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RESPONSE OF SEED IRRADIATION WITH GAMMA RAY, N-FERTILIZATION AND BIkO FERTILIZATION OF BARLEY (*Hordeum vulgare* L.) GROWN ON A SAND SOIL

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ABSTRACT

Seed irradiation during pre-sowing processes is one of the most effective methods to increase plant growth, yield components and its chemical composition. A three factor split-split plot, factorial experiment was conducted on barley to study seed irradiation, biofertilization with N_2 fixing bacteria (NFB), P-dissolving bacteria (PDB) and N fertilization in the Agricultural Research Station of El-Zagazig University at El-Khattara region, El-Sharkia Governorate, Egypt during 2009/2010 season. Main plots were assigned to gamma irradiation: non-radiated, 20 and 40 Gy gamma radiations. Sub-plots were assigned to N: 0, 119, 238 and 298 kg N ha^{-1}. Sub–sub plots were assigned to biofertilization: none, (*Azospirillum lipoferum* + *Bacillus polymxa* "NFB1"), (*Azospirillium braselence* + *Azotobacter chroccocum* "NFB2"+*Bacillus megatherium* "PDB") and NFB1 + NFB2 + PDB. The NFB1 was given in a commercial product of "Cerealin" while (NFB2 + PDB) was in a product of Microbin. Barley yield and yield components as well as N, P and K content and uptake increased by gamma irradiation, N rates and biofertilization singly or combined. Number of spike *per* m^2, grain weight *per* spike, yields of: grains + straw, grains and straw increased also, highest response occurred by N238 + (Cerealin + Microbin) with 40Gy gamma ray. The highest straw yield was observed due to N179 + (Cerealin + Microbin) with 40Gy gamma ray. Treatment of N179 + Cerealin with 40Gy gamma ray gave highest N-uptake in straw, as well as P-uptake in grains and straw. Protein content and protein yield increased by treatments especially with increasing N rate up to N298 + Microbin + 20Gy and gave highest protein content. Nitrogen use efficiency (NHI) was increased with increasing N rates up to N238 followed by decrease at N298.

Keywords: Gamma irradiation, Barley, N fertilization, Biofertilizers, Sand soil

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the most important cereal crops in Egypt. Total production of barley in Egypt reached 102000 megagrams (Mg) in 2011, produced from an area of 65000 ha, (FAO, 2012). Recently, a great attention has been directed to increase the productivity of barley to minimize the gap between the production and consumption. Gamma radiation can be useful for the alteration of physiological characters (Kiong *et al.,* 2008). The biological effect of gamma rays is based on the interaction with atoms or molecules in the cell, particularly water, to produce free radicals **(**Kovacs and Keresztes 2002). Seed irradiation during the pre-sowing is one of the effective methods to improve plant production, yield components and chemical composition. Gamma ray ionizes molecules and causes free radicals that attack DNA molecules which break one or two chains of DNA (Jyoti *et al.,* 2009). Artik and Peksen (2006) investigated the effect of gamma irradiation of 25, 50, 75 and 100 Gy, they found that low doses of stimulated cell division, growth and development of faba bean plants. Rahimi and Abdallah (2011) reported that doses of 25 and 50Gy were the most effective for increasing grain yield, harvest index and grain protein content of wheat.

Farag and El-Khawaga, (2013) found that gamma irradiation in a low dose (10, 20 and 30Gy), increased seed yield of sesame plants.

Extending the role of biofertilizers can reduce the need for chemical fertilizers, decrease adverse environmental effects and fix atmospheric N_2. Therefore, biofertilization is of great importance in alleviating environmental pollution (Namvar *et al.,* 2012 and Rana *et al.,* 2012). Inocula of *Azotobacter* sp. and *Azospirillum* sp. are used as biofertilizers for many crops. The estimated contribution of these free-living N fixing prokaryotes to the N input of soil ranges from 0–60 kg/ha per year (Vessey, 2003). Existence of microbial communities like *Azotobacter* sp. and *Azospirillum* sp. in the rhizosphere promotes the growth of the plant through the cycling and availability of nutrients, increasing the health of roots during the growth stage by competing with root pathogens and increasing the absorption of nutrients and water (Daneshmand *et al.,* 2012). Kizilkaya (2008), Sary *et al.* (2009) and Kandil *et al.* (2011) studied the effects of inoculation with *Azotobacter* sp. and *Azospirillum* sp. on wheat and observed that inoculated wheat plants gave higher plant height, spike per unit of area, grains per spike, grain weight, biological yield, grain yield and straw yield. Saini *et al.* (2004) and Piccinin *et al.* (2013) suggested that integrated nutrient management strategies involving inoculation of seeds with *Azotobacter* sp. and *Azospirillum* sp. in combination with chemical fertilizers result in improving both growth and yield of crops. Inocula of organisms which act as biofertilizers are prepared in different forms (in suspensions or on solid organic matter) and are marketed commercially under different trade manes. In Egypt one of such products is Cerealin (produced by Ministry of Agriculture, Egypt) which consists of inocula of N_2 fixing strains of *Azospirillium lipoferum* and *Bacillus polmxa.* Another product is Microbin which consists of N2-fixing microorganisms along in the P-dissolving microorganisms (El-Kramany *et al.,* 2000).

Nitrogen is the most important essential nutrient in plant nutrition. It is a constituent of a large number of necessary organic compounds such as amino acids, proteins, