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EFFECT OF GAMMA IRRADIATION AND POTASSIUM FERTILIZATION ON GRIDGETH AND PRODUCTIVITY OF BORAGE (*Borago officinalis* L.) PLANT

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ABSTRACT: The present study was carried out at Nuclear Research Center, Atomic Energy Authority, Inshas, Sharkia Governorate, Egypt, during the two consecutive seasons of 2013/2014 and 2014/2015 to study the effect of using different gamma irradiation doses, potassium fertilization levels and their interaction treatments on gridgeth, yield components, fixed oil percentage and leaf green color degree (SPAD-unit) of borage (*Borago officinalis*, L.) plant. The used gamma irradiation treatments were 0 (control), 2, 4, 6, 8 and 10 kilo rad (kr). Whereas, potassium fertilization levels were 0 (without K addition), 50 and 100 kg potassium sulphate/faddan, each treatment of gamma irradiation doses was combined with each level of potassium fertilization to form 18 interaction treatments. The obtained results cleared that using gamma irradiation dose of 2 kr increased most values of plant height, dry weight of herb per plant, number of inflorescences per plant, seed yield per plant and per faddan, fixed oil percentage and leaf green color degree. Furthermore, the maximum increase in this respect was obtained from the potassium fertilization treatment of 100 kg potassium sulphate/faddan compared with the other ones under study. Generally, the interaction treatment between 2 kr of gamma irradiation with 100 kg potassium sulphate/faddan of potassium fertilization mostly gave the maximum increase in the above mentioned parameters. Therefore, it seems to be recommended treatment under Sharkia Governorate conditions. Moreover, potassium fertilization at 100 kg potassium sulphate/faddan could be overcome the harmful effect of gamma irradiation in this respect on borage plant.

Key words: *Borago officinalis,* gamma irradiation, potassium, gridgeth, yield, oil production.

INTRODUCTION

Borage (*Borago officinalis* Linn.) which belongs to the family Boraginaceae is an annual medicinal plant native to Europe, North Africa, and Asia Minor, (Beaubaire and Simon, 1987). The stem and leaves are covered with coarse, prickly hairs, and the flowers are large, star-shaped and bright blue with contrasting black anthers. Borage leaves and flowers contain mucilage, tannin, saponins, essential oil, alkaloid (pyrrolizidine), vitamin C, calcium and potassium, (Gupta and Singh, 2010). Borage is a better resource of the gamma linolenic acid (Sayanova *et al.*,1999; Belch and Hill, 2000). The plant is reputed as antispasmodic, antihypertensive, antipyretic, aphrodisiac, demulcent, diuretic and is also considered useful to treat asthma, bronchitis, cramps, diarrhea, palpitations and kidney ailments (Usmanghani *et al.*, 1997; Duke *et al.*, 2002).

Gamma rays are high energy electromagnetic ionizing radiation emitted in the excitation of the atomic nucleus. The most often unit used to quantify the biological effects of ionizing radiation is the gray. (Ahloowalia and Maluszynski, 2001; Lemus *et al.*, 2002). Gamma rays affect plant gridgeth and development by inducing

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cytological, biochemical, physiological and morphological changes in cells and tissues *via* producing free radicals in cells (Gunckel and Sparridge, 1961; Kim *et al.*, 2004; Wi *et al.*, 2005).

The higher doses of gamma radiation were reported to be inhibitory (Kumari and Singh, 1996; Radhadevi and Nayar, 1996), whereas lower doses may be stimulatory. Low doses of gamma rays have been reported to increase cell proliferation, germination, cell gridgeth, enzyme activity, stress resistance, and crop yields (Charbaji and Nabulsi, 1999; Baek *et al.*, 2005; Chakravarty and Sen, 2001; Kim *et al.*, 2000 and 2005).

Potassium is a major plant nutrient, which is needed by the plants in large amount and is supplied by the fertilizer. It is available to the plants in the form of cation (k^+). Potassium is the main inorganic cation in plants and plays a significant role in many physiological and metabolic processes, such as activation of numerous enzymes, maintenance of charge balance, cytoplasmic pH homeostasis, osmotic potential and water uptake, regulation of stomatal activity and photosynthate translocation (Oosterhuis *et al.*, 2014). Potassium plays roles in promotes the gridgeth of meristematic tissues, aids in nitrogen metabolism, catalyzes activities of some mineral elements, and aids in carbohydrate metabolism and translocations (Bhandal and Malik, 1988).

The most important aim of this study is to investigate the effect of pre-sowing gamma irradiation of seeds and soil addition of potassium as well as their interaction treatments on gridgeth, seed yield components and fixed oil production as well as some chemical constituents of *Borago officinalis* plant under Sharkia Governorate conditions.

MATERIALS AND METHODS

The present work was carried out at the Experimental Farm, Nuclear Research Center, Atomic Energy Authority, Inshas, Sharkia Governorate, Egypt, during the two consecutive seasons of 2013/2014 and 2014/ 2015 aiming to investigate the effect of gamma irradiation and potassium fertilization as well as their interaction treatments on the gridgeth, seed yield components, fixed oil production and some chemical constituents of borage plant.

Borage (*Borago officinalis* L.) seeds were obtained from Research Center of Medicinal and Aromatic Plants, Bani Sweif. Seeds of borage crop were sown on 15th October in the two seasons. After treatment with gamma irradiation doses, seeds were manually sown then immediately irrigated. After one month from planting, germinated plants were thinned to be one plant/ hill for borage. The mechanical and chemical properties of the used soil are shown in Table 1 according to Chapman and Pratt (1978).

The treatments were arranged in a split plot in randomized complete block design with three replicates. While gamma irradiation dose treatments were randomly distributed in the main plots and potassium fertilizition level treatments were randomly arranged in the sub-plots.

The plot area was 4.5 × 2.40 meter and it was included three ridges. The ridge was 0.80 meter apart and 4.5 meter in length. The seeds were sown on ridge in hill on one side. The distance between hills were 50 cm, under drip irrigation system.

Dry seeds of borage were irradiated at 0 (control), 2, 4, 6, 8, 10 kilo-rad (Kr) in building of cyclotron in the Atomic Energy Authority, Anchas. Using gamma cell Co-60 (at the rate of 1.2 kr/hr). Potassium (0, 50 or 100 kg/fad.) was applied, as potassium sulphate (50% K_2O) during soil preparation as a soil application.

All plants received normal agricultural practices whenever they needed. All plants fertilized with nitrogen and phosphorus fertilization at the rate of 200 kg/faddan of ammonium sulfate (20.5% N) and 200 kg/ faddan of calcium super phosphate (15.5% P_2O_5). Phosphorus fertilizer was added during soil preparation as a soil application. While, nitrogen fertilizer divided into three equal portions and added to the soil at 30, 45 and 60 days from sowing.

At full flowering stage, plant height was recorded. Plants were then harvested and total dry weight of herb were determined.

Yield components *i.e.,* number of inflorescences per plant, seed yield per plant (g) and per faddan (kg)] of borage plant were determined after 120 days of sowing.

Table 1. Mechanical and chemical properties of the experimental soil before sowing and after harvest

Mechanical analysis						
Soil Depth (cm)	Coarse sand (%)	Fine sand (%)	Total sand (%)	Silt (%)	Clay (%)	Texture class
20-40	80.00	14.55	94.55	1.25	4.20	Sandy soil

Time	pH	EC*	O.M	Cations meq/100 g						Anions meq/100 g				ppm	
				Na^+	Mg^{++}	N	P	K^+	Mn^{++}	$CaCO_3$	HCO_3^-	Cl^-	SO_4^{--}	Zn	B
Before sowing	7.5	0.11	0.66	0.56	0.49	0.008	0.20	0.06	0.10	1.21	0.55	1.30	0.09	0.25	4.0
After harvest	7.5	0.11	0.66	0.56	0.49	0.008	0.20	0.06	0.10	1.22	0.55	1.30	0.09	0.26	4.0

* EC: Electerical conductivity.

Fixed oil percentage of borage seed was extracted by using petroleum ether in a Soxcelt system HT apparatus according to the methods of AOAC (1984).

Leaf green color degree (SPAD unit) was determind in fresh leaves of borage after 65 days from planting by SPAD-502 meter according to Markwell *et al.* (1995).

Statistical Analysis

Data of the present work were statically analyzed and the differences between means of the treatments were considered significant or highly significant when they were more than the least significant differences (LSD) at the 5% or 1% levels, respectively. The statistical calculations were performed with statistix software version 9 (Analytical Software, 2008).

