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Implications of Seed Irradiation with γ-Rays on the Growth Parameters and GrainYield of Faba Bean

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FABA bean productivity is highly influenced by N-inputs; however, mineral N-fertilizers might undergo rapid leaching in light textured soils. On the other hand, mineral fertilizers are preferable than organic N-sources to raise protein content in bean grains. Thus, the current study investigates to what extent organic fertilizers can partially substitute chemical N-inputs to satisfy plant needs for nutrients. Also, irradiating seeds is another approach to increase plant productivity by inducing further cell membrane carriers to increase the efficiency of the grown plants to utilize the applied N-fertilizers. These two approaches were used in combination, in this study, to test their effectiveness in increasing bean productivity grown on a poor fertile light textured soil (90.5% sand). To fulfill this aim, a field experiment was carried out during the winter season of 2017/2018 following a split plot design where the different N-sources (organic vs inorganic and mixtures of these two N- sources, all applied at the recommended dose, i.e. 48 kg N ha^{-1} were plotted in the main plots while γ-irradiated seed treatments were plotted in the subplots. Irradiating bean seeds with gamma rays at a rate of 20 Gy (the least dose) increased significantly NPK uptake by beans and also enhanced plant growth. This consequently raised significantly the grain yield; however, increasing the dose of seed irradiation (>20 Gy) lessened significantly plant growth parameters and seed yield. Mixed N-sources also raised considerably NPK uptake by bean recording the highest significant increases in plant growth parameters and grain yield. Moreover, mixed treatments recorded comparable protein contents in bean grains vs plants that received 100% ammonium sulphate. Combination between seed irradiation and mixed N-sources were of positive effect on plant growth parameters and grain yield at only 20Gy. In conclusion, seed irradiation may be a useful technique to increase legume plant growth; however, slight increases in the used dose may negatively affect the total quantity of the grain yield. The aforementioned results also highlighted the importance of amending light textured soils with the mixed (organic+mineral) N-sources to increase the productivity of faba bean grown on a such soil.

Keywords: Gamma rays; Seed irradiation; Faba bean; Compost; Sandy soil.

Introduction

Faba bean (*Vicia faba* L.) is arich protein source for human food and animal feed (Khazaei et al., 2019; Samaei et al., 2020). This crop belongs to the Fabaceae family (Barker and Dennett, 2013) and is ranked the 4th in total legume production worldwide after *Cicer arietinum*, *Pisum sativum* and *Lens culinaris* (AIharbi and Adhikari, 2020). Its yield is characterized by high potential and nutrition-dense grains (Maalouf et al., 2019). It is also considered an excellent nitrogen fixer (Tang et al., 2019) and therefore, contributes effectively

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to sustainable farming (De Cillis et al., 2019). Yet this crop also needs a starter dose of N to stimulate N-fixation during early plant growth until N fixation provides adequate N (Abdul Rahman et al., 2018). Excessive N fertilization may delay the reproductive growth (Jafari-Jood et al., 2013); and consequently diminish grain yield (Manning et al., 2020). Thus, managing N inputs is essential to increase grain productivity while sustaining soils. It is worthy to mention that beans can be grown successfully in poor light textured soils (Nafady et al., 2018; Akl and Abd el-Fattah, 2019; Saad Mohamed, 2020). Raising the productivity of such soils should be considered during bean production through successive applications on chemical fertilizers; however, these fertilizers may be lost rapidly from the top soil through leaching (Matichenkov et al., 2020). Thus, the application of organic fertilizers may be an alternative option to supply plants with slow release-N and this probably reduces nutrients losses through leaching (Farid et al., 2014 and Elshony et al., 2019). Nevertheless, chemical fertilization is preferable than organic fertilizers to raise protein content in bean seeds (Cucci et al., 2019).

A promising technique that is recommended by many researchers to increase plant productivity is through irradiating seeds with gamma rays (Parchin et al., 2019; Volkova et al., 2020; Abbas et al., 2015 and 2020). This technique increases root elongation (Melki and Marouani, 2010), shoot length (Toker et al., 2005), induces further nutrient carriers (Abbas et al., 2020), stimulates plant growth and development (Marcu et al., 2013; Galal et al., 2018), increases free radicals (Bhat et al., 2007), inactivates plant pathogens (Rajkowski and Thayer, 2001) and enhances plant tolerance to biotic/abiotic stresses (Macovei et al., 2014). In legumes, the combination between seed irradiation and symbiotic biota might not be beneficial for legume plants as for non-legume ones. In this study, we test two scenarios for this combination (faba bean productivity and seed irradiation). Based on the findings of Soliman and Abd-ElHamid (2003), germination of kidney bean seeds and growth parameters increased significantly with seed irradiation at relatively low doses of gamma rays. Probably, seed irradiation, at low doses, increases the symbiotic relationship between soil biota and the host plants (Challougui Fatnassi et al., 2011). Accordingly, translocation of fixed atmospheric N to the grown plants increases. This might consequently increase the growth of plant roots, beside of improving the nutritional status of the grown plants. The second scenario is based on the findings of Fan et al. (2017) who indicated that low doses of gamma irradiation did not influence the growth of mung beans, while higher radiation doses inhibited their growth. Probably, irradiated plants compete with the free living symbiotic bacteria on soil nutrients (Hodge et al., 2000), during the early stages of plant growth and hence lessen their capability for symbiotic relationships (Jingguo and Bakken, 1997). Accordingly, the nutritional status of irradiated bean plants and their growth parameters decrease significantly.

The current study investigates the implications of applying different N sources (organic vs mineral) to faba bean grown on a light textured soil and to what extent organic fertilization can partially substitute chemical fertilizers in such a soil to satisfy plant needs for nutrients. This study also considers the consequences of irradiating bean seeds with low doses of gamma ray (0-80 Gy) on the nutritional status of the grown plants and hence faba bean productivity. Probably, irradiating seeds is another approach to increase plant productivity by inducing further nutrient carriers to take up more nutrients from soil and consequently raise the efficiency of applied N-fertilizers

Materials and Methods

Materials of study

Surface soil samples (0-30 cm) were collected from the experimental farm of Soils and Water Research Department (SWRD), Nuclear Research Center (NRC), Egyptian Atomic Energy Authority (EAEA), Abou-Zaable, Egypt during the winter season of 2017/2018.These samples were mixed thoroughly, air dried, crushed then sieved through a 2-mm sieve. Chemical and physical characteristics of the collected sample were determined according to the standard methods outlined by Sparks et al. (1996) and Klute (1986), respectively and the obtained results are summarized in Table 1.

Faba bean seeds (*Vicia faba* L. var Misr 1) were obtained from the Agricultural Research Center (ARC), Giza, Egypt. Seeds were then divided into 5 equal portions. Each portion was subjected to irradiation with gamma rays at either of the following doses 0 GY (control, R0), 20 GY (R1), 40 GY (R2), 60 GY (R3) and 80 GY (R4) in^{60}Co Gamma Irradiation Unit (Russian, CM-20), at 0.823 kGy/h This facility was provided by the Sicolitron Project, NRC, Egyptian Atomic Energy Authority (EAEA). Non-irradiated and irradiated seeds were kept at room temperature and were sown after irradiation immediately.

TABLE 1. Main properties of soil of the experimental field

Parameter	Particle size distribution %			Textural class (USDA)	pH*	EC* dS m^{-1}	OM* g kg^{-1}	$CaCO_3$, g kg^{-1}
	Clay	Silt	Sand					
Value	6.8	2.7	90.5	Sand	7.91	1.11	3.01	0.01

*OM: Organic matter content, *: pH was determined in soil:water suspension (1:2.5), EC **: was determined in soil paste extract.

TABLE 2. Main properties of organic compost used in the study

Parameter	EC, (1:2.5) (dS m^{-1})	pH (1:2.5)	Organic carbon, g kg^{-1}	Total content, g kg^{-1}			C/N ratio
				N	P	K	
value	4.2	7.1	207.0	21.0	9.4	19.1	9.9:1

Compost was purchased from Bani-Swief company and its chemical composition is estimated and presented in Table 2.

The field investigation

A field experiment was carried out at the farm of SWRD, NRC, EAEA, Abou-Zaable, Egypt during the winter season of 2017/2018 to study the response of faba beans grown on a sandy soil, under drip irrigation system, towards N-fertilization from different sources. Also, irradiating bean seeds with gamma ray at different doses and its implications on plant productivity was a matter of concern in this study. To fulfill the aims of this study, a field experiment with a split plot design was followed where the different N-sources (all applied at the recommended starter dose of 48 kg N $ha^{-1}$to stimulate microbial fixation) were plotted in the main plots while gamma-irradiation treatments were plotted in the subplots.

Factor one (five N sources based on their total N-content):

Including100% mineral N fertilization (as ammonium sulphate, N_1), 100% organic N fertilization (org-N as compost, N_2), 50% mineral N (mrl-N) + 50% organic N (N_3), 25% mineral N + 75% organic N (N_4) and 75% mineral N + 25% organic N (N_5). Compost was added to the experimental plots seven days before cultivation, while the inorganic-N was added 14 days after planting.

Factor two (5 doses of seed irradiation with gamma ray)

Comprising the non-irradiated seeds (R_0), seed irradiation with 20 GY (R_1), irradiation with 40 GY (R_2), irradiation with 60 GY (R_3) and irradiation with 80 GY (R_4).

