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Importance of Gamma Irradiation, Micronutrient Mixtures and Their Application Methods for Improving Faba Bean (Vicia Faba L) Growth and Yield.

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Abstract:*Importance of gamma irradiation doses; zero, 15, 30 and 60 Gy, in addition to three micronutrient application methods i.e. coating, soaking and spraying , as well as micronutrient mixtures, which were control, Fe +Zn +Mn and Fe +Zn+ Mn +Mo on growth, yield and yield attributes of Faba bean cultivar Sakha 1, was investigated during 2010-2011 and 2011- 2012 seasons. The work was conducted in an experimental field at Balbees district, Sharkia Governorate, Egypt. The experimental farm soil was sandy texture.*
Recorded results showed that gamma irradiation dose of 30 Gy was the most effective, while dose of 60 Gy was the most depressive on number of nodules/ plant and day weight of nodules (mg/plant) at 50 and 75 DAS; leaf area /plant and LAI at 75 DAS; leaf content of chlorophyll A, B and carotene at 75 DAS; number of branches, Pods and seeds/ plant; Seed index as well as seeds, straw and biological yields/ fad. In view of micronutrient application methods, foliar spraying method was the most enhancing for the above-named traits followed by seed soaking method, while seed coating method was the least. Both micronutrient mixtures outbraved the control regarding the aforementioned characters; results averred that appliance of (Fe + Zn+ Mn) micronutrient mixture was more effective than application of (Fe+ Zn +Mn +Mo) micronutrient mixture, on each of growth and yield trails studied.
Key words:*Gamma Irradiation Micronutrient, Faba Bean, Growth and Yield.*

I. Introduction

Broad bean (Vicia faba L.) is one of the important legumes in the Middle Eastern countries. It can be used as a dietary item alone or can serve as a potential supplement to cereal diets, especially for the preparation of inexpensive protein rich food for children (Al-Kaisey et al., 2002)[1]. In Egypt, faba bean is among the main nutritional source of plant protein (Bakry et al., 2011)[2]. Several studies have indicated that irradiation technique is one of prime importance in agriculture for improvement not only the productivity of crop but also for increasing the nutritive value of produced crops. It is well known that the modification in plant growth and yield imposed by any of the environmental stresses is considered to be a reflection of certain alterations in some metabolic events in tissue. Consequently, it is thought that seed irradiation may affect some of the biochemical regulatory mechanisms involved in seed germination and plant growth. The plant growth characteristics and yield were reported to be variously affected inconsequence of gamma irradiation of seeds pre-sowing (Abou El-Yazied, 2011)[3]; (Soliman and Abd El-Hamid, 2003)[4].

In the last two decades, several investigators in Egypt reported positive response of different field crops (faba bean) to micronutrient fertilization (El- Fouly et al., 2011)[5]. Micronutrients are required in small amounts and they affect directly or indirectly photosynthesis, vital processes in higher plant such as respiration, protein synthesis, reproduction phase (Marschner, 1995)[6] .El-Akabawy et al. (2001)[7] stated that the beneficial effects of micronutrients application on maize were recorded by many workers. Manganese has an essential role in amino acid synthesis by activating number of enzymes particularly decarboxylases and dehydrogenases of the tricarboxylic acid cycle. Ashoub et al., (1998)8[] showed that using maize grain coating with Mn increased plant height, dry weight /plant, number of green leaves /plant, weight of 100-grains, grain yield, straw yield, Mn uptake and protein content in grains. El-Gizawy (2000)[9] found that the highest grain yield was recorded by foliar application or grain soaking with Mn. Iron is a constituent of many enzymes involved in the nutritional metabolism of plant (Kabata-Pendias and Pendias 1999)[10]. Zinc plays an important role as a metal component of enzymes (superoxide dismutase, carbonic anhydrase an polymerase) or as a functional, structural, or regulate RNA cofactor of a large number of enzymes (Kabata-Pendias and Pendias 1999)[10]. Kanwal et al., (2010)[11] found that zinc application to soil had a positive significant effect on grain yield of maize. Rego et al.,` (2007)[12] reported an increase in grain yield of maize by Zn application. Molybdenum is known to be a relatively mobile nutrient in the plant system and readily concentrated by plants (Clarkson and Hanson, 1980)[13].

The aim of the present investigation is to study the effect of gamma irradiation, micronutrient application methods and micronutrient mixtures (control, Fe+ Zn+ Mn, Fe+ Zn+ Mn+ Mo) on faba bean growth and yield.