RESULTS AND DISCUSSION

Gridgeth Parameters

Effect of gamma irradiation

Results in Tables 2 and 3 indicate that increasing gamma irradiation doses decreased borage plant height and dry weight of herb per plant (g), in most cases. Moreover, 2 kr dose mostly gave the highest values in plant height of borage plant with insignificant increase compared with other doses under study. However, the same dose showed highly significant increase in dry weight of herb per plant compared with control and the other ones under study.

These results are in similar with those found by Basha *et al.* (2015) on oat regarding decreasing effect on plant height and, El-Beltagi *et al.* (2013) on cowpea (*Vigna sinensis*) concerning increasing effect. In addition, in this respect, Abdul Majeed and Muhammad (2010) on *Lepidum sativum* L. and Elangovan and Pavadai (2015) on bhendi (*Abelmoschus esculentus* [L.] Moench) revealed that increasing gamma irradiation significantly decreased plant height. Also, Ilyas and Naz (2014) cleared that dry weights of turmeric (*Curcuma longa*) were decreased with increased gamma irradiation dose.

These results are in consistent with the common assumption that the stimulating effect of low dose of gamma rays irradiation on plant gridgeth may be due to stimulation of cell division and/or cell elongation, alteration of metabolic processes that affect synthesis of phytohormones or nucleic acids leading to taller plants (Pitirmovae, 1979). In contrast, the gridgeth inhibition induced by high-dose of gamma irradiation may be related to auxin and DNA destroy directly. As with other found responses, irradiation tissues often produce endogenous ethylene (Chervin *et al.,* 1992 ; Liu *et al.,* 2008).

Effect of potassium fertilization level

It is evident from the results in Tables 2 and 3 that, plant height and dry weight of herb per plant of borage was increased with increasing potassium fertilization level. Moreover, potassium fertilization treatments, significantly increased plant height (cm) and herb dry weight (g) of borage compared with control (without potassium fertilization). Furthermore, the maximum increase in this respect was obtained from the treatment of potassium sulphate (100 kg/faddan) compared

Table 2. Effect of gamma irradiation dose, potassium sulphate fertilization level and their interactions on plant height (cm) of borage plant during the two seasons of 2013/2014 and 2014/2015

Gamma irradiation dose Kr (G)	Potassium sulphate fertilization Kg/faddan (K)							
	0.00	50.00	100.00	Mean (G)	0.00	50.00	100.00	Mean (G)
	First season (2013/2014)				Second season (2014/2015)			
	Plant height (cm)							
Control (untreated)	110.30	117.30	118.30	115.30	97.00	115.00	126.67	112.89
2	119.70	120.00	124.00	121.23	101.33	115.67	127.33	114.78
4	113.00	120.00	122.00	118.33	103.67	113.33	118.00	111.67
6	105.30	115.30	117.70	112.77	96.00	118.33	113.67	109.33
8	109.30	114.80	117.30	113.80	102.33	102.67	120.00	108.33
10	107.00	110.00	113.00	110.00	101.67	107.00	114.00	107.56
Mean (K)	110.77	116.23	118.72		100.33	112.00	119.95	
	G	K		GK	G	K		GK
LSD at 5%	7.43	5.25		12.87	3.15	1.54		4.40
LSD at 1%	9.97	7.05		17.28	4.48	2.08		6.10

Table 3. Effect of gamma irradiation dose, potassium sulphate fertilization level and their interactions on dry weight of herb (g) of borage plant during the two seasons of 2013/ 2014 and 2014/2015

Gamma irradiation dose Kr (G)	Potassium sulphate fertilization Kg/faddan (K)							
	0.00	50.00	100.00	Mean (G)	0.00	50.00	100.00	Mean (G)
	First season (2013/2014)				Second season (2014/2015)			
	Dry weight of the herb (g)							
Control (untreated)	51.60	70.30	89.11	70.34	43.33	68.33	80.66	64.11
2	75.10	87.70	93.30	85.37	51.66	85.66	86.00	74.44
4	44.00	63.30	82.20	63.17	39.00	70.33	73.66	61.00
6	47.00	57.70	77.00	60.57	54.33	52.33	74.33	60.33
8	39.30	56.00	73.00	56.10	47.33	50.00	53.66	50.33
10	42.40	48.10	66.30	52.27	36.00	46.00	62.00	48.00
Mean (K)	49.90	63.85	80.15		45.28	62.11	71.72	
	G	K		GK	G	K		GK
LSD at 5%	10.37	4.47		13.68	4.12	4.85		10.54
LSD at 1%	14.75	6.05		19.05	5.86	6.58		14.39