Faba bean seeds were cultivated on 9/11/2017 using 2-seeds per gore at 30 cm distance apart from each other. All plots received P and K fertilizers according to the recommendations of the Egyptian Ministry of Agriculture, i.e. 46 kg P ha^{-1} as calcium superphosphate (8.5 % P) and 80 kg K ha^{-1} as potassium sulphate (48% K). Common agricultural practices were followed as recommended according to the local conditions. Plants were harvested at the physiological maturity stage on 23/4/2018. Soil samples were also collected from the rhizosphere of each treatment.

Methods of analyses

Soil analyses

Soil samples were digested using sulphuric acid + H_2O_2 for nutrients analysis (Estefan et al., 2013); afterwards, total P and K contents were determined using Spectrophotometer (model: Bk-F93, China) and flame photometer (model: PFP7/C), respectively. Total content of N was determined by the Kjeldahl method.

Plant analyses

After plant harvest, plants were washed several times with deionized water, separated into roots, shoots, grains and wall pods. These parts were then oven dried at 70°C and digested using sulphuric acid (H_2SO_4) according to Estefan et al. (2013). Nitrogen content in plant digests was then estimated using micro Kjeldahl apparatus (model Rypa) and protein content was calculated by multiplying %N by 6.25. Total contents of P and K were determined using Spectrophotometer and flame photometer, respectively.

Results

Plant growth parameters and the total yield (dry weight basis)

Roots dry weights

Table 3 reveals that the dry weights of bean roots decreased significantly owing to seed irradiation with gamma rays. The negative effect of irradiation can be arranged in the following descending order: R_0>R_1(≈R_2) >R_3>R_4. On the other hand, the dry weights of roots did not vary significantly among plants that received either 100% mrl (N_1) or those received 100% org (N_2). Also, the treatment "75%mrl+25% org" (N_5) recorded a comparable root growth with both $N_1$and N_2. The other two N-treatments, i.e."50% mrl+50% org" (N_3) and "25% mrl+75% org" (N_4) recorded the highest significant increases in root dry weights with no significant variations between these two N-sources.

Also, the combinations between N-source and seed irradiation were of further significant effects on values of root dry weight. In this concern, plants, whose seeds were irradiated with 80 Gy, and fertilized with 100% mrl-N (N_1) achieved the highest value of root dry weight (Fig 1). On the other hand, The lowest value of the root dry weight were detected in the treatment that received "80Gy + 100% organic fertilization" (R_5N_2), while the highest weights were recorded for R_0N_4 (no gamma irradiation and 25% mrl+75% org,R_0N_4).

Straw dry weights

Irradiating bean seeds with 20 Gy gamma radiation (R_1) improved significantly shoot dry weight by 7.1% vs the non-irradiated control ones (R_1), yet such increases seemed to be insignificant. Increasing the dose of γ radiation resulted in significant reductions in shoot dry weights. The effect of gamma radiations on shoot dry weights can be arranged in the followed descending order: R_1 (≈R_0) >R_2>R_3>R_4. It was found that the reductions in shoot dry weight were about 30.7, 43.1 and 51.2% owing to R_2, R_3 and R_4, respectively. It can therefore be deduced that the positive impacts of gamma radiation on bean plants could be observed when seeds were irradiated with 20 Gy or less; afterwards, negative effects occur on the grown plants. On the other hand, the source of N-fertilization was of no significant effect on shoot dry weight, except when the soil was amended with either "50% mrl+50% org" (N_3) or"25% mrl+75% org" (N_4). Concerning the combination between N-source and seed irradiation, the highest increases in shoot dry weights were recorded forthe treatment that received "20Gy of gamma irradiation and 25% Mrl+75% Org" (R_1N_4).

Pod walls dry weights

Table 3 reveals that the lowest radiation dose, i.e. 20 Gy led to significant increases in bean pod walls; however, significant reductions occurred thereafter following the order: R_1>R_0 (≈R_2)>R_3>R_4. Nitrogen source also influenced positively and significantly; however, slightly the pod following the order: N_1(≈N_2)>N_5 (≈N_4)>N_3

Interactions between these two factors were of further significant effect on bean pods yield. In this concern, the highest pod dry matter `was recorded for the treatment that received "20Gy of gamma irradiation and 100% mrl-N fertilization" (R_1N_1), while the least one was recorded for the treatment which received "80Gy and 100% organic fertilization" (R_4N_2). It is worthy to mention that pod yield dry weight did not vary significantly among R_3N_4, R_3N_5, R_4N_3, R_4N_4 and R_4N_5 interaction treatments

Seed yield (dry weights)

Seed irradiation seemed to be an effective technique to increase bean seed yield when treated with only 20 Gy (recording an increase of approximately 30.7% in seed yield). Higher doses of seed irradiation reduced effectively seed yield and in this concern the effect of irradiation on seed yield followed the descending order: R_1>R_0>R_2>R_3>R_4.