II. Materials and Methods

The field experiment was conducted during the 2 consecutive seasons of 2010-2011 and 2011- 2012 in an experimental field at Belbeesdistric, Sharkia Governorate, Egypt. The experimental farm soil was sandy texture, comprising of 79.51% sand, 10.33% silt and 10.13% clay, 0.82 % organic matter, available phosphorus 10.11 ppm, available nitrogen21.91 ppm, available K 153.40ppm with PH of 7.71, the experiment was laid out in split-split plot design with four replications. Irradiation treatments (0, 15, 30 and 60 Gy) were assigned to the main plots, while, micronutrients application methods i.e. (coating, soaking and foliar) were arranged in the subplots, mixture of micronutrients i.e. (control, Fe+ Zn+ Mn , Fe+ Zn+ Mn+ Mo) were located in the sub-sub plots. For coating method, micronutrients were added at the rate of 0.3 g/kg seeds for Fe, Zn and Mn, however Mo was applied at 0.039 g/Kg seeds, regarding foliar or soaking application methods, micronutrients concentration was 300 ppm.

Micronutrients were added in the form of EDTA except molybdenum, which was added as ammonium molybdate. In the foliar spray treatments, micronutrients were sprayed twice, the first when plants aged 30 days and the second was on 45 days from sowing .Seeds were soaked in micronutrients solution for four hours.

Irradiation was performed using Co^{60} source from unit gamma chamber 4000, at the National Center for Radiation Research and Technology. The experimental plot area was $12.25m^2$, contained 6 ridges with 3.5 m length and each ridge was 60 cm apart. The distance between hills was 30 cm, 2 plants per hill. Seeds of faba bean Sakha1 cultivar were obtained from legume crops research institute, Giza, Egypt, and hand sown on 17^{th} Oct. and20^{th} Oct. in both seasons.

Calcium superphosphate (15.5%P_2O_5) was used as a source of phosphorus at the level of30 Kg P_2O_5/ fad., added during soil preparation . Ammonium nitrate (33%N) as a source of nitrogen was applied at the level of 20 Kg N / fad, also potassium sulphate (48-52%K_2O) was used as a source of potassium on the level of 24 kg K_2O/ fad, both nitrogen and potassium fertilizers were supplied after 20 days from sowing. Flood irrigation system was used. All other cultural practices were carried out as recommended for faba bean production in both seasons.

At both 50 and 75 days after sowing (DAS), number of nodules / plant and weight of nodules (mg/plant) were recorded from random sample of five plants for each experimental unit. Leaf area (cm^2/ plant) was measured at 75 DAS, then leaf area index was calculated .Also, at 75 DAS, chlorophyll A, chlorophyll B and carotene were determined according to (Metzneret al., 1965)[14]

At harvest, random sample of five guarded plants from each sub-subplot was taken and plant height (cm), number of branches and pods/ plant, number of seeds/ pod, seed weight (g/ plant), were measured. 100- Seed weight (g) for each plot was recorded. Seed straw and biological yields were determined per plot and then total seed, straw and biological yields/ fad,were calculated.

III. Statistical analyses

All the collected data were analyzed statically according to Steel et al., (1997) [15]. Combined analysis of the two seasons was computed. Differences between means were compared by using Dun can multiple range test (Gomez and Gomez ,1984)[16]

IV. Results and Discussion

1.1. Number of Nodules / Plant and Dry Weight of Nodules (Mg / Plants)

Number of nodules / plant and dry weight of nodules (mg / plants), at 50 and 75 DAS as affected by gamma irradiation doses, micronutrient application methods and micronutrient mixtures are presented in Table 1.

1.1.1. Gamma irradiation effect

Generally, number of nodules/plant and dry weight of nodules plant of gamma irradiation plants recorded 50 and 75 DAS in both seasons and their combined analysis, surpassed those of unirradiated plants. The most effective irradiation dose in increasing number and dry weight of nodules/plant was 30 Gy, followed by 15 Gy, while the highest irradiation dose (60 Gy) ranked last.

1.1.2. Micronutrient application methods effect

Nodulation parameters of faba bean plants (Table 1) expressed as number of nodules / plant and dry weight of nodules (mg/ plant) were the highest when the micronutrient application was via spraying method, while nodulation parameters were the lowest when the micronutrient application methods was via pre-sowing seed coating. Micronutrient application via seed soaking has a moderate efficiency on nodulation parameters.

The previous results were in conformity with those of both seasons and their combined data. Foliar application with micronutrients could be more effective than soil application because it overcomes deficiency problem in the soil (Modaihsh, 1997) [17]

1.1.3. Micronutrient mixtures effect

In general, application micronutrient mixtures in comparison with the control treatment resulted in more number of nodules/ plant and heavier weight of nodules (mg/ plant) in both seasons and their boold analysis. Inter the two micronutrient mixtures, the mixture of Fe+Zn+Mn compared with the mixture of Fe+Zn+Mn +Mo caused significant increments in both number and dry weight of nodules/plant recorded at 50 and 75 DAS in both seasons and the combined analysis . Based on the combined data, number of nodules /plant were 39.38 vs 33.55 and 45.60 vs 42.0 at 50 and 75 DAS, moreover, dry of nodules (mg/plant) recoded 0.41vs 0.35 and 0.66 vs 0.53 at 50 and 75 DAS.