with the other ones under study. These results were found in both seasons. The increase recorded in this respect due to adding 100 kg/faddan potassium fertilization was also found by Hussain *et al.* (2015) on maize. While, Zelelew *et al.* (2016) on potato and Mekdad and El-Sherif (2016) on sweet sorghum showed that the plant height was increased with increasing potassium fertilization and El-Bassiony *et al.* (2010) on sweet pepper (*Capsicum annuum* L.) on total dry weight of plant.

However, the increase in gridgeth parameters due to the application of potassium fertilization might be attributed to its importance as primary osmolyte and ion involved in plant cell membrane dynamics, including the regulation of stomata and the maintenance of turgor and osmotic equilibrium. It also plays an important roles in the activation and regulation of enzyme activity (Wiedenhoeft, 2006) and thus increase the vegetative gridgeth.

Effect of interaction between gamma irradiation and potassium fertilization treatments

Results presented in Tables 2 and 3, reveal that plant height of borage was highly significantly increased with interaction treatments between gamma irradiation and potassium fertilization rates compared with control in the second season and insignificant increase in the first one. Furthermore, under each treatment of gamma irradiation borage plant height and dry weight of herb per plant was mostly increased with increasing potassium fertilization levels. However, the interaction treatment between gamma irradiation of 2 kr with 100 kg/fad., of potassium sulphate fertilization was superior in this respect compared to the other ones under study in the two seasons. Furthermore, the treatment of 2, 4 and 6 kr combined with 100 kg / faddan potassium fertilization highly significantly increased dry weight of herb per plant compared with the control in the two seasons. Similar results were found by Abo El-Seoud *et al.* (1994) on roselle.

The stimulatory effect of the treatment of gamma irradiation at 2 kr plus potassium fertilization on dry weight of herb might be due to the role of potassium on the plant and gamma irradiation which was previously mentioned in the case of plant height as the increase in these parameters which reflected on dry weight of borage plant.

Yield components

Number of inflorescences/plant

Effect of gamma irradiation

From results presented in Table 4 it is clear that, increasing gamma irradiation doses decreased number of inflorescences per plant of borage. In addition, number of inflorescences per borage plant showed significant decrease with gamma irradiation treatment at 10 kr in the two seasons compared to control. Furthermore, 2 kr treatment mostly recorded an increase in number of inflorescences without significant differences compared with the other ones under study. Such results hold true in both seasons.

These results are in consistent with the common assumption that Gamma irradiation leads to changes in the plant cellular structure and metabolism (Jain *et al.*, 1998; Stoeva, 2002). Low doses of gamma rays have been increase cell proliferation, germination, cell gridgeth, enzyme activity, stress resistance, and crop yields (Charbaji and Nabulsi, 1999; Kim *et al.*, 2000 and 2005; Chakravarty and Sen, 2001; Baek *et al.*, 2005). In contrast, the gridgeth inhibition induced by high-dose of gamma irradiation may be related to auxin and DNA destroy directly. As with other wound responses, irradiation tissues often produce endogenous ethylene (Chervin *et al.,* 1992 ; Liu *et al.,* 2008).

Effect of potassium fertilization level

As shown in Table 4, maximum increase in number of inflorescences per borage plant was obtained from the treatment of 100 kg/faddan of potassium fertilization compared with the other ones under study. Such increase was highly significant in both seasons. Moreover, all potassium fertilization treatments highly significantly increased number of inflorescences per plant compared with control. Furthermore, number of inflorescences of borage was increased with increasing potassium levels. These results are in harmony with those reported by Badawy *et al.* (2015) on *Helichrysum bracteatum* Andr.

