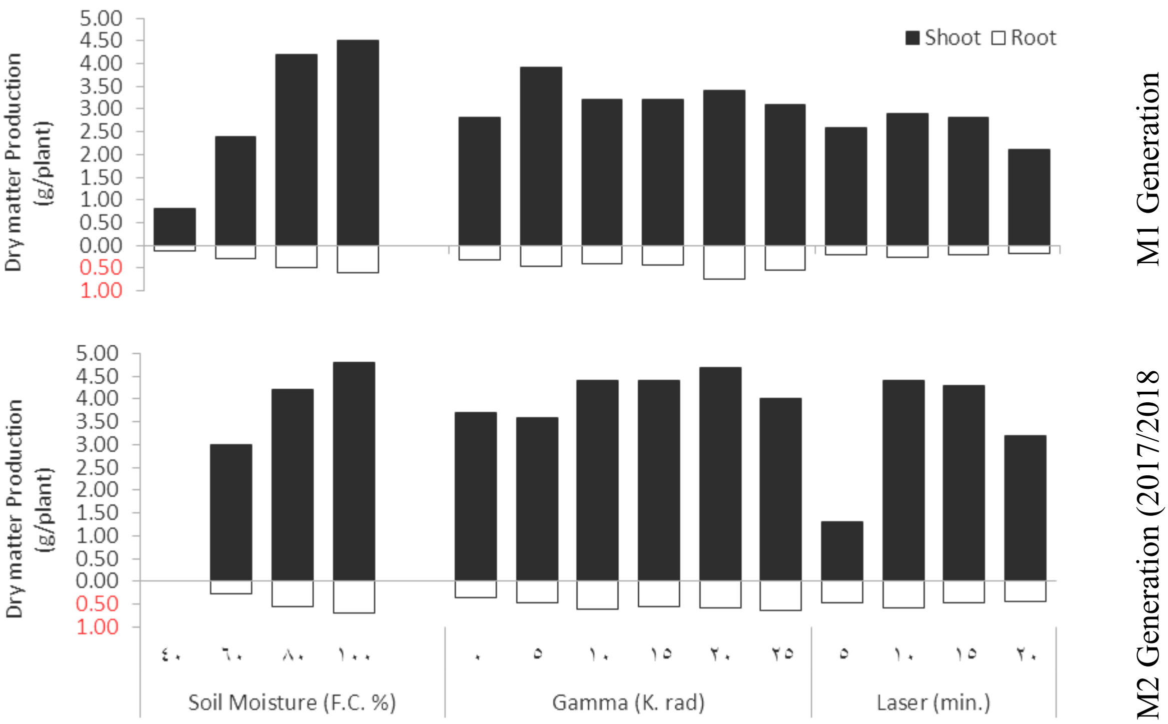

Fig. (1): Whole plant dry weight in *Salvia coccinea* plants as affected by soil moisture and pre-sowing irradiation treatments in M1 and M2 generations.

Flowering characteristics

Earliness

Results presented in Table 5 showed that number of days to flowering of *S. coccinea* was significantly affected by soil moisture content. Higher response to earliness was obviously taking place with well-watered plants (100% F.C.). It was more favourable in accelerating and advancing the flowering whereas it significantly induced earlier flowering by 6, 15, 31 days than 80, 60, 40% F.C, respectively in M_1 generation. Whilst, M_2 showed a similar trend, but it was earlier on flower appearance than in M_1. These results were consistent with those obtained by Momin *et al*. (2012) on chrysanthemum who revealed that the most sensitive growth stage to drought was flowering depending on the time and length of each treatment.

Apparently, neither gamma nor laser-rays at different doses induced promotive effects on earliness in M_1 and M_2 generations.

Inflorescence number

Results in Table 6 showed that water deficit at 80% F.C., mostly was superior in inflorescence production resulting in significant differences compared to other moisture levels in both generations. These observations are in agreement with evidence presented by others; Eakes *et al*. (1991a and b) on *Salvia splendens* and Serpe and Mattews (1994) on begonias.

Table 5. Number of days to flowering as affected by soil moisture levels and pre-sowing irradiation treatments of *Salvia coccinea* seeds in M_1 and M_2 generations.

Irradiation treatments	Generation								
	M_1 (2016/2017)					M_2 (2017/2018)			
	Soil moisture at irrigation (% F.C)								
	100 (control)	80	60	40	Mean	100	80	60	Mean
Control (without exposure) 0	204	203	212	234	**213**	194	194	197	**195**
Gamma (K. rad)									
5 (G_1)	197	202	209	213	**205**	191	195	198	**195**
10 (G_2)	201	204	210	217	**208**	192	193	194	**193**
15 (G_3)	202	204	210	230	**212**	192	194	194	**193**
20 (G_4)	188	205	213	252	**215**	178	196	197	**190**
25 (G_5)	191	204	222	226	**211**	187	199	198	**195**
Laser (min.)									
5 (L_1)	205	206	215	233	**215**	192	195	200	**196**
10 (L_2)	201	205	211	229	**212**	192	195	198	**195**
15 (L_3)	201	207	217	235	**215**	192	193	199	**195**
20 (L_4)	199	211	217	234	**215**	192	194	197	**194**
Mean	**199**	**205**	**214**	**230**		**190**	**195**	**197**	
L.S.D. 0.05	Soil moist. 5	Irrad. N.S		Inter. 14		Soil moist. 2	Irrad. N.S		Inter. 9

Table 6. Number of inflorescence per plant as affected by soil moisture levels and pre-sowing irradiation treatments of *Salvia coccinea* seeds in M_1 and M_2 generations.

Irradiation treatments		Generation								
		M_1 (2016/2017)					M_2 (2017/2018)			
		Soil moisture at irrigation (% F.C)								
		100 (control)	80	60	40	Mean	100	80	60	Mean
Control (without exposure)	0	7.0	8.0	4.3	1.0	**5.1**	6.0	8.0	4.7	**6.2**
Gamma (K. rad)										
5	(G_1)	9.3	9.0	3.7	1.0	**5.8**	8.3	9.0	4.7	**7.3**
10	(G_2)	8.3	7.3	3.7	1.0	**5.1**	8.7	9.7	7.3	**8.6**
15	(G_3)	8.7	9.3	3.3	1.0	**5.6**	8.7	10.3	8.3	**9.1**
20	(G_4)	8.0	7.7	3.3	1.0	**5.0**	7.0	8.7	6.7	**7.5**
25	(G_5)	6.0	11.0	2.0	1.0	**5.0**	7.0	8.7	4.3	**6.7**
Laser (min.)										
5	(L_1)	6.0	8.7	4.0	1.0	**4.9**	8.0	7.3	4.0	**6.4**
10	(L_2)	8.3	7.0	6.0	1.0	**5.6**	9.7	10.0	5.0	**8.2**
15	(L_3)	6.7	6.7	1.0	1.0	**3.9**	7.3	7.0	5.7	**6.7**
20	(L_4)	7.0	10.0	3.0	1.0	**5.3**	8.3	7.7	4.0	**6.7**
Mean		**7.5**	**8.5**	**3.4**	**1.0**		**7.9**	**8.6**	**5.5**	
L.S.D. 0.05		**Soil moist. 0.6**		**Irrad. N.S**		**Inter. 2.2**	**Soil moist. 1.4**	**Irrad. 1.6**		**Inter. N.S**