1.1.4. Interaction effect

It is obvious from Table 1 that the dualist interactions between the three main factors under study were significant in both seasons and the combined analysis; it was also explicit that the interaction effects on both number and dry weight of nodules/plant tented to be in conformity with the main effects; consequently, interaction tables were not discussed.

1.2. Leaf Area (Cm2/Plant) and Leaf Area Index

Effect of gamma irradiation, micronutrient application methods and micronutrient mixture on faba bean leaf area (cm^2/plant) and leaf area index (LAI) recorded 75 DAS are shown in Table 2.

1.2.1. Gamma irradiation effect

Leaf area (cm^2/ plant) and leaf area index of faba bean plants measured 75 DAS were larger when any gamma irradiation dose was used as pre-sowing treatment, compared with the unirradiated treatment. Based on combined data, the largest leaf area (624.39 cm^2/plant) and leaf area index (0.69) could be attained when gamma irradiation dose of 30 Gy was used followed by using 15 Gy. Moussa (2006)[18] reported that low doses of gamma radiation may increase the enzymatic activation and awakening of the young embryo, which results in stimulating the rate of cell division and affects vegetative growth Abou El-Yazeid (2011)[3] indicated that pre-sowing irradiation with 30 Gy, produced the higest value of leaf area.

1.2.2. Micronutrient application methods effect

Various micronutrient application methods caused marked and significant effect on faba bean vegetative growth expresses as leaf area (cm^2/ plant) and leaf area index recorded at 75 DAS. The most favorable micronutrient application method was foliar application, followed by soaking, while coating ranked last, these views were avouched in both seasons and their combined analysis. These results are in agreement with those of Salem and El-Gizawy (2012)[19], who found that foliar application method, gave the highest value of leaf area compared to soaking and coating methods.

1.2.3. Micronutrient mixtures effect

The two micronutrient mixtures i.e. Fe +Zn +Mn ; Fe +zn +Mn +Mo enhanced significantly faba bean leaf area/ plant and LAI (sample aged 75 days)compared to the control (unfertilized plants) in both seasons and the combined analysis. The most outgrow of faba bean plants in both leaf area / plant and leaf area index caused due to the application of(Fe +Zn +Mn) micronutrient mixture. Salem and El-Gizawy (2012)[19] concluded that, micronutrient fertilization using Fe +Zn +Mn was the most effective treatment in increasing maize leaf area/ plant.

1.2.4. Interaction effect

As shown in both seasons and the combined analysis (Table 2), The interaction effect (gamma irradiation dose × micronutrient application methods, gamma irradiation doses ×micronutrient mixtures, micronutrient application methods× micronutrient mixtures) on both leaf area (cm^2 /plant) and leaf area index were significant. But, no additional information could be obtained other than the main effects. Therefore, interaction tables were neither shown nor discussed.

1.3. Chlorophyll A, Chlorophyll B and Carotene

Data in (Table 3) demonstrate the effect of gamma irradiation doses, micronutrient application methods and micronutrient mixtures on faba bean leaf content of chlorophyll A, B and carotene at75 DAS.

1.3.1. Gamma irradiation effect

Faba bean leaves content of photosynthetic pigments i.e. chlorophyll A, chlorophyll B and carotene increased gradually with raising gamma irradiation dose up to 30 Gy, additional increase in gamma irradiation dose up to 60 Gy was of no avail and accompanied by significant reduce in faba bean leaves content of photosynthetic pigments. It is worth to note that irradiation treatments surpassed the un – irradiated plants respecting leaves content of photosynthetic pigments. The abovementioned results were inferred in both seasons and the combined analysis. Similarly, Hegazi and Hamideldin (2010)[20] postulated that all photosynthetic pigments content were significantly increased as a result of gamma irradiation treatment.

1.3.2. Micronutrient application methods effect

Micronutrient application methods affected significantly leaves content of photosynthetic pigments in both seasons and the combined analysis. Foliar application of micronutrients resulted in the highest leaves content of chlorophyll A, chlorophyll B and carotene compared with either seed coating or seed soaking. Salem and El-Gizawy (2012)[19] stated that foliar spray with (Fe +Zn +Mn) was the most efficient method in increasing chlorophyll A, chlorophyll B and carotene concentrations in maize leaves comparing with soaking and coating methods.