Effect of interaction between gamma irradiation and potassium fertilization treatments

Results presented in Table 4 show that, under each potassium fertilization level, treatment number of inflorescences per borage plant was decreased by using gamma irradiation treatments, in most cases. In the same time, the interaction treatments between gamma irradiation at 2 or 4 kr and 100 kg/faddan of potassium fertilization in the two seasons was superior in this respect with highly significant increase compared to the other ones under study. Also, under each treatment of gamma irradiation, number of inflorescences of borage was increased gradually with increasing potassium fertilization levels. Moreover, number of inflorescences per borage plant was insignificantly increased with interaction treatments between gamma irradiation and potassium fertilization rates compared with control [without irradiation (0 dose) and unfertilized (0 dose)] in most cases. Such results indicate that potassium fertilization might be overcome the harmful effect of gamma irridiation on number of inflorescences of borage plant.

Table 4. Effect of gamma irradiation dose, potassium sulphate fertilization level and their interactions on number of inflorescences of borage plant during the two seasons of 2013/2014 and 2014/2015

Gamma irradiation dose Kr (G)	Potassium sulphate fertilization Kg/faddan (K)							
	0.00	50.00	100.00	Mean (G)	0.00	50.00	100.00	Mean (G)
	First season (2013/2014)				Second season (2014/2015)			
	Number of Inflorescences							
Control (untreated)	162.00	195.00	235.00	197.33	142.00	172.00	234.33	182.78
2	192.00	192.00	215.00	199.67	154.00	187.33	228.67	190.00
4	171.10	181.00	244.00	198.70	157.67	169.33	234.00	187.00
6	171.00	188.00	192.00	183.67	146.00	165.00	209.00	173.33
8	104.00	167.00	194.00	155.00	138.33	149.33	231.00	172.89
10	125.00	126.00	127.00	126.00	129.00	155.67	165.33	150.00
Mean (K)	154.18	174.83	201.17		144.50	166.44	217.06	
	G	K		GK	G	K		GK
LSD at 5%	19.48	14.42		34.79	20.52	11.61		30.97
LSD at 1%	27.71	19.55		47.83	29.19	15.74		45.47

Seed yield/plant (g) and faddan (kg)

Effect of gamma irradiation

Results presented in Tables 5 and 6 show that, 2 kr treatment mostly recorded higher and significant increase in seed yield per plant and per faddan compared with the other ones under study in both seasons. Whereas, high doses of gamma irradiation treatments recorded significant decrease in this respect compared to control in the two seasons. In the same time, increasing gamma irradiation doses decreased seed yield per borage plant and per faddan in most cases. In this respect, Moussa (2006) suggested that application of gamma irradiation at 20 Gy significantly increased total yield of rocket (*Eruca vesicaria* subsp. sativa). While, Elangovan and Pavadai (2015) on bhendi (*Abelmoschus esculentus* [L.] Moench) showed that increasing gamma irradiation dose decreased seed yield.

Such results could be attributed to that the low dose of irradiation stimulate gridgeth by changing the hormonal signaling network in plant cells (Wi *et al.,* 2005), this might be reflected on seed yield per plant. In contrast, the gridgeth inhibition induced by high-doses of gamma irradiation may be related to auxin and DNA destroy directly.

Effect of potassium fertilization level

Results recorded in Tables 5 and 6 reveal that, seed yield per plant as per faddan were increased with increasing potassium fertilization rates during two seasons. The maximum and significant increase in this respect was obtained from the treatment of 100 kg/faddan of potassium fertilization compared with the other ones under study. These results are in harmony with those stated by Islam *et al.* (2016) on rice, Loeza-Corte *et al.* (2016) on sunflower and Khanam *et al.* (2016) on soybean.

Such increase in seed yield of borage plants due to increasing potassium application level can be attributed as reported by Marschner (1995) to the crucial role of potassium in the energy status of the plant, translocation and storage of assimilates and maintenance of tissue water relations leading to more seed yield.