Regarding irradiation effects, although number of inflorescences per plant was not affected by any radiation treatment in M_1, G_3 gave the highest number resulting in 47% over unirradiated control in M_2. The next high values were obtained from G_2 and L_2 showing significant increases compared to control. These results agree with earlier observations by Soedjono (1979) on chrysanthemum and El-Khateeb *et al*. (2017) on *Helichrysum bracteatum* were irradiated with gamma-rays, in addition Metwally *et al*. (2013) on *Celosia argentea* var. *cristata* irradiated with laser-rays.

Florets number

Apparently, number of florets per inflorescence was progressively increased with increasing moisture level in M_1 (Table 7). As for M_2 generation, soil moisture at 80% F.C. produced higher florets than in 100% F.C without significant differences. Both 80 and 100% F.C. significantly increased the florets by 34 and 22% over 60% F.C, respectively. These results confirmed the previous results obtained by Eakes *et al*. (1991a and b) on *Salvia splendens*.

With regard to irradiation effects, most of treatments significantly increased number of florets per inflorescence compared to unirradiated control (Table 7). However, L_4 was more pronounced increase in this concern in M_1. The behavior of L_4 in M_2 generation was in direct contrast to that of M_1. Similar findings were observed by Sedel and Tarasenko (1980) on gladiolus irradiated with gamma-rays, besides Podlesny and Podlesna (2004) on which lupine-irradiated with laser-rays.

Inflorescence length

It is noticed that length of main inflorescence was significantly decreased with decreasing soil moisture content in M_1 (Table 8). Thus, water-stressed plant at 40% F.C. produced the shortest inflorescences with significant reductions compared to 80 and 100% F.C. in M_1 generation, but there was no significant difference between the laters in M_2. These results were supported by Cocozza (1971) on gladiolus and Eakes *et al.* (1991a and b) on *Salvia splendens*.

In respect of irradiation effects, it was found that the treatments of G_5, L_2 and L_4 significantly decreased inflorescence length compared to unirradiated control since the rest treatments had no significant effect in M_1. In relation to M_2, most of treatments showed no significant effects compared to control. Although L_4 and L_2 produced shorter inflorescences in M_1, they were more longer in M_2. These results corroborate with the findings of Sedel and Tarasenko (1980) on gladiolus irradiated with gamma-rays, also Metwally *et al.* (2013) on *Celosia argentea* var. *cristata* irradiated with laser-rays.

Table 7. Number of florets per main inflorescence as affected by soil moisture levels and pre-sowing irradiation treatments of *Salvia coccinea* seeds in M_1 and M_2 generations.

Irradiation treatments	Generation								
	M_1 (2016/2017)					M_2 (2017/2018)			
	Soil moisture at irrigation (% F.C)								
	100 (control)	80	60	40	Mean	100	80	60	Mean
Control (without exposure) 0	113	80	79	24	**74**	81	94	85	**87**
Gamma (K. rad)									
5 (G_1)	124	101	82	33	**85**	95	97	74	**89**
10 (G_2)	117	76	78	40	**78**	87	105	94	**95**
15 (G_3)	94	108	115	22	**85**	85	106	79	**90**
20 (G_4)	130	127	89	40	**97**	89	109	80	**93**
25 (G_5)	140	116	74	20	**88**	78	99	68	**82**
Laser (min.)									
5 (L_1)	97	133	69	50	**87**	92	80	55	**76**
10 (L_2)	132	103	58	37	**83**	105	103	70	**93**
15 (L_3)	121	110	65	39	**84**	89	92	69	**83**
20 (L_4)	60	80	50	32	**56**	94	105	63	**87**
Mean	**113**	**103**	**76**	**34**		**90**	**99**	**74**	
L.S.D. 0.05	Soil moist. 4	Irrad. 13		Inter. 26		Soil moist. 13	Irrad. N.S		Inter. N.S

Table 8. Length of main inflorescence (cm) as affected by soil moisture levels and pre-sowing irradiation treatments of *Salvia coccinea* seeds in M_1 and M_2 generations.

Irradiation treatments	Generation								
	M_1 (2016/2017)					M_2 (2017/2018)			
	Soil moisture at irrigation (% F.C)								
	100 (control)	80	60	40	Mean	100	80	60	Mean
Control (without exposure) 0	17.3	12.1	11.2	3.0	**10.9**	12.0	14.3	12.0	**12.8**
Gamma (K. rad)									
5 (G_1)	13.7	11.8	8.0	4.2	**9.4**	14.0	15.7	13.0	**14.2**
10 (G_2)	14.2	10.8	9.7	4.5	**9.8**	13.3	17.0	13.3	**14.5**
15 (G_3)	13.5	14.2	11.3	5.2	**11.1**	15.0	16.0	11.7	**14.2**
20 (G_4)	14.3	16.2	9.5	5.0	**11.3**	14.7	15.3	12.7	**14.2**
25 (G_5)	15.0	11.0	6.5	3.0	**8.9**	13.3	15.7	10.7	**13.2**
Laser (min.)									
5 (L_1)	14.0	14.2	8.0	4.0	**10.1**	15.3	12.3	9.0	**12.2**
10 (L_2)	11.2	15.0	5.5	3.0	**8.7**	17.7	14.3	11.3	**14.4**
15 (L_3)	14.7	13.0	7.0	3.3	**9.5**	15.0	17.3	14.7	**15.7**
20 (L_4)	11.0	12.0	5.0	3.4	**7.9**	16.7	15.3	13.0	**15.0**
Mean	**13.9**	**13.0**	**8.2**	**3.9**		**14.7**	**15.3**	**12.1**	
L.S.D. 0.05	Soil moist. 0.7	Irrad. 1.6		Inter. 3.2		Soil moist. 1.5	Irrad. 2.1		Inter. N.S

Further development of the irradiated plants takes place with the formation of new effectors desuppressing the genes responsible for the synthesis of enzymes which are essential to the plants for subsequent development the synthesis of flowering hormones causing early flowering and ripening in the irradiated plants and the more profuse formation of generative organs; Timofeev-Resovskii (1965a and b).