1.3.3. Micronutrient mixtures effect

Response of faba bean leaves content from each of chlorophyll A, chlorophyll B and carotene to micronutrient mixtures was significant. Appliance of either (Fe +Zn +Mn) or (Fe +Zn +Mn+ Mo) micronutrient mixture outstripped the control treatment (underutilization).The highest leaves concentration of photosynthetic pigments could obtained by supplying the micronutrient mixture of (Fe +Zn +Mn), followed by supplying the micronutrient mixture of (Fe+Zn+Mn+Mo). All the above views were ascertained in both seasons and the combined analysis. Chlorophyll A and B has the higher values with supplying (Fe +Zn +Mn) mixture nutrient than other Zn, Mn and Fe treatments, these views were expressed by Salem and El-Gizawy(2012)[19]

1.4. Plant Height (cm), Number of Branches and Number of Pods/Plant

Table 4 shows faba bean plant height (cm), number of branches, and number of pods/ plant at harvest in the two seasons and their combined as affected by gamma irradiation doses, micronutrient application methods and micronutrient mixtures.

1.4.1. Gamma irradiation effect

Results in Table 2 revealed significant differences in both seasons and their combined as well , regarding plant height , number of branches and number of pods/ plant. Data of both seasons and the combined analysis indicated that pre-sowing seed irradiation with 15, 30 and 60 Gy produced tall plants with more branches and pods number/ plant compared with the un-irradiated plants. The most favorable gamma irradiation dose was 30 Gy, surpassing that dose up to 60 Gy was accompanied by significant decrease, that influence was affirmant in each of plant height, number of branches and pods/ plant in both seasons and the combined data.

In the literature , several worker doucemented the importance of gamma irradiation in meliorting plant height , number of branches and number of pods/ plant (Farag , 1996[21]; Gaberet al. ,2000[22]; Tamaset al. 2005[23]; Norfadzrinet al., 2007[24]; Dubeyet al. , 2007[25]; farag and El-Khawaga 2013[26]; Farag and Abd El-Hameed , 2013[27]).

1.4.2. Micronutrient application methods effect

According to the combined data, micronutrient application via spraying methods produced the tallest plants (105.7 cm), the highest number of branches / plant (3.51) and the highest number of pods/ plant (12.92), micronutrient application via seed soaking ranked second and recorded 102.0, 3.26 and 11.91 for plant height, number of branches/ plant and number of pods/ plant , respectively, further, micronutrient application throw seed coating ranked last. Salem and El-Gizawy(2012)[19] found that, the foliar spraying gave the highest values of plant height than other application methods (seed soaking and coating).

1.4.3. Micronutrient mixtures effect

Comparing application of micronutrient mixtures with the control, revealed that fertilized plants outrankrd unfertilized plants in each plant height, number of branches and number of pods/plant, that was valid in both seasons and their combined data. Over and above, supplies of (Fe+Zn+ Mn) as micronutrient mixture was more affective than supplies of (Fe+Zn+ Mn +Mo) as micronutrient mixture, consequently produced taller plants with more number of branches and pods/plant. Data reported by Salem and El- Gizawy (2012)[19] on maize showed that micronutrients fertilization using Fe+Zn+ Mn treatment was the most effective treatment regarding plant height.

1.4.4. Interaction effect

Plant height was significantly affected by the dualist interactions between gamma irradiation doses, micronutrient application methods and micronutrient mixtures that was true in first seasons and the combined analysis. It is worth to note that the interaction effects on plant height was in conformity with the main effects, consequently interaction tables were not shown and were not discussed. Based on combined analysis, interaction effect were insignificant on each of number of branches /plant and number of pods/plant.

1.5. Number of Seeds/Pod, Seed Weight (g/Plant) and 100 Seed Weight (g)

The effect of gamma irradiation doses, micronutrient application methods and micronutrient mixtures on each of number of seeds /pod, seed weight/plant and 100 –seed weight (g) is shown in Table (5).

1.5.1. Gamma irradiation effect

As per data of number of seeds/pod in both seasons and their combined analysis , it was obvious that pre-sowing seed irradiation with doses of 15,30 and 60 Gy was ineffectual on number of seed/ pod, but out of regard for gamma irradiation treatments effect on both seed weight / plant and 100 seed weight, all pre-sowing seed irradiation treatments were superior over the control(un-irradiated plants). The highest seed weight/plant as well as 100- seed weight could be obtained due to pre-sowing seed irradiation with the dose of 30 Gy, that was true in both seasons and the combined analysis. The superiority of seed weight / plant due to pre-sowing seed irradiation with the dose of 30 Gy, was expected, because of its effective impact on each of plant height, number of branches / plant and number of pods /plant, therefore increment in seed weight/plant was obtained.