Effect of interaction between gamma irradiation and potassium fertilization treatments

Results under discussion in Tables 5 and 6 indicate that, under each treatment of gamma irradiation seed yield per plant (g) and per faddan (kg) was increased with increasing potassium fertilization levels, in most cases. Generally, seed yield per plant as well as per faddan mostly showed significant and insignificant

Table 5. Effect of gamma irradiation dose, potassium fertilization level and their interactions on seed yield per plant of borage plant during two seasons of 2013/2014 and 2014/2015

Gamma irradiation dose Kr (G)	Potassium sulphate fertilization Kg/faddan (K)							
	0.00	50.00	100.00	Mean (G)	0.00	50.00	100.00	Mean (G)
	First season (2013/2014)				Second season (2014/2015)			
	Seed yield/plant (g)							
Control (untreated)	11.80	12.60	12.90	12.43	10.40	12.60	12.90	11.97
2	12.39	12.79	12.99	12.72	12.40	12.50	12.60	12.50
4	10.97	11.82	12.35	11.71	9.40	12.20	12.50	11.37
6	11.53	10.70	12.59	11.61	11.30	11.60	12.70	11.87
8	10.44	10.58	12.62	11.21	10.10	9.60	12.50	10.73
10	10.36	10.80	12.41	11.19	9.30	9.40	10.40	9.70
Mean (K)	11.25	11.55	12.64		10.48	11.32	12.27	
	G	K		GK	G	K		GK
LSD at 5%	0.75	0.49		1.24	0.50	0.35		0.86
LSD at 1%	1.07	0.67		1.71	0.70	0.47		1.18

Table 6. Effect of gamma irradiation dose, potassium fertilization level and their interactions on seed yield per faddan of borage plant during two seasons of 2013/2014 and 2014/2015

Gamma irradiation dose Kr (G)	Potassium sulphate fertilization Kg/faddan (K)							
	0.00	50.00	100.00	Mean (G)	0.00	50.00	100.00	Mean (G)
	First season (2013/2014)				Second season (2014/2015)			
	Seed yield/fad. (kg)							
Control (untreated)	166.67	201.60	206.40	191.56	188.80	201.60	206.40	198.93
2	198.40	200.00	201.60	200.00	198.24	204.64	207.84	203.57
4	150.40	195.20	200.53	182.04	175.52	189.12	197.60	187.41
6	180.80	186.03	203.20	190.01	184.48	171.20	201.44	185.71
8	161.97	153.60	200.00	171.86	167.04	169.28	201.92	179.41
10	148.80	150.40	166.77	155.32	165.76	172.80	198.56	179.04
Mean (K)	167.84	181.14	196.42		179.97	184.77	202.29	
	G	K		GK	G	K		GK
LSD at 5%	12.04	7.92		19.89	7.94	5.60		13.71
LSD at 1%	17.13	10.73		27.41	11.29	7.58		18.88

increase with the interaction treatments between gamma irradiation and potassium fertilization rates compared with control [gamma (0 dose) and potassium fertilization (0 dose)] in the first and second seasons, respectively. Similarly, under 50 kg/faddan of potassium fertilization level treatment, seed yield was decreased by increasing gamma irradiation treatments, in most cases. In the same time, the interaction treatment between gamma irradiation of 2 kr with 100 kg of potassium fertilization mostly recorded higher values and was superior in increasing seed yield per plant and per faddan with insignificant increase compared to the other ones under study in the two seasons. Such results reveal that potassium fertilization might be overcome the harmful effect of gamma irridiation on seed yield per plant and per faddan.

Consulting the available literature, there was no information concerning the effect of interaction treatments between gamma irradiation and potassium fertilization levels on seed yield/ faddan.

The stimulatory effect of the treatment of gamma irradiation at 2 kr plus potassium fertilization on seed yield per faddan might be due to the role of potassium on the plant and gamma irradiation which was previously mentioned in the case of number of inflorescences per plant and seed yield per plant as the increase in these parameters and were reflected in seed yield per faddan of borage plant.

Fixed Oil Percentage

Effect of gamma irradiation

It is quite clear from the results in Table 7 that, oil percentage of borage seeds was decreased with high doses of gamma irradiation compared to control, in most cases. Such decrease was significant in the second season and insignificant in the first one. In addition, 2 kr treatment recorded higher increase in oil percentage of borage compared with the other ones under study in the two seasons. Such increase was significant in the second season. In this regard Ilyas and Naz (2014) on turmeric (*Curcuma longa*) found that higher doses of gamma irradiation from 50 Gy up to 100 Gy decreased essential oil yield. While, Nassar *et al.* (2004) suggested that treated chamomile (*Chamomilla recutita* L. Rauschert) with gamma irradiation increased oil percentage if compared with control. Morever, Bhata *et al.* (2015) indicated that increasing gamma irradiation doses increased essential oil yield on *Psoralea corylifolia*.