Total soluble phenolic compounds (TSPC)

Data cleared that TSPC in *S. coccinea* leaves were significantly increased with decreasing soil moisture content in M_1 and M_2 generations (Table 9). The present findings are similar to that of Petridis *et al.* (2012). They declared that TSPC in leaves were more pronounced increase under water deficit conditions.

In respect of irradiation treatments, results revealed that all gamma doses, as well as L_1 and L_2 significantly decreased TSPC compared to unirradiated plants. Meanwhile, L_3 and L_4 had no significant effect in M_1. Mostly the pattern of TSPC response to irradiation treatments in M_2 was similar to that observed in M_1. These results are in harmony with those reported by Abou-Zied and Abdel-Latif (2014) and Hamideldin and Eliwa (2015) used gamma-radiation, besides, Perveen *et al.* (2011) and Sivaci *et al.* (2018) used laser. They reported that gamma- and laser-radiations at certain doses were more effective in increasing TSPC.

Table 9. Total soluble phenolic compounds content (mg/g dry wt.) in leaves as affected by soil moisture levels and pre-sowing irradiation treatments of *Salvia coccinea* seeds in M_1 and M_2 generations.

Irradiation treatments	Generation								
	M_1 (2016/2017)					M_2 (2017/2018)			
	Soil moisture at irrigation (% F.C)								
	100 (control)	80	60	40	Mean	100	80	60	Mean
Control (without exposure) 0	1.23	1.90	2.94	5.32	**2.85**	1.64	2.52	3.91	**2.69**
Gamma (K. rad)									
5 (G_1)	0.76	1.17	1.82	3.29	**1.76**	0.98	1.51	2.34	**1.61**
10 (G_2)	0.84	1.30	2.01	3.64	**1.95**	1.16	1.78	2.76	**1.90**
15 (G_3)	0.94	1.45	2.24	4.05	**2.17**	1.24	1.90	2.95	**2.03**
20 (G_4)	1.01	1.55	2.40	4.33	**2.32**	1.28	1.97	3.05	**2.10**
25 (G_5)	1.07	1.65	2.56	4.63	**2.48**	1.37	2.11	3.27	**2.25**
Laser (min.)									
5 (L_1)	0.98	1.51	2.35	4.24	**2.27**	1.13	1.74	2.70	**1.86**
10 (L_2)	1.04	1.60	2.48	4.48	**2.40**	1.26	1.93	2.99	**2.06**
15 (L_3)	1.15	1.77	2.75	4.97	**2.66**	1.52	2.33	3.62	**2.49**
20 (L_4)	1.26	1.94	3.01	5.43	**2.91**	1.72	2.64	4.10	**2.82**
Mean	**1.03**	**1.58**	**2.46**	**4.44**		**1.33**	**2.04**	**3.17**	
L.S.D. 0.05	Soil moist. 0.32	Irrad. 0.36		Inter. 0.70		Soil moist. 0.09	Irrad. 0.20		Inter. 0.35

Proline content

Results clearly indicated that proline accumulation in leaves and roots was decreased with increasing soil moisture level in both generations (Fig. 2). These results corroborate with the findings of El-Said *et al.* (1993). They declared that deficit irrigation resulted in significantly higher proline content in plant.

In this connection, Hare and Cress (1997) concluded that proline accumulation may reduce stress-induced cellular acidification or prime oxidative respiration to provide energy needed for recovery. High levels of proline synthesis during water stress may maintain other common accumulation solute such as sorbitol, sugar alcohol and betaine. Most chemicals associated with osmotic adjustment share the property that they do not significantly interfere with normal metabolic processes.

With refer to irradiation effects, it was appeared that proline content was reduced with increasing either gamma or laser level in both generations. The present findings are similar to those of Hamideldin and Eliwa (2015) and Hanafy and Akladious (2018) used gamma-radiation, also Perveen *et al*. (2011) used laser-ways.

Abscisic acid content (ABA)

It is quite clear that ABA level in both leaves and roots were gradually decreased with increasing moisture content (Fig. 3). Accordingly, the tissues of well-irrigated plants contained the minimum concentration, while the water-stressed ones have a great capacity to retain the inhibitor, and thus to affect its ultimate chemical form and distribution. So soil moisture content seemed to become a controlling factor for growth. Similar results of increased ABA with drought stress were also reported by Schulte-Altedorneburg (1990). In this respect, the relationships between drought stress and ABA accumulation were explained by some investigators. Zacharias and Reid (1990) found that ABA increases during drought stress as a result of synthesis in the leaf, distribution in the mesophyll cell and import from the root. On rewatering, ABA is degraded and then exported out of the leaf. Apart from saving water by regulating the stomatal water release, with drought stress ABA increases the water flow in the plant by increasing the hydraulic conductivity. Abscisic acid seems to modify membrane properties by promoting ion uptake and osmotic water flow. Waterland *et al.* (2010) declared that ABA regulates drought stress responses by mediating stomatal closure, thereby reducing transpiration water loss. The content of ABA was increased under water stress conditions. Exogenous ABA applications delay wilting and allow plants to survive short periods of severe drought.