TABLE 3. Grand means of the effects of gamma irradiation and different N sources on faba bean growth parameters and grain yield

	Irradiation dose					N-source				
	R_0	R_1	R_2	R_3	R_4	N_1	N_2	N_3	N_4	N_5
Root dry matter, Mg ha^{-1}	0.96^{a}	0.79^{bc}	0.80^{b}	0.73^{c}	0.47^{d}	0.61^{c}	0.65^{c}	0.83^{b}	1.09^{a}	0.62^{c}
Straw dry matter, Mg ha^{-1}	5.11^{a}	5.28^{a}	3.54^{b}	2.91^{c}	2.47^{d}	3.33^{c}	3.47^{c}	4.02^{b}	5.31^{a}	3.28^{c}
Pod wall dry matter, Mg ha^{-1}	1.26^{b}	1.53^{a}	1.17^{b}	0.65^{c}	0.37^{d}	1.02^{ab}	1.12^{a}	0.71^{c}	0.95^{b}	0.99^{b}
Grain dry yield, Mg ha^{-1}	1.68^{b}	2.20^{a}	1.32^{c}	1.02^{d}	0.74^{e}	1.37^{bc}	1.27^{cd}	1.18^{d}	1.46^{ab}	1.54^{a}

Notes: R_0, R_1, R_2, R_3 and R_4 are 0, 20, 40, 60 and 80 Gy, respectively... N_1, N_2, N_3, N_4 and N_5 are 100% mineral, 100% organic, 50% mineral-N (mrl)+50% organic (org), 25% mrl+75% org and 75% mrl+25% org. Similar letters within rows indicate no significant variations among treatments.

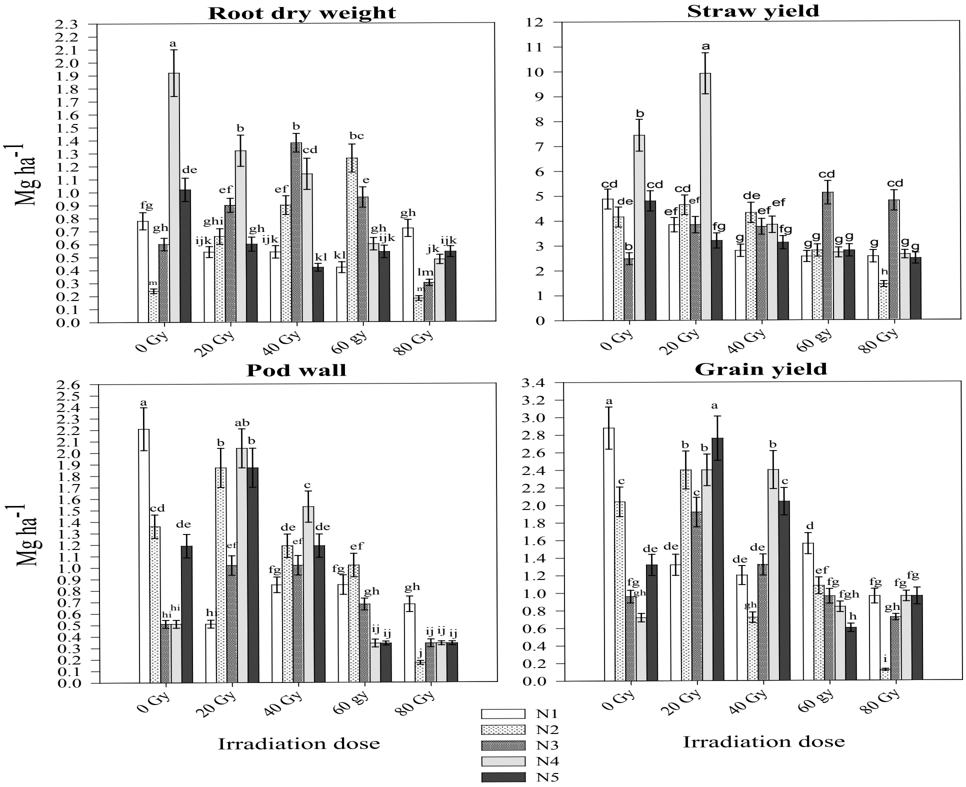

Fig. 1. Response of faba bean growth parameters and grain yield to different N sources and gamma irradiation. See footnotes of Table 3; Similar letters indicate no significant variations among treatments

Nitrogen fertilization source also affected significantly bean seed yield, recording its highest yield in N_4 and N_5 treatments. Interactions between seed irradiation and nitrogen fertilization were also effective in inducing bean seed yield. In this concern, the highest seed yield was achieved by the treatment that received 0Gy of gamma irradiation in presence of 100% mrl-N fertilizers (R_0N_1), with no significant variations with R_1N_5.