Effect of potassium fertilization levels

The results tabulated in Table 7 show that, increasing potassium rates mostly increased oil percentage of borage in both seasons. Moreover, the maximum and significant increase in this respect was obtained from the treatment of 100 kg / faddan of potassium fertilization in the first season compared with the other ones under study. In this regard Nurzynska-Wierdak *et al.* (2013) reported that increasing rate of potassium fertilization significantly increased essential oil of sweet basil (*Ocimum basilicum*, L.).

Effect of interaction between gamma irradiation and potassium fertilization treatments

Results listed in Table 7 suggest that, under each treatment of gamma irradiation oil percentage of borage seeds was mostly increased with increasing potassium fertilization levels in the first season. However, the interaction treatment between gamma irradiation of 2 kr with 100 kg / faddan of potassium fertilization recoded higher increasing values compared to the other ones under study, in most cases.

Leaf Green Color Degree (SPAD Unit)

Effect of gamma irradiation

Results in Table 8 show that, the treatments of 4 kr in the first season and 2 kr in the second one recorded higher increase in leaf green color degree of borage plant with no significant differences compared with the other ones under study. Furthermore, the treatment of gamma irradiation at 4 and 6 kr insignificantly increased leaf green color degree compared to control during both seasons. Whereas, the doses of 8 and 10 kr decreased leaf green color degree, in the two seasons. Moreover, as gamma irradiation doses increased from 6 kr to 10 kr, the leaf green color degree was decreased in the two seasons. The increase recorded in this concern due to 2 or 4 kr of gamma irradiation was also found by Moussa (2011) on soybean. While, Kiong *et al.* (2008) on *Orthosiphon stamineus* found a decrease in this regared.

Table 7. Effect of gamma irradiation dose, potassium sulphate fertilization level and their interactions on fixed oil percentage of borage during two seasons of 2013/2014 and 2014/2015

Gamma irradiation dose Kr (G)	Potassium sulphate fertilization Kg/faddan (K)							
	0.00	50.00	100.00	Mean (G)	0.00	50.00	100.00	Mean (G)
	First season (2013/2014)				Second season (2014/2015)			
	Fixed oil percentage							
Control (untreated)	3.68	3.64	3.69	3.67	3.70	3.71	3.72	3.71
2	3.68	3.70	3.68	3.69	3.72	3.70	3.71	3.71
4	3.67	3.64	3.68	3.66	3.70	3.67	3.70	3.69
6	3.67	3.59	3.67	3.64	3.66	3.69	3.67	3.67
8	3.63	3.64	3.68	3.65	3.67	3.70	3.69	3.69
10	3.65	3.66	3.66	3.66	3.68	3.69	3.68	3.68
Mean (K)	3.66	3.65	3.68		3.69	3.69	3.70	
	G	K		GK	G	K		GK
LSD at 5%	0.03	0.02		0.05	0.01	N.S		0.04
LSD at 1%	0.04	0.03		0.07	0.02	N.S		0.05

Table 8. Effect of gamma irradiation dose, potassium sulphate fertilization level and their interactions on leaf green color degree (SPAD unit) of borage plant during the two seasons of 2013/2014 and 2014/2015

Gamma irradiation dose Kr (G)	Potassium sulphate fertilization Kg/faddan (K)							
	0.00	50.00	100.00	Mean (G)	0.00	50.00	100.00	Mean (G)
	First season (2013/2014)				Second season (2014/2015)			
	Leaf green color degree (SPAD Unit)							
Control (untreated)	53.67	51.30	61.33	55.43	44.53	45.36	48.76	46.22
2	42.76	58.66	63.11	54.84	45.56	45.86	51.33	47.58
4	54.43	61.11	59.30	58.28	44.76	47.70	46.80	46.42
6	52.33	51.40	62.76	55.50	46.40	46.63	47.70	46.91
8	43.00	51.66	65.33	53.33	42.63	46.56	48.96	46.05
10	42.36	46.66	55.30	48.11	44.10	45.03	47.03	45.39
Mean (K)	48.09	53.47	61.19		44.66	46.19	48.43	
	G	K		GK	G	K		GK
LSD at 5%	7.05	4.98		12.21	N.S*	2.24		5.87
LSD at 1%	9.46	6.69		16.39	N.S*	3.03		8.11