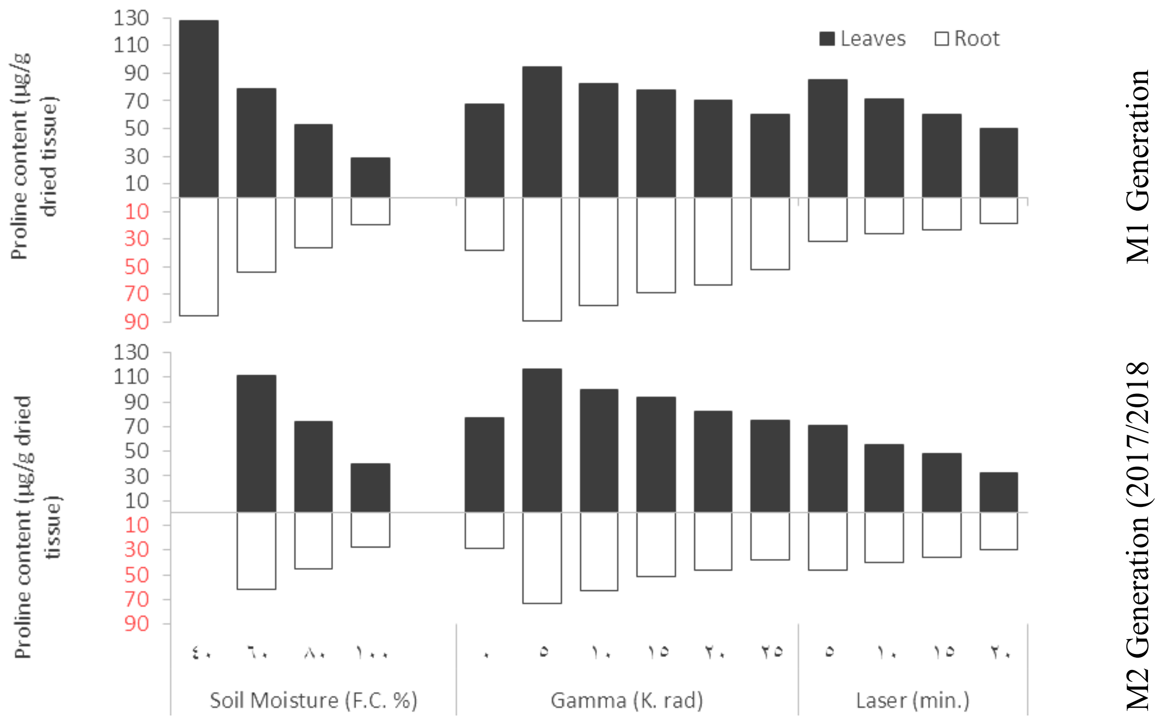

Fig. (2): Proline content in *Salvia coccinea* plants as affected by soil moisture and pre-sowing irradiation treatments in M1 and M2 generations.

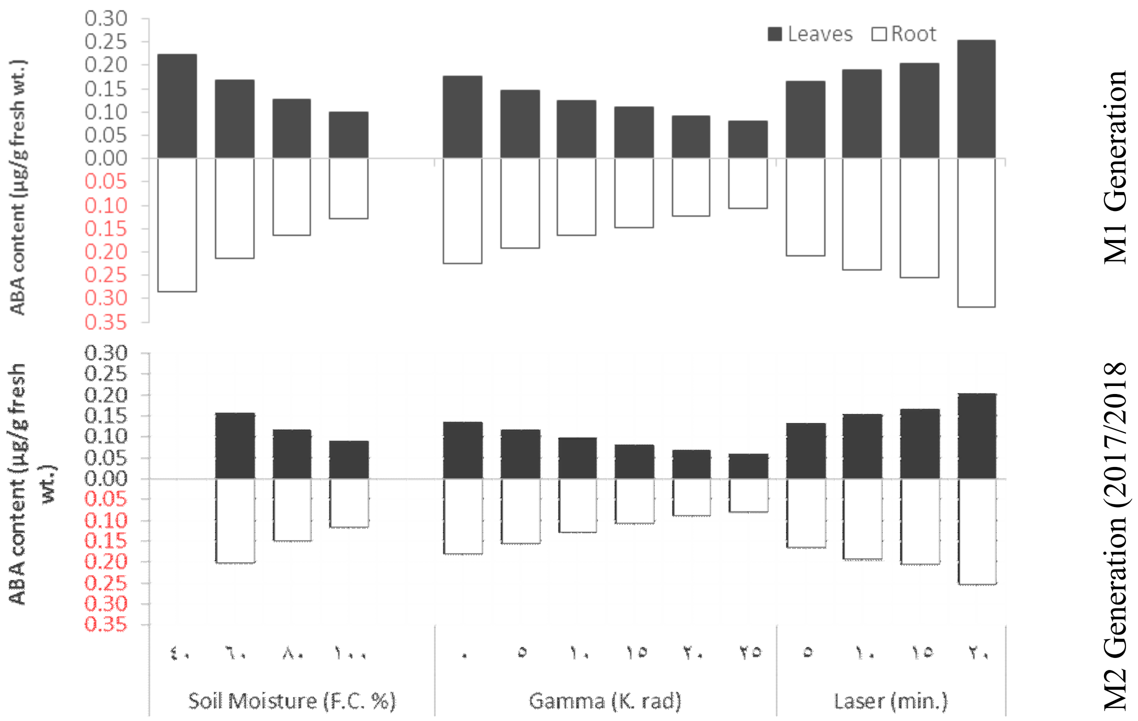

Fig. (3): Abscisic acid content in *Salvia coccinea* plants as affected by soil moisture and pre-sowing irradiation treatments in M1 and M2 generations.

Concerning the irradiation treatments, the behaviour of ABA status in gamma-irradiated plants is in direct contrast to that of laser-irradiated ones. Since the later was increased with increasing the dose in both generations (Fig. 3). These results are in agreement with those reported by Abou El-Yazied (2011) used gamma-rays, Soliman and Harith (2010) used laser-rays, and Metwally *et al*. (2015) used both radiations.

Enzymatic activities

Peroxidase activity (PA)

It is appeared that PA in *S. coccinea* leaves was strongly influenced by different soil moisture treatments (Table 10). The PA was gradually increased with decreasing soil moisture up to 60% F.C. in M_1 and M_2 generations. No significant difference between the well-irrigated plants and the high stressed ones was found. This is in line with the results of several workers; Abedi and Pakniyat (2010) and Mohammadi *et al*. (2011); they reported that PA was increased in shoots under water stress conditions. Antioxidant defense systems in plants are responsive to drought stress and play an important role in drought resistance.

Concerning irradiation effects, although gamma- and laser-rays cleared considerable increments in PA compared to control, no significant differences among the treatments were found in M_1. However, L_1, L_2 and L_3 were more effective in increasing PA resulting in significant differences compared to most of irradiation treatments in M_2. These results are in accordance with findings of Chen *et al.* (2009), and Hamideldin and Eliwa (2015) used gamma-radiation, also Wu *et al.* (2007) used laser-rays.

Catalase activity (CA)

It is quite clear that CA was significantly increased with increasing water moisture level up to 60% F.C in M_1 and M_2 generations (Table 11). Meanwhile, high water-stress level showed the least activation with significant reductions compared to 80 and 60% F.C, but no significant effects compared to unstressed treatments were observed in M_1. These results are in similar to the observations of Mohammadi *et al*. (2011) and Mirzaee *et al*. (2013), they postulated that the antioxidant defense system consists of several antioxidant enzymes such as catalase. It protects plants from the deleterious effects of drought.

Regarding irradiation treatments, it was noticed that the most effective treatments in increasing CA were G_4, L_2 and L_4 in M_1 and G_3 and M_2. These treatments cleared significant increases compared to unirradiated plants. These results are in close conformity with the findings of Chen *et al.* (2009) used gamma-rays, and Wu *et al.* (2007) used laser-radiation.