The positive and stimulatory effects on seed weight /plant was conformed with the finding of Sundaravadiveluet al., (2006)[28]; Sujaya – Das et al. (2007)[29]; Khan et al.(2010)[30]; Rahm Din et al. ,(2010)[31]; Singh and Datta(2010)[32];as well as Farag and Abed El – Hameed (2013)[27].

1.5.2. Micrinutrient application methods effect

Number of seeds /pod in both seasons and their combined analysis exhibited insensitive response to micronutrient application methods. Both seed weight /plant and 100 –seed weight had significantly affected by varying micronutrient application methods, foliar spraying resulted in the best seed weight / plant as well as the heaviest 100 –seed weight ,whlist coating application method resulted in the lowest seed weight/ plant and 100 –seed weight in both seasons and the combined analysis. Micronutrient application via seed soaking had a moderate efficiency on both seed weight / plant and 100- seed weight. The previous results were in conformity with those of number of nodules/ plant, dry weight of nodules / plant (Table 1); leaf area / plant , leaf area index (Table 2); chlorophyll A,B and carotene content (Table 3); Plant height , number of branches / plant and number of pods/ plant (Table 4).

1.5.3. Micronutrient mixtures effect

Generally, application of micronutrient mixture comparing to the control treatment, resulted in heavier seed weight /plant as well as heavier 100- seed weight in both seasons and their boold analysis. Inter the two-micronutrient mixtures, the mixture of Fe+Zn+Mn compared with the mixture of Fe+Zn+ Mn +Mo caused significant increments in both seed weight /plant and 100-seed weight, in both seasons and the combined analysis. Micronutrient mixtures effect number of seeds/pod was of no use. Superiority of Fe+Zn+ Mn micronutrient mixture was also obvious in most of growth traits as well as yield component studied. The increase of yield component due to micronutrient application might be due to their positive effect of micronutrients on seed yield component were reported by Abdoet al., (2002)[33]; Farzanianet al., (2010)[34]; Babaeianet al., (2010)[35]; Ebrahimian and Bybordi (2011)[36] and Omar and Abd-El- Hameed (2012)[37].

1.5.4. Interaction effect

Regarding to seed weight / plant and 100- seed weight, it is obvious from Table 5 that the dualist interactions between the three main factors studied, were significant in both seasons and their combined analysis, it was also explicit that the interaction effects on both seed weight / plant and 100 –seed weight, tended to be in conformity with the main effects, So interaction tables were not shown and were not discussed . Number of seeds /pod was significantly affected by the three dual interactions.

1.6. Seed, Straw and Biological Yield/Fad

Results of seed yield (ardab/fad.), straw yield (ton/ fad.) and biological yield (ton/ fad.) as influenced by gamma irradiation doses, micronutrient application methods and micronutrient mixtures are presented in Table (6).

1.6.1. Gamma irradiation effect

Pre-sowing seed irradiation with 15, 30 or 60 Gy yielded more seeds, straw and biological yields compared with yields produced from unirradiated plants, that was valid in both seasons and the combined analysis . The highest seed, straw and biological yields were obtained due to the irradiation dose of 30 Gy, raising gamma irradiation dose up to 60 Gy decreased that yields. These results were expected since the efficacious role of gamma irradiation with 30 Gy was obvious in most growth traits as well as most yield components studied. In the literature, several workers documented the importance of gamma irradiation in meliorating seed, straw and biological yields (Farag ,1996[21]; Gaberet al. 2000[22]; Tamaset al., 2005[23]; Khan et al., 2010[30]; Rahm Din et al.,2010[31]; Singh and Datta ,2010[32]; Farag and El-Khawaga, 2013[26]; Farag and Abd El- Hameed, 2013[27])

1.6.2. Micronutrient application methods effect

It is evident from Table 6 that, the three-micronutrient application methods under study reflected significant effects on seed, straw and biological yields; the ascending order was spraying >soaking >coating in the two seasons and their combined analysis. Supereminence of foliar spraying application method over both soaking and coating application methods was obvious not only in seed , straw and biological yields, but also in each of number of nodules /plant, dry weight of nodules / plant , plant height, number of branches/ plant, number of pods /plant, seed weight/ plant and 100 –seed weight. Similar views were expressed by Modaihsh, 1997[17]; Hegazi and Hamideldin ,2010[20] and Salem and El Gizawy 2012[19].

1.6.3. Micronutrient mixtures effect

Application of micronutrient mixtures in general seed, straw and biological yields comparied with the control, that was valid in both seasons and the combined analysis. Furthermore, supplies of (Fe+Zn+Mn) as micronutrient mixture was more efficient than supplies of (Fe+Zn+Mn+ Mo) as micronutrient mixture, consequently produced more seed , straw and biological yields. It is worth to mention that supplies of the micronutrient mixture (Fe+Zn+Mn) was superior also in most growth and yield attributes studied. The increase of yield components due to micronutrients application might be due to their positive effects on assimilates translocation, activation of photosynthetic enzymes, chlorophyll formation and improvement of plant growth. The meliorating effect of micronutrient mixture was also reported by Abdoet al., (2002)[33]; Farzanianet al., (2010)[34]; Babaeianet al., (2010)[35]; Babaeianet al., (2011)[38]Ebrahimian and Bybordi (2011)[36] and Omar and Abd El- Hameed (2012)[37].

1.6.4. Interaction effect

Seed, straw and biological yields were significantly affected by the dualist interaction between gamma irradiation doses, micronutrient application methods and micronutrient mixtures that was true in both seasons and the combined analysis. It is worth to note that the interaction effects on seed , straw and biological yields were in conformity with the main effects, using gamma irradiation dose of 30 Gy with foliar spraying as micronutrient application methods produced the highest seed, straw and biological yields, while the lowest yields were obtained due to pre-sowing gamma irradiation dose of 60 Gy in combination with seed coating as micronutrient application methods.

V. Figures and Tables

Table (1) Effect of gamma irradiation, micronutrient application methods and micronutrient mixtures on number and dry weight of nodules/plant of faba bean at 50 and 75 DAS* in two seasons and their combined

Main effects and interaction	Number of nodules /plant						Dry weight of nodules(mg /plant)					
	50 DAS*			75 DAS*			50 DAS*			75 DAS*		
	2010/11	2011/12	Comb.	2010/11	2011/12	Comb.	2010/11	2011/12	Comb	2010/11	2011/12	Comb.
A- Gamma irradiation (GY)												
Zero	28.02d	27.21d	27.62d	32.30d	30.76d	31.53d	0.25d	0.27d	0.26d	0.37d	0.43d	0.40d
15	38.83b	33.32b	36.08b	40.76b	40.85b	40.81b	0.35b	0.38b	0.37b	0.51b	0.64b	0.58b
30	41.12a	37.63a	39.38a	47.91a	43.28a	45.60a	0.40a	0.43a	0.42a	0.59a	0.73a	0.66a
60	30.58c	31.12c	30.85c	40.51c	38.89c	39.70c	0.27c	0.32c	0.30c	0.42c	0.51c	0.47c
F-test	*	*	*	*	*	*	*	*	*	*	*	*
B- Micronutrient application methods												
Coating	28.62	37.21c	31.27c	40.69c	35.98c	39.41c	0.23c	0.23c	0.23c	0.37c	0.51c	0.44c

	c											
Soaking	35.87 b	26.66b	32.92b	45.39b	39.15b	43.17b	0.31b	0.39b	0.35b	0.46b	0.55b	0.51b
Spraying	39.43 a	33.08a	36.26a	45.50a	40.88a	44.73a	0.41a	0.43a	0.42a	0.58a	0.68a	0.63a
F-test	*	*	*	*	*	*	*	*	*	*	*	*
C- Micronutrient mixtures												
Control	27.99 c	27.00c	27.50c	40.52c	38.89c	39.71c	0.23c	0.25c	0.24c	0.34c	0.42c	0.37c
Fe+Zn +Mn	41.12 a	37.63a	39.38a	47.91a	43.28a	45.60a	0.39a	0.43a	0.41a	0.59a	0.75a	0.66a
Fe+Zn +Mn+ Mo	34.77 b	32.32b	33.55b	43.15b	40.85b	42.00b	0.33b	0.37b	0.35b	o.48b	0.57b	0.53b
F-test	*	*	*	*	*	*	*	*	*	*	*	*
Interaction												
AxB	*	*	*	*	*	*	*	*	*	*	*	*
AxC	*	*	*	*	*	*	*	*	*	*	*	*
BxC	*	*	*	*	*	*	*	*	*	*	*	*

DAS* = Days after sowing Comb. =combined analysis

Table (2) Effect of gamma irradiation , micronutrient application methods and micronutrient mixtures on leaf area (cm2/plant) and Leaf area index of faba bean at 75 DAS* in two seasons and their combined

Main effects and interaction	Leaf area (cm^2/plant)75 DAS			Leaf area index 75 DAS		
	2010/2011	2011/2012	Comb	2010/2011	2011/2012	Comb
A-Gamma irradiation (GY)						
Zero	532.28d	574.72d	553.50d	0.59d	0.64d	0.62d
15	575.15b	619.67b	597.41b	0.64b	0.69b	0.66b
30	598.54a	650.24a	624.39a	0.67a	0.72a	0.69a
60	550.2c	599.89c	575.05c	0.61c	0.67c	0.64c
F-test	*	*	*	*	*	*
B-Micronutrient application methods						
Coating	477.62c	526.16c	501.89c	0.53c	0.58c	0.56c
Soaking	565.84b	586.88b	576.36b	0.63b	0.65b	0.64b
Spraying	632.08a	686.44a	659.26a	0.70a	0.76a	0.73a
F-test	*	*	*	*	*	*
C-Micronutrient mixtures						
Control	530.59c	546.19c	538.39c	0.59c	0.61c	0.60c
Fe+Zn+Mn	587.82a	603.47a	595.65a	0.65a	0.67a	0.66a
Fe+Zn+Mn+Mo	557.23b	575.98b	566.61b	0.62b	0.64b	0.63b
F-test	*	*	*	*	*	*
Interaction						
AxB	*	*	*	*	*	*
AxC	*	*	*	*	*	*
BxC	*	*	*	*	*	*

DAS* =Days after sowing

Table (3): Effect of gamma irradiation , micronutrient application methods and micronutrient mixtures on faba bean leaves content of Chlorophyll A, Chlorophyll B and Carotene (mg/g fresh weight) at 75 DAS* in two seasons and their combined

Main effects and interaction	Chlorophyll A			Chlorophyll B			Carotene		
	2010/2011	2011/2012	Comb	2010/2011	2011/2012	Comb	2010/2011	2011/2012	Comb
A-Gamma irradiation (GY)									
Zero	8.33d	8.33d	8.33d	5.38d	5.67d	5.53d	13.71d	14d	13.86d
15	9.37b	9.37b	9.37b	5.83b	6.21b	6.02b	15.2b	15.58b	15.39b
30	9.73a	9.73a	9.73a	6.37a	6.69a	6.53a	16.1a	16.42a	16.26a
60	9.14c	9.14c	9.14c	5.75c	5.87c	5.81c	14.89c	15.01c	14.95c
F-test	*	*	*	*	*	*	*	*	*
B-Micronutrient application methods									
Coating	8.77c	8.77c	8.77c	5.39c	5.66c	5.53c	14.16c	14.43c	14.30c
Soaking	8.96b	8.96b	8.96b	5.82b	6.11b	5.97b	14.78b	15.07b	14.93b
Spraying	9.69a	9.69a	9.69a	6.28a	6.57a	6.43a	15.97a	16.26a	16.12a

F-test	*	*	*	*	*	*	*	*	*
C-Micronutrient mixtures									
Control	8.61c	8.61c	8.61c	5.47c	5.73c	5.60c	14.08c	14.34c	14.21c
Fe+Zn+Mn	9.32a	9.32a	9.32a	6.18a	6.49a	6.34a	15.5a	15.81a	15.66a
Fe+Zn+Mn+Mo	8.89b	8.89b	8.89b	5.83b	6.11b	5.97b	14.72b	15.0b	14.86b
F-test	*	*	*	*	*	*	*	*	*
Interaction									
AxB	*	*	*	*	*	*	*	*	*
AxC	*	*	*	*	*	*	*	*	*
BxC	*	*	*	*	*	*	*	*	*

Table (4) Effect of gamma irradiation , micronutrient application methods and micronutrient mixtures on Plant height(cm) , number of branches and pods of faba bean in two seasons and their combined

Main effects and interaction	Plant height(cm)			Number of branches /plant			Number of pods /plant		
	2010/2011	2011/2012	Comb	2010/2011	2011/2012	Comb	2010/2011	2011/2012	Comb
A- Gamma irradiation (GY)									
Zero	96.15d	97.06c	96.61c	2.29d	2.99d	2.64d	9.18d	9.79d	9.49d
15	100.50b	106.94a	103.72a	3.03b	3.18b	3b.11b	11.36b	11.94b	11.65b
30	102.93a	105.03a	103.98a	3.44a	3.73a	3.59a	13.55a	14.22a	13.89a
60	99.86c	103.01b	101.44b	2.62c	3.45c	3.04c	11.18c	11.84c	11.51c
F-test	*	*	*	*	*	*	*	*	*
B-Micronutrient application methods									
Coating	94.59c	98.61c	96.60c	2.89c	3.07c	2.98c	9.67c	10.43c	10.05c
Soaking	100.48b	103.52b	102.00b	3.16b	3.35b	3.26b	11.55b	12.27b	11.91b
Spraying	104.53a	106.90a	105.72a	3.43a	3.59a	3.51a	12.71a	13.13a	12.92a
F-test	*	*	*	*	*	*	*	*	*
C-Micronutrient mixtures									
Control	94.25c	95.27c	94.76c	3.05c	2.96c	3.01c	9.48c	10.36c	9.92c
Fe+Zn+Mn	105.79a	108.71a	107.25a	3.48a	3.64a	3.56a	13.09a	13.37a	13.23a
Fe+Zn+Mn +Mo	99.55b	105.03b	102.29b	3.27b	3.41b	3.34b	11.37b	12.11b	11.74b
F-test	*	*	*	*	*	*	*	*	*
Interaction									
AxB	*	*	*	N.S	N.S	N.S	N.S	N.S	N.S
AxC	*	N.S	*	*	N.S	N.S.	*	N.S	N.S
BxC	*	*	*	N.S	*	N.S	*	N.S	N.S

Table (5): Effect of gamma irradiation, micronutrient application methods and micronutrient mixtures on number of seeds/pod, seed weight (g/plant) and100-seeds weight (g) of faba bean in two seasons and their combined

Main effects and interaction	Number of seeds /pod			Seed weight (g/ plant)			100-seeds weight (g)		
	2010/2011	2011/2012	Comb	2010/2011	2011/2012	Comb	2010/2011	2011/2012	Comb
A-Gamma irradiation (GY)									
Zero	3.17	3.29	3.13	30.01d	32.01d	31.01d	77.05d	77.18d	77.12d
15	3.33	3.91	3.62	36.78b	41.85b	39.32b	80.53b	81.30b	80.92b
30	3.23	4.11	3.77	40.4a	46.32a	43.36a	82.78a	83.31a	83.05a
60	3.27	3.53	3.40	34.4c	38.7c	36.55c	78.41c	79.22c	78.82c
F-test	N.S	N.S	N.S	*	*	*	*	*	*
B-Micronutrient application methods									
Coating	2.33	3.51	2.92	30.55c	35.5c	33.03c	77.04c	77.30c	77.17c
Soaking	3.59	3.68	3.64	35.34b	38.32b	36.83b	79.02b	79.61b	79.32b
Spraying	3.83	3.94	3.89	40.32a	43.31a	41.82a	83.02a	83.98a	83.50a
F-test	N.S	N.S	N.S	*	*	*	*	*	*
C-Micronutrient mixtures									
Control	2.46	3.5	2.98	30.01c	32.01c	31.01c	76.02c	76.12c	76.07c
Fe+Zn+Mn	3.85	3.91	3.88	39.4a	45.3a	42.35a	82.63a	83.34a	3.85a
Fe+Zn+Mn+ Mo	3.44	3.72	3.58	36.78b	41.85b	39.32b	80.43b	81.30b	80.87b

F-test	N.S	N.S	N.S	*	*	*	*	*	*
Interaction									
AxB	N.S	N.S	N.S	*	*	*	*	*	*
AxC	N.S	N.S	N.S	*	*	*	*	*	*
BxC	N.S	N.S	N.S	*	*	*	*	*	*

Table (6) Effect of gamma irradiation, micronutrient application methods and micronutrient mixtures on seed, straw and biological yields /fad., of faba bean in two seasons and their combined

Main effects and interaction	Seed yields (ardab* /fad)			Straw yield (ton/fad)			Biological yield (ton/fad)		
	2010/2011	2011/2012	Comb	2010/2011	2011/2012	Comb	2010/2011	2011/2012	Comb
A-Gamma irradiation (GY)									
Zero	8.14d	8.24d	8.19d	2.28d	2.37d	2.33d	3.50d	3.61d	3.56d
15	9.55b	10.73b	10.14b	2.65b	2.93b	2.79b	4.08b	4.54b	4.31b
30	10.47a	11.20a	10.84a	2.88a	3.17a	3.03a	4.45a	4.85a	4.65a
60	9.39c	10.06c	9.73c	2.61c	2.82c	2.72c	4.02c	4.33c	4.18c
F-test	*	*	*	*	*	*	*	*	*
B-Micronutrient application methods									
Coating	8.29c	8.56c	8.43c	2.31c	2.43c	2.37c	3.55c	3.71c	3.63c
Soaking	9.35b	10.02b	9.69b	2.67b	2.87b	2.77b	4.07b	4.37b	4.22b
Spraying	10.52a	11.59a	11.06a	2.83a	3.16a	3.00a	4.41a	4.90a	4.66a
F-test	*	*	*	*	*	*	*	*	*
C-Micronutrient mixtures									
Control	8.22c	8.73c	8.48c	2.28c	2.37c	2.33c	3.51c	3.68c	3.60c
Fe+Zn+Mn	10.50a	11.42a	10.96a	2.88a	3.16a	3.02a	4.46a	4.87a	4.67a
Fe+Zn+Mn +Mo	9.44b	10.02b	9.73b	2.65b	2.94b	2.80b	4.07b	4.44b	4.26b
F-test	*	*	*	*	*	*	*	*	*
Interaction									
AxB	*	*	*	*	*	*	*	*	*
AxC	*	*	*	*	*	*	*	*	*
BxC	*	*	*	*	*	*	*	*	*

Ardab*=150 kg

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