NPK uptake by bean plants

Irradiating faba bean seeds with gamma rays decreased significantly NPK-uptake by bean roots except for the treatment R_1 which recorded significantly higher K uptake values than the corresponding non-irradiated plants (R_0). Generally, according to the effect of gamma irradiation on decreasing nutrient uptake by roots, the irradiation doses can be arranged descending as follows: $R_1>R_0>R_2>R_3>R_4$.

The combined organo-mineral-N treatments recorded the highest increases in N-and K- uptake by bean plants, especially N_4, while the least N, P and K uptake values were detected in plants that received either 100% mrl or 100% org with no significant variations between these two treatments (except for K). Interactions between seed irradiation and N-fertilization were of significant effect on NPK-uptake by plant roots. The highest increases in NPK uptake by plants were attained for R_1N_4 then R_2N_4.

Total NPK contents in soil

Seed irradiation recorded no significant effect on total N-content in soil; yet this technique seemed to be effective on increasing P and K contents in soil. The dose 60 Gy resulted in the highest increases in total P content in soil, while the dose 20 Gy resulted in the highest increases in total K content in soil. On the other hand, the source of N resulted in further significant effects in total NPK contents in soil. In this concern, the organic treatments (+/-mineral-N) recorded the highest increases in total PK contents. Likewise, the organic amendment applied solely as a source of N (N_2) raised significantly total N-content in soil; however a comparable increase in total-N content was recorded due to N_1 treatment. It seems that the least concentrations of total-N were found due to the combination between organic-N +mineral-N treatments. Probably, this combination stimulated further microbial activities that could utilize soil-N; hence significant reductions occurred in its content in soil.

Concerning the combination among the different doses of seed irradiation and N-sources, it seems that N_2 treatments recorded the highest increases in total N content, irrespective to the dose of seed irradiation. The highest values of P –contents were recorded due to the treatments R_1N_4, R_3N_1, R_3N_2, R_4N_5, with no significant variations among these treatments. In case of K-, R_1N_4 recorded the highest increases in K total content in soil among the investigated treatments.

Protein content in bean grains

Gamma radiations did not affect significantly protein content in faba bean grains (Fig 3). Increasing the dose of gamma radiations was also of no significant effect on protein content in beans. On the other hand, N-treatments affected significantly this content following the descending order: $N_4 \approx N_5 > N_3 > N_1 > N_2$. Although, the mineral

TABLE 4. Response of faba bean to different N sources and gamma irradiation: total NPK uptake (kg ha^{-1}) by bean plants

Seed irradiation, R	N source					Mean
	N_1	N_2	N_3	N_4	N_5	
			N-uptake, kg N ha^{-1}			
R_0	218.27 ± 5.86^{bc}	157.98 ± 3.48^{ef}	94.51 ± 2.23^{i}	192.16 ± 3.23^{d}	170.48 ± 2.92^{e}	166.68 B
R_1	114.48 ± 4.10^{h}	193.36 ± 5.30^{d}	166.73 ± 3.89^{ef}	321.81 ± 3.71^{a}	211.96 ± 1.03^{c}	201.67 A
R_2	60.36 ± 2.86^{j}	114.28 ± 4.86^{h}	155.60 ± 4.93^{f}	228.54 ± 5.65^{b}	164.34 ± 4.15^{ef}	144.62 C
R_3	116.35 ± 7.85^{h}	110.07 ± 10.43^{h}	141.14 ± 5.15^{g}	95.89 ± 3.05^{i}	83.33 ± 2.98^{i}	109.35 D
R_4	89.28 ± 4.30^{i}	28.26 ± 4.30^{k}	121.68 ± 4.09^{h}	94.78 ± 8.20^{i}	92.91 ± 2.89^{i}	85.38 E
Mean	119.75 C	120.79 C	135.93 ^{B}	186.64 A	144.60 B	
			P-uptake, kg P ha^{-1}			
R_0	35.86 ± 2.02^{b}	$23.17\pm1.62^{d-f}$	12.37 ± 1.01^{jk}	27.72 ± 0.92^{cd}	25.21 ± 1.12^{de}	24.87 B
R_1	$19.72\pm1.60^{e-h}$	33.06 ± 2.11^{bc}	$22.82\pm1.39^{d-f}$	42.71 ± 1.46^{a}	$23.45\pm0.39^{d-f}$	28.35 A
R_2	$13.13\pm0.87^{i-k}$	$19.97\pm1.71^{e-h}$	$21.56\pm1.63^{d-g}$	31.70 ± 1.49^{bc}	$19.11\pm1.48^{e-i}$	21.09 C
R_3	$13.85\pm1.01^{h-k}$	$19.23\pm1.45^{e-i}$	$22.43\pm2.19^{d-f}$	12.80 ± 1.01^{jk}	10.66 ± 0.97^{k}	15.79 D
R_4	$15.33\pm1.55^{g-k}$	$5.03\pm0.19l$	$18.17\pm1.19^{f-j}$	11.90 ± 0.93^{jk}	12.57 ± 0.98^{jk}	12.60 E
Mean	19.58 B	20.09 B	19.47 B	25.37 A	18.20 B	
			K-uptake, kg K ha^{-1}			
R_0	111.15 ± 9.50^{bc}	$96.39\pm5.29^{c-f}$	$57.54\pm0.26^{i-k}$	124.79 ± 0.22^{b}	$73.89\pm0.27^{f-i}$	92.75B
R_1	$60.55\pm4.04^{h-k}$	124.27 ± 8.58^{b}	$100.29\pm0.52\ ^{c-e}$	153.90 ± 0.32^{a}	$86.99\pm0.15^{d-g}$	105.20A
R_2	$52.26\pm0.28^{i-l}$	$96.02\pm6.50^{c-f}$	$83.65\pm0.42^{b-d}$	107.07 ± 0.41^{bcd}	$70.59\pm0.44^{g-j}$	81.92C
R_3	44.38 ± 0.42^{kl}	$66.40\pm5.74^{g-k}$	$94.49\pm0.39^{i-k}$	$56.69\pm0.31^{i-k}$	$48.71\pm0.27^{j-l}$	62.13D
R_4	$56.15\pm0.51^{i-k}$	$31.38\pm2.40l$	$82.967\pm0.31^{i-l}$	$53.91\pm0.23^{i-l}$	45.34 ± 0.26^{kl}	53.95E
Mean	64.90 C	82.89 B	83.79 B	99.27 A	65.10C	

See footnotes of Table 3. Similar results indicate no significant variations among treatments

TABLE 5. Grand means of theeffects of gamma irradiation and different N sources on total NPK contents in soil

	Total NPK contents, mg kg^{-1}									
	Irradiation dose					N-source				
	R0	R1	R2	R3	R4	N1	N2	N3	N4	N5
Total N	14.40^{a}	14.56^{a}	14.28^{a}	15.04^{a}	15.24^{a}	16.80^{a}	17.00^{a}	13.56^{c}	12.92^{d}	14.00^{b}
Total P	4.57^{c}	4.84^{b}	4.96^{b}	5.36^{a}	5.24^{a}	4.78^{c}	5.08^{ab}	5.22^{a}	4.88^{bc}	5.01^{abc}
Total K	6.47^{b}	8.75^{a}	7.71^{ab}	7.46^{ab}	7.88^{ab}	6.68^{b}	9.81^{a}	7.13^{b}	8.57^{a}	6.09^{b}

See footnotes of Table 3. Similar letters within rows indicate no significant variations among treatments.

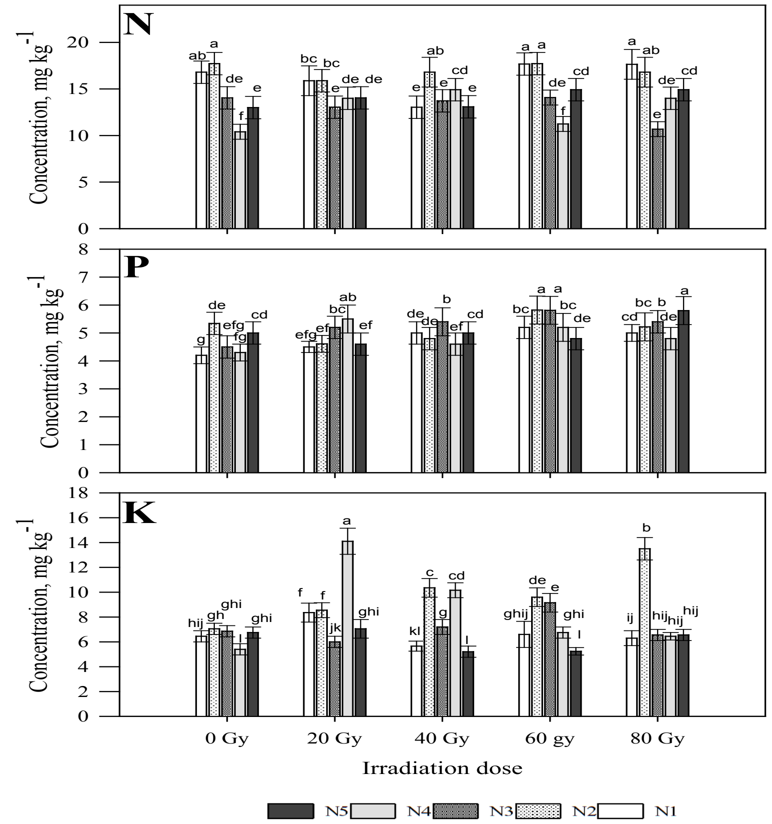

Fig. 2. Effects of gamma irradiation and different N sources on the total NPK contents in soil. See footnotes of Table 3. Similar results indicate no significant variations among treatments

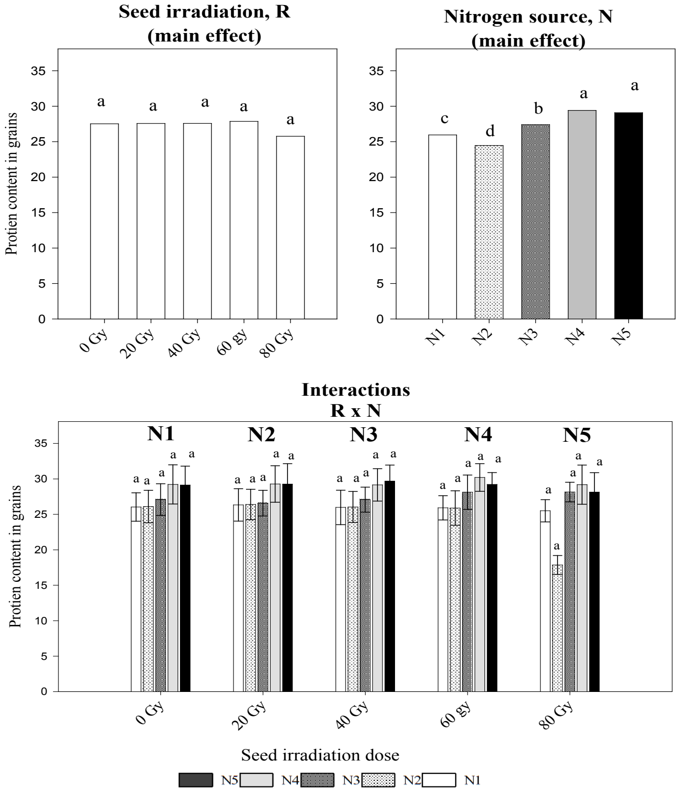

Fig. 3. Protein content in faba bean grains as affected by different N sources and gamma irradiation doses

N-fertilizer (N_1) was more efficient in increasing the protein content in bean grains than the organic source did; yet, the combination between these two sources (compost and mineral sources, i.e. N_3, N_4 and N_5) seemed to be more efficient in raising this content. No further significant effects were detected for the interactions among seed irradiation treatments and N-sourceson protein content in bean grains.

Discussion

Effect of seed irradiation of faba bean on growth and seed yield (quantity and quality)

Irradiating bean seeds with gamma rays at a rate of 20 Gy enhanced significantly the dry weights of bean roots, shoots and this consequently raised significantlythe seed yield. This might occurred because seed irradiation increased significantly root elongation in search of soil nutrients (Li et al., 2016). Moreover, this technique may increase the uptake carriers of soil nutrients in a unit area of plant roots (Abbas et al., 2020); accordingly NPK uptake improved considerably in plants whose seeds were exposed to relatively low irradiation doses (<20 Gy) of gamma rays. However, increasing the dose of seed irradiation with gamma rays (>20 Gy) decreased significantly plant growth parameters and the seed yield. Such high radiations probably caused physiological and biochemical damage in plant roots (Hanafy and Akladious, 2018); hence these plants suffered considerably during their growth. Seed irradiation had no significant effect on the buildup of soil-N (total-N in soil); consequently these findings did not support the hypothesis which indicates that seed irradiation suppressed the symbiotic relationship between the grown plants and soil biota. This technique (seed irradiation) raised significantly total P and K contents in soil. Probably, seed irradiation increased root exudates(Rasmann and Turlings, 2016) and consequently stimulated the activities of the surrounding soil biota (El-Bialee and Nawito, 2020). On the other hand, PK uptake values decreased considerably with increasing the dose of seed irradiation. The physiological damage that might occurred in roots of bean plant when exposed to high irradiation doses probably enhanced soil biota or soil borne pathogens to attack the plant roots. Further investigations are needed in this concern. Generally, seed irradiation had no significant effect on the protein content in bean seeds.

Effect of the N-source on faba bean growth and gain seed (quantity and quality)

The combined N-treatments, i.e., “50% mrl+50% org” (N_3) and “25% mrl+75% org” (N_4) recorded the highest significant increases in root, shoot and grain dry weights when compared with the application of either 100%mrl-N (N_1) or 100% organic-N (N_2). It is worthy to mention that N is needed for bean seedlings to increase their growth (Liu et al., 2019) and also stimulate the activities of the surrounding symbiotic biota within the rhizosphere (Pichon et al., 2020). Though, this soluble mineral N-source might be subjected to excessive losses in the investigated light textured soil (Shareef et al., 2020), but in presence of compost such loses might be limited (Bah et al., 2020). Moreover, this organic amendment is a source of soil nutrients (Abbas et al., 2011; Farid et al., 2014 and 2018; Abdelhafez et al., 2018; Elshony et al., 2019; Mosa et al., 2020; Abou Hussien et al., 2021); besides legumes solubilize insoluble soil phosphorus (Etemadi et al., 2019). This may explain why the combined “mineral+organic” nitrogen sources raised considerably NPK uptake by plants; consequently the combined treatments improved significantly the plant growth parameters and grain yield.

Conclusions

Seed irradiation may be a useful technique to increase legume plant growth; however, slight increases in the dose of seed irradiation may negatively affect the total grain yield quantity. Also, our results highlighted the importance of amending light textured soils with the mixed (organic+mineral) N-sources to increase the productivity of such a crop grown on the investigated soils.

Author Contributions

Conceptualization, All authors; methodology, Mohamed H.E. Afify, Ahmed A.A. Moursy and Mohamed A. Hekal; formal analysis, all authors; resources and writing—original draft preparation, all authors; writing—review and editing, all authors.

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Conflicts of Interest

The authors declare no conflict of interest

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تداعيات تشعيع البذوربأشعة جاما على معدلات النمو ومحصول حبوب الفول البلدى

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تتأثر إنتاجية الفول كثيرا بالمصادر النيتروجينية ،و مع ذلك فقد تخضع الأسمدة المعدنية للفقد السريع في التربة ذات القوام الخفيف، ومن جهة أخري فإن الأسمدة المعدنية أفضل من المصادر النيتروجينية العضوية لزيادة محتوي البروتين في بذور الفول. لهذا تهدف الدراسة الحالية إلي أي مدي يمكن إستبدال الأسمدة العضوية جزئيا محل الاسمدة النيتروجينية الكيميائية لتلبية إحتياجات النبات من العناصر الغذائية. تشعيع البذور يعد نهجاً آخر لزيادة إنتاجية النبات عن طريق تحفيز امتصاص المغذيات لزيادة فعالية الأسمدة النيتروجينية المستخدمة. تم إستخدام كلا العاملين في هذه الدراسة لرفع إنتاجية الفول الذي تم زراعته في تربة فقيرة الخصوبة ذات قوام خفيف (٩٠,٥٪ رمل).ولتحقيق الهدف تم عمل تجربة جقلية خلال الموسم الزراعى شتاء ٢٠١٧/ ٢٠١٨ بإتباع تصميم القطع المنشقة حيث تم التسميد بمصادر نيتروجينية مختلفة (عضوية ، و غير عضوية ، و خليط منهما ، و تم إستخدام الجرعة الموصي بها في كل حالة و هي ٤٨ كجم نيتروجين لكل هكتار) في قطع رئيسية بينما تمت زراعة البذور المشععة (صفر – ٨٠ جراي) في قطع فرعية. تشعيع بذور الفول بأشعة جاما بمعدل ٢٠ حراي (أقل جرعة إشعاعية مستخدمة) أدي إلي زيادة إمتصاص الفول للنيتروجين والفوسفور والبوتاسيوم بشكل ملحوظ، كما عزز أيضا من نمو النبات. مما أدي إلي زيادة محصول الحبوب. و مع ذلك فإن زيادة جرعة التشعيع للبذور (أكبر من ٢٠ جراي) خفضت بشكل ملحوظ من نمو النبات ومحصول البذور. كما أدت المعاملات النيتروجينية المختلطة إلي زيادة إمتصاص الفول للنيتروجين والفوسفور والبوتاسيوم بشكل ملحوظ وعليه تم تسجيل أعلي زيادات محسوسة في عوامل نمو النبات و في محصول الحبوب. كما أدت المعاملات المختلطة إلي تحقيق محتويات من البروتين في حبوب الفول مشابهة للنباتات التي سمدت بـ١٠٠٪ من سلفات الامونيوم. التداخل بين تشعيع البذور وإستخدام المصادر النيتروجينية المختلطة أدي إلي الحصول علي تأثير إيجابي علي عوامل نمو النبات و محصول الحبوب وذلك في حالة التشعيع بـ ٢٠ جراي فقط، بينما إنخفضت هذه العوامل بشكل ملحوظ عند التشعيع بجرعات أعلي من ٢٠ جراي. في النهاية يمكن القول أن تشعيع البذور يُعد تقنية مفيدة لزيادة نمو النباتات البقولية و لكن لابد من التحكم جيدا في الجرعات المستخدمة حيث أن أي زيادات طفيفة في هذه الجرعات الإشعاعية المستخدمة قد تؤثر سلبا علي محصول البذور .كما أبرزت النتائج أهمية تعديل التربة ذات القوام الخفيف بإضافة مصادر نيتروجينية مختلطة (عضوية و معدنية) لرفع إنتاجيتها.