Table 10. Peroxidase activity (PA) in leaves (µmol pyrogallin/g fresh wt/min.) as affected by soil moisture levels and pre-sowing irradiation treatments of *Salvia coccinea* seeds in M_1 and M_2 generations.

Irradiation treatments	Generation								
	M_1 (2016/2017)					M_2 (2017/2018)			
	Soil moisture at irrigation (% F.C)								
	100 (control)	80	60	40	Mean	100	80	60	Mean
Control (without exposure) 0	8.2	11.6	12.2	11.1	**10.8**	10.7	11.0	14.8	**12.2**
Gamma (K. rad)									
5 (G_1)	9.3	11.2	7.5	8.4	**9.1**	6.2	6.4	15.6	**9.4**
10 (G_2)	8.0	10.6	16.4	7.8	**10.7**	3.8	13.0	32.5	**16.4**
15 (G_3)	4.2	16.1	51.0	7.4	**19.7**	9.0	11.3	15.5	**11.9**
20 (G_4)	8.2	14.6	34.4	7.3	**16.1**	23.7	11.4	9.2	**14.8**
25 (G_5)	13.3	15.4	16.9	10.3	**14.0**	9.2	7.3	21.6	**12.7**
Laser (min.)									
5 (L_1)	18.6	23.8	8.6	12.7	**15.9**	16.3	14.3	31.9	**20.8**
10 (L_2)	7.7	34.3	9.9	19.2	**17.8**	7.2	20.9	31.8	**20.0**
15 (L_3)	4.3	13.7	20.7	7.7	**11.6**	10.6	34.2	22.3	**22.4**
20 (L_4)	7.1	10.0	33.6	3.8	**13.6**	6.8	11.3	10.9	**9.7**
Mean	**8.9**	**16.1**	**21.1**	**9.6**		**10.3**	**14.1**	**20.6**	
L.S.D. 0.05	Soil moist. 6.3	Irrad. N.S		Inter. 22.8		Soil moist. 2.8	Irrad. 6.9	Inter. 11.9	

Table 11. Catalase activity (CA) in leaves (µmol H_2O_2/g fresh wt./min.) as affected by soil moisture levels and pre-sowing irradiation treatments of *Salvia coccinea* seeds in M_1 and M_2 generations.

Irradiation treatments		Generation								
		M_1 (2016/2017)					M_2 (2017/2018)			
		Soil moisture at irrigation (% F.C)								
		100 (control)	80	60	40	Mean	100	80	60	Mean
Control (without exposure)	0	23.96	31.25	42.29	15.00	**28.13**	23.33	40.83	43.33	**35.83**
Gamma (K. rad)										
5 (G_1)		13.54	18.75	67.71	10.83	**27.71**	13.54	20.21	78.13	**37.29**
10 (G_2)		21.67	32.92	40.63	15.83	**27.76**	15.00	73.13	61.46	**49.86**
15 (G_3)		19.17	40.63	42.71	36.67	**34.79**	13.54	78.75	80.00	**57.43**
20 (G_4)		24.58	33.33	65.63	56.25	**44.95**	7.92	34.17	47.50	**29.86**
25 (G_5)		13.75	70.00	53.13	2.08	**34.74**	38.75	28.33	56.25	**41.11**
Laser (min.)										
5 (L_1)		12.92	26.25	36.46	9.17	**21.20**	22.71	40.63	58.96	**40.76**
10 (L_2)		46.88	43.13	41.67	48.75	**45.10**	34.38	43.96	60.00	**46.11**
15 (L_3)		29.79	64.79	70.42	7.29	**43.07**	13.33	40.21	31.67	**28.40**
20 (L_4)		39.17	42.50	99.79	6.67	**47.03**	8.75	47.08	74.79	**43.54**
Mean		**24.54**	**40.35**	**56.04**	**20.85**		**19.13**	**44.73**	**59.21**	
L.S.D. 0.05		Soil moist. 13.80	Irrad. 15.11		Inter. 30.22		Soil moist. 13.17	Irrad. 20.59	Inter. 35.66	

The important role of irradiation on enzymatic activities was explained by Timofeev-Resovskii (1962). He reported that under low gamma-irradiation doses, the stimulation effect can cause processes like the intensified respiration that create an energetic base for stimulation; heterogeneity emergence as a result of different radio-sensitivities of individual tissues and enzymes in the irradiated seeds.

Leaf relative water content (LRWC)

It is clearly noticed that water stress treatments at 60 or 40% F.C gave significant reductions in LRWC compared to 100 and 80% F.C in both generations, but no significant effect between the laters was found (Table 12). These results are parallel to those resulted with Kirnak *et al.* (2001) and Keyvan (2010). They found that water stress resulted in significant decreases in LRWC which is usually used as a reference to describe leaf water status and as an indicator of drought resistance.

Respecting irradiation effects, it was noticed that G_4 and G_5 significantly increased LRWC, contrast to this, L_3 and L_4 significantly decreased it compared to unirradiated control in M_1. However, there were no significant differences among irradiation treatments found in M_2. These results are in similar to the observations of Abou-Zied and Abdel-Latif (2014) used gamma-rays, and Perveen *et al.* (2011) used laser-radiation.

Table 12. Leaf relative water content (%) as affected by soil moisture levels and pre-sowing irradiation treatments of *Salvia coccinea* seeds in M_1 and M_2 generations.

Irradiation treatments	Generation								
	M_1 (2016/2017)					M_2 (2017/2018)			
	Soil moisture at irrigation (% F.C)								
	100 (control)	80	60	40	Mean	100	80	60	Mean
Control (without exposure) 0	65.3	74.7	73.7	54.7	**67.1**	73.7	75.3	62.0	**70.3**
Gamma (K. rad)									
5 (G_1)	82.0	70.7	66.3	55.3	**68.6**	78.3	77.3	61.7	**72.4**
10 (G_2)	76.7	76.0	68.0	60.3	**70.3**	76.0	79.3	67.0	**74.1**
15 (G_3)	62.3	72.3	70.0	75.7	**70.1**	74.3	81.0	72.3	**75.9**
20 (G_4)	73.3	76.3	77.3	62.7	**72.4**	72.0	76.0	71.3	**73.1**
25 (G_5)	83.0	79.0	66.0	74.0	**75.5**	81.0	74.3	63.7	**73.0**
Laser (min.)									
5 (L_1)	68.7	69.0	66.7	56.0	**65.1**	67.0	81.0	66.0	**71.3**
10 (L_2)	65.3	65.7	73.0	58.0	**65.5**	80.0	70.3	66.7	**72.3**
15 (L_3)	69.7	64.7	50.7	53.3	**59.6**	75.3	72.3	69.3	**72.3**
20 (L_4)	71.7	57.3	53.0	62.7	**61.2**	80.3	67.7	64.0	**70.7**
Mean	**71.8**	**70.6**	**66.5**	**61.3**		**75.8**	**75.5**	**66.4**	
L.S.D. 0.05	Soil moist. 2.7	Irrad. 5.3		Inter. 10.6		Soil moist. 5.9	Irrad. N.S		Inter. 9.3

Generally, there was apparent direct relationship between drought tolerant and the active biochemical constituents (phenolics proline, ABA, as well as antioxidant enzymes of peroxidase and catalase) in *Salvia coccinea* plants. This was positively reflected on growth and flowering. Thus, data cleared that pre-sowing irradiation of seeds with doses of gamma-rays at 15-25 k.rad followed by laser exposure for 10 min. under moderate drought stress (80% F.C) were markedly higher in stimulating growth and flowering than 60% F.C, mostly, insignificant effects when they compared to well-irrigated treatment (100% F.C) were found. The best combination can tolerate soil water deficit that consume irrigation water by 30%. It must be taken such factors into consideration during the growth season to produce high plant quality in the shortest time possible from sowing to flowering.

Fertility reduction in M_1 plants may be related to various reasons; (1) severe stunting or growth inhibition which prevents flowering, (2) flowers are formed but lake reproductive structures, (3) reproductive structures are present but pollen is not viable (the most common occurrence), (4) fertilization occurs but embryos abort before maturity, and (5) seeds form but fail to germinate properly or die after germination according to Shu *et al*. (2012).

References

Abdel-Tawab, F.M.; A. Fahmy; A. Bahieldin; A.A. Mahamoud; S.H. Abdel-Aziz and O. Moseilhy (2002). Genetic improvements of bread wheat (*Triticum aestivum* L.) for drought tolerance by molecular breeding. Egypt. J. Genet. Cytol., 31: 331-353.

Abd El-Samad, G.A. and S.A. Sief (2002). Water use determination by using water deficit to control vegetative growth and productivity of Canino and Early Perfection apricot trees. Fayoum J. Agric., Res. & Dev., 16: 24-36.

Abedi, T. and H. Pakniyat (2010). Antioxidant enzyme changes in response to drought stress in ten cultivars of soil seed rape (*Brassica napus* L.). Czech J. Genet. Plant Breed., 46 (1): 27-34.

Abou El-Yazied, A. (2011). Growth, biochemical constituents and yield of snap bean as influenced by low gamma irradiation doses under different sowing dates. Aust. J. Basic & Appl. Sci., 5: 30-42.

Abou-Zied, H.M. and S.A. Abdel-Latif (2014). Effects of gamma irradiation on biochemical and antioxidant defense system in wheat (*Triticum aestivum* L.) seedlings. Inter. J. Adv. Res., 2 (8): 287-300.

Absten, G.T. (1992). Physics of light and Laser: Laser in Gynacology, Chissutton. 1st ed., 1-33, Chapman and Hall Medical.

Aebi, H. (1984). Catalase in vitro. Methods in Enzymology 105: 121-126.

Bachiri, H.; R. Djebbar and C. Djenadi (2014). Gamma irradiation effects on some physiological traits of wheat (*Triticum aestivum* L.) under control and water stress conditons. Amer. J. Plant Physiol., 10: 3923.

Batygin, N.F. (1963). The problem of the concept of radio-stimulation processes. Izdo-vo AN SSSR, Moscow, pp. 21-27. In: Presowing Irradiation of Plant Seeds. Edited by A.M. Kuzin. Oxonian Press PVI. LTD., New Delhi, India, p. 287.

Bettaieb, N.; W. Zakhama; M.E. Aidi and B.M. Kchouk (2009). Water deficit effects on *Salvia officinalis* L. fatty acids and essential oils composition. Sci. Hort., 120 (2): 271-275.

Chen, C.; S. Lu; Y. Chen; Z. Wang; Y. Niu and Z. Guo (2009). A gamma-ray-induced dwarf mutant from seeded bermudagrass and its physiological responses to drought stress. J. Amer. Soc. Hort. Sci., 134 (1): 22-30.

Cocozza, M. (1971). Gladiolus production and quality: Pepinieristes Hort. Maraichers 119: 31-36. (Hort. Abst., 42: 4306).

Corell, M.; M.C. Garcia; J.I. Contreras; M.L. Segura and P. Cermeńo (2012). Effect of water stress on *Salvia officinalis* L. bioproductivity and its bioelement concentrations. Communications in Soil Sci. & Plant Analysis 43 (2): 419-425.

Dichio, B.C.; V. Xiloyannis; G. Nuzzo; M. Montanaro and A.M. Palese (2004). Postharvest regulated deficit irrigation of peach tree in a mediterranean environment: Effects on vegetative growth and yield. Irrig. Hort. Crops Acta Hort., 664: 169-174.

Dowdy, S. and S. Wearden (1983). Statistics for Research. John Wiley and Sons, New York, USA, pp. 640.

Eakes, D.J.; R.D. Wright and J.R. Seiler (1991a). Water relations of *Salvia splendens* "Bonfire" as influenced by potassium nutrition and moisture stress conditioning. J. Amer. Soc. Hort. Sci., 116 (4): 712-715.

Eakes, D.J.; R.D. Wright and J.R. Seiler (1991b). Moisture stress conditioning effects on *Salvia splendens* "Bonfire". J. Amer. Soc. Hort. Sci., 116 (4): 716-719.

El-Keltawi, N.E.; G.T. Mousa and A.A. El-Lakany (1984). Effect of certain water regimes on growth, flowering and some nutrient elements in *Ageratum conyzoides* L. Assiut J. Agric. Sci., 15 (2): 145-154.

El-Kereti, M.A.; S.A. El-Feky; M.S. Khater; Y.A. Osman and E.A. Al-Sherbini (2013). ZnO nanofertilizer and He-Ne laser irradiation for promoting growth and yield of sweet basil plant. Recent Patents on Food, Nutr. & Agric., 5 (3): 1-13.

El-Khateeb, M.A.; R.A. Eid; H.a. Mahfouze; H.A. Ashor and R.M.

Mabrouk (2017). Induction of mutation with gamma radiation in *Helichrysum bracteatum* L. and identification of mutants by molecular markers. Middle East J. Agric. Res., 6 (2): 282-293.

El-Said, M.E.; I. Saad El-Deen; V.F. Noaman and S. Sari El-Deen (1993). Response of olive seedlings to different water regimes. Ann. Agric. Sci., Moshtohor 31 (1): 353-370.

El-Tobgy, K.M.; Y.A. Osman and A.M. El-Sherbini (2009). Effect of laser radiation on growth, yield and chemical constituents of anise and cumin plants. J. Appl. Sci. Res., 5 (5): 522-528.

Fonshtein, L.M. and L.P. Cheltsova (1969). The effects of irradiation wheat seed endosperm on the mitotic activity of cells. Biol., 4: 619-623.

Gad, M.M. (1988). Effects of gamma-irradiation and ethanol amine on growth and flowering of *Viola odorata* L. M.Sc. Thesis, Fac. Agric., Assiut Univ., Egypt.

Gupta, M.N. and S.K. Datta (1978). Effects of gamma-rays on growth, flowering behaviour and induction of somatic mutations in chrysanthemum. Sabrao J., 10 (2): 149-161.

Hamideldin, N. and N.E. Eliwa (2015). Gamma radiation and sodium azide influence on physiological aspects of maize under drought condition. Basic Res. J. Agric. Sci. & Rev., 4 (1): 5-13.

Hanafy, R.S. and S.A. Akladious (2018). Physiological and molecular studies on the effect of gamma radiation in fenugreek (*Trigonella foenum-graecum* L.) plants. J. Gen. Eng. & Biol., 2-12.

Hare, P.D. and W.A. Cress (1997). Metabolic implications of stress-induced proline accumulation in plants. Plant Growth Reg., 21: 79-102.

Hopkins, W.G. (1995). Introduction to Plant Physiology. 2nd ed., John Wiley & Sons, Inc. New York, USA, p. 512.

Keyvan, S. (2010). The effects of drought stress on yield, relative water content, proline, soluble carbohydrates and chlorophyll of bread wheat cultivars. J. Animal & Plkant Sci., 8: 1051-1060.

Khudadatov, A.I. (1969). Some methodical problems of pre-sowing irradiation. Izv. AN SSSR, Ser. Biol., 12: 33-35. In: Presowing Irradiation of Plant Seeds. Edited by A.M. Kuzin. Oxonian Press PVT. LTD., New Delhi, India, p. 287.

Kirkham, M.B. (2005). Principles of Soil and Plant Water Relations. Elsevier Academic Press Pub., New York, USA, p. 500.

Kirnak, H.; C. Kaya; I. Tas and D. Higgs (2001). The influence of water deficit on vegetative growth, physiology, fruit yield and quality in eggplants. BULG. J. Plant Physiol., 27: 34-46.

Kuzin, A.M. (1962). About the initial biological effects of ionizing radiation. Izd-vo AN SSR, Moscow, pp. 3-13. In: Presowing Irradiation of Plant Seeds. Edited by A.M. Kuzin. Oxonian Press PVT. LTD., New Delhi, India, p. 287.

Macadam, J.W.; C.J. Nelson and R.E. Sharp (1992). Peroxidase activity in the leaf elongation zone of tall fescue. I. Spatial distribution of ionically bound peroxidase activity in genotypes differing in length of the elongation zone. Plant Physiol., 99 (3): 872-880.

Mansori, M.; H. Chernane; S. Latique; A. Benaliat; D. Hsissou and M. El. Kaoua (2016). Effect of seaweed extract (*Ulva rigida*) on the water deficit tolerance of *Salvia officinalis* L. J. Appl. Phycol., 28: 1363-1370.

Metwally, S.A. M. Abou-Ellail; B.H. Abo-Leila and K.A. Aboud (2013). Effect of laser radiation on the growth, anatomical and biochemical genetic markers of *Celosia argentea* plants. Inter. J. Academic Res., 5 (3): 200-206.

Metwally, S.A.; A.E. Awad; B.H. Abou-Leila; T.A. El-Tayeb and I.E. Habba (2015). Studies on the effect of gamma, laser irradiation and progesterone treatments on gerbera leaves. Euro. J. Biophys., 3 (6): 43-50.

Metwally, S.A.; S.L. Meawad; B.H. Abou-Leila and M.S. Aly (2014). Effect of drought stress and helium neon (He-Ne) laser-rays on growth, oil yield and fatty acids content in caster bean (*Ricinus communis* L.). Agric., Forest. & Fish., 3 (3): 203-208.

Mirzaee, M.; A. Moieni and F. Ghanati (2013). Effects of drought stress on the lipid peroxidation and antioxidant enzyme activities in two canola (*Brassica napus* L.) cultivars. Agric. Sci. Technol., 15: 593-602.

Mohammadi, A.; D. Habibi; M. Rohami and S. Mafakheri (2011). Effect of drought stress on antioxidant enzymes activity of some chickpea cultivars. J. Agric. & Environ. Sci., 11 (6): 782-785.

Momin, K.C.; V.S. Gonge; S.R. Dalal and S.G. Bharad (2012). Radiation induced variability studies in chrysanthemum under net house. Asian J. Hort., 7 (2): 524-527.

Moustfa, R.A.K. and H.G.M. Ali (2009). Evaluation of some chemical and technological properties of induced erect chickpea mutant lines developed under drought stressed conditions. J. Rad. Res. Appl. Sci., 2 (4): 839-849.

Perveen, R.; Y. Jamil; M. Ashraf; Q. Ali; M. Iqbal and M.R. Ahmad (2011). He-Ne laser-induced improvement in biochemical, physiological, growth and yield characteristics in sunflower (*Helianthus annus* L.). Photochem. & Photobiol., 87: 1453-1463.

Petridis, A.; I. Therios; G. Samouris; S. Koundouras and A. Giannakoula (2012). Effect of water deficit on leaf phenolic composition, gas exchange, oxidative damage and antioxidant activity of four Greek olive (*Olea europaea* L.) cultivars. Plant Physiol. & Biochem., 60: 1-11.

Podleśny, J. and A. Podleśna (2004). Morphological changes and yield of selected species of leguminous plants under the influence of seed treatment with laser light. Inter. Agrophysics 18: 253-260.

Sanam, A.; H.L. Mohammad; K. Ali and H.S.R. Amir (2012). Effect of drought stress on the morphology of three *Salvia sclarea* populations. Ann. Bio. Res., 3 (9): 4503-4507.

Schulte-Altedorneburg, M. (1990). The quantitative determination of the phytohormone abscisic acid and its synthesis in beets (*Beta vulgaris* L.) under drought stress. Planta 165: 302-308.

Sedel, L.L. and N.D. Tarasenko (1980). Changes in M_1 of hybrid gladioli caused by gamma irradiation. Bull. Bot., 116: 3742. (Hort. Abst., 51: 3758).

Serpe, M.D. and M.A. Matthews (1994). Changes in cell wall yielding and growth in *Begonia argenteo-gwttata* L. leaves during the development of water deficits. Plant and Cell Physiol., 35 (4): 619-626.

Shams El-Din, S.A. (1976). Studies on some cultural treatments on the growth and flowering of chrysanthemum plants in the field. M.Sc. Thesis, Fac. Agric., Ain-Shams Univ., Egypt.

Soliman, A.S. and M.A. Harith (2010). Effects of laser bio-stimulation on germination of *Acacia farnesiana* L. Egypt. Acta. Hort. 854: 41-50.

Shu, Q.Y.; B.P. Forster and H. Nakagawa (2012). Plant Mutation Breeding and Biotechnology. CAB Inter. And FAO, p. 608.

Sivaci, A.; M. Tektas; K. Baba and G. Yarsi (2018). Effects of laser hair removal pre-treatment on the germination of sunflower seeds (*Helianthus annus* L.), phenolics and malondialdehydes contents. Fresenius Environ. Bull., 27 (4): 2270-2274.

Soedjono, S. (1979). Mutation breeding of *Chrysanthemum morifolium*. Bull. Penel. Hort., 7 (1): 19-25. (Hort. Abst., 49: 8677).

Suzuki, S. (1979). Effect of soil moisture and temperature on the growth and flowering of some annual flowers. I. Effects of differences in soil moisture regime on growth and flowering. J. Agric. Sci., Japan 23 (4): 235-242. (Hort. Abst., 50: 430).

Taiz, L. and E. Zeiger (2010). Plant Physiology. 5th ed. Sinauer Associates Inc., Sunderland, USA, pp. 782.

Thomas, B.; D.J. Murphy and D. Muray (2003). Growth and Development: Growth Analysis, Individual Plants. Encyclopaedia of Appl. Plant Sci., Academic Press, London, pp. 588-596.

Timofeev-Resovskii, N.V. (1962). Biophysical interpretation of the phenomena of radiostimulation in plants. Biophysiol., 1 (7): 616-621.

Timofeev-Resovskii, N.V. (1965a). The effects of low doses of ionizing radiation on the growth and development of plants. Filiala AN SSSR., 1 (9): 57.69. In: Presowing Irradiation of Plant Seeds. Edited by A.M. Kuzin. Oxonian Press PVT. LTD., New Delhi, India, p. 227.

Timofeev-Resovskii, N.V. (1965b). Cytological and biophysical bases of radiostimulation. Filiala AN SSSR., 3 (13): 5-11. In: Presowing Irradiation of Plant Seeds. Edited by A.M. Kuzin. Oxonian Press PVT. LTD., New Delhi, India, p. 227.

Vasco, C.; J. Ruales and A. Kamal-Eldin (2008). Total phenolic compounds and antioxidant capacities of major fruits from Ecuador. Food Chemistry 111: 816-823.

Veihmeyer, F.J. and A.H. Hendrickson (1931). The moisture equivalent as a measure of the field capacity of soils. Soil Sci., 32 (3): 181-193.

Waterland, N.L.; C.A. Campbell; J.J. Finer and M.L. Jones (2010). Abscisic acid application enhances drought stress tolerance in bedding plants. HortSci., 45 (3): 409-413.

Wu, J.L.; G. Xuehong and Z. Shequi (2007). Effect of laser pretreatment on germination and membrane lipid peroxidation of Chinese pine seeds under drought stress. Front. Biol. China 2 (3): 314-317.

Yamasaki, S. and L.R. Dillenburg (1999). Measurements of leaf relative water content in *Araucaria angustifolia*. J. Brasil. Physiol. Vegetal. 11 (2): 69-75.

Zacharias, L. and M.S. Reid (1990). Role of growth regulators in the senescence of *Arabidopsis thaliana* leaves. Physiol. Plant., 80: 549-554.

Zhang, Z.; Z. Wang; Q. Zhang and R. Lin (1998). Rapid separation and quantification of the internal hormones from tartary buckwheat leaf using high performance liquid chromatography. Proc. VII Inter. Symposium on Buckwheat, Advances in Buckwheat Res., Winnipeg, Manitoba, Canada.

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تحفيز تحمل نباتات السلفيا كوكسينيا للجفاف بالمعاملات المبدئية بأشعة جاما والليزر

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الملخص

تم إجراء هذه الدراسة بتشعيع بذور السلفيا كوكسينيا بجاما (بجرعات ٥ ، ١٠ ، ١٥ ، ٢٠ ، ٢٥ كيلو راد) أو الليزر (فترة تعرض ٥ ، ١٠ ، ١٥ ، ٢٠ دقيقة) وزراعتها في أصص تحت ظروف الجفاف [١٠٠ (كنترول) ، ٨٠ ، ٦٠، ٤٠% من السعة الحقلية].

وقد أظهرت النتائج ما يلي:

- كانت معاملات التشعيع بالليزر أقل تأثيراً في تحمل النباتات للجفاف عن التشعيع بجاماً.
- نتج عن النباتات النامية تحت ظروف الإجهاد المائي المرتفع (٤٠ ، ٦٠% من السعة الحقلية) نقصاً جوهرياً في جميع قياسات النمو الخضرية والزهرية المدروسة مقارنة بالكنترول.
- ارتبط نقص نمو النبات وجودة الأزهار الناتجان من الجفاف بنقص المحتوي النسبي المائي في الأوراق وزيادة محتويات كل من الفينولات الكلية ، البرولين وحمض الأبسيسيك في النبات.
- كانت هناك تغييرات معنوية في نظام النشاط الإنزيمي الوقائي في النبات تحت ظروف الإجهاد المائي. وقد إتضح ذلك جلياً في زيادة نشاط إنزيمي البيروكسيديز والكتاليز في أوراق النبات المعاملة بأشعة جاما أو الليزر عند مستوي رطوبي ٦٠% من السعة الحقلية مقارنة بمثيلاتها النامية تحت مستويات الرطوبة الأخرى.
- تشير النتائج بصفة عامة أن المقاومة المبدئية للجفاف لنباتات السلفيا كوكسينيا يمكن تحفيزها بتشعيع البذور بجاما عند جرعة ١٥–٢٥ كيلو راد يليها في ذلك التشعيع بالليزر لمدة عشرة دقائق.
- أظهر التأثير المتبادل بين معاملات التشعيع والرطوبة أن أفضل معاملة مشتركة مكونة من التشعيع بجاما (١٥–٢٥ كيلو راد) + محتوي رطوبي ٨٠% من السعة الحقلية حيث أدت هذه المعاملة إلي حماية النباتات من أضرار الجفاف ، كما أنها وفرت ماء الري بنسبة ٣٠% ويمكن النصح بتطبيقها.