Effect of potassium fertilization levels

The results described in Table 8 indicate that, leaf green color degree was increased gradually with increasing potassium fertilization levels. Also, the maximum increase in this respect was obtained from the treatment of 100 kg/faddan of potassium fertilization compared with the other ones under study. Such increase was highly significant in both seasons. These results were recorded in the two seasons. In this regard El-Bassiony *et al.* (2010) on sweet pepper (*Capsicum annuum* L.) and Asgharipour and Heidari (2011) on sorghum reported that total chlorophyll was increased with increasing potassium fertilization rate. Whereas, El Gendy *et al.* (2015) suggested that treatd chervil plant (*Anthriscus cerefolium* L.) with potassium fertilizer increased photosynthetic pigments if compared with control.

These results are in consistent with the common assumption that potassium is essential for a variety of process such as photosynthesis and plays an substantial function in protein fashioning resulting in the increase of leaf green color degree, Yadav *et al.* (2003).

Effect of interaction between gamma irradiation and potassium fertilization treatments

The results presented in Table 8 show that, under each treatment of gamma irradiation leaf green color degree of borage leaves was increased with increasing potassium fertilization levels, in most cases. However, the interaction treatment between gamma irradiation of 2 kr with 100 kg of potassium fertilization was superior in this respect with significant increase compared to the other ones under study, in most cases. These results hold true in the two seasons.

Conclusion

Generally, it can be recommend by using interaction treatment between gamma irradiation of 2 kr and 100 kg/faddan of potassium sulphate fertilization because it was superior in seed yield per plant as well as fixed oil yield per plant increase of borage plant compared to the other ones under Sharkia Governorate conditions. Moreover, potassium fertilization at 100 kg/faddan could be overcome the harmful effect of gamma irradiation in this respect on borage plant.

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تأثيــر أشعة جاما والتسميد البوتاسي على نمو وإنتاجية نبات خبز النحل

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أجريت هذه الدراسة في المزرعة البحثية لمركز البحوث النووية بهيئة الطاقة الذرية بإنشاص بمحافظة الشرقية خلال موسمين متتاليين ٢٠١٤/٢٠١٣ و٢٠١٥/٢٠١٤ لدراسة تأثير جرعات أشعة جاما ومستويات التسميد البوتاسى والتفاعل بينهما على النمو والمحصول ومكوناته ونسبة الزيت الثابت المئوية ودرجة إخضرار لون الأوراق (وحدة SPAD) لنبات خبز النحل، استخدمت أشعة جاما بجرعات صفر (كنترول) ، ٢ ، ٤ ، ٦ ، ٨ و١٠ كيلوراد والتسميد البوتاسى بمعدل صفر (كنترول) ،٥٠ و١٠٠ كيلوجرام سلفات بوتاسيوم/فدان، إلى جانب ذلك، كل معاملة من معاملات أشعة جاما تداخلت مع كل مستوي من مستويات التسميد االبوتاسى لتكون ١٨ معاملة تفاعل، أظهرت النتائج المتحصل عليها أن استخدام أشعة جاما بجرعة ٢ كيلو راد أدت إلى زيادة قيم إرتفاع النبات والوزن الجاف الكلي للنبات وعدد النورات/نبات ومحصول البذور للنبات وللفدان ونسبة الزيت الثابت المئوية ودرجة إخضرار لون الأوراق، وعلاوة على ذلك، تم الحصول على أعلى قدر من الزيادة من المعاملة ١٠٠ كجم سلفات بوتاسيوم/فدان من التسميد البوتاسى بالمقارنة بمستويات التسميد الأخرى تحت الدراسة، وأعطت معاملة التفاعل بين أشعة جاما ٢ كيلوراد مع ١٠٠ كجم سلفات بوتاسيوم/فدان من التسميد البوتاسى غالباً أعلى قيم من الزيادة في الصفات المذكورة أعلاه، ولذا، يمكن التوصية بهذه المعاملة تحت ظروف محافظة الشرقية. علاوة على ذلك، فإن التسميد البوتاسي بمعدل ١٠٠ كجم/فدان يمكن أن يقلل من التأثير الضار للتشعيع بأشعة جاما في هذا الصدد على نبات خبز النحل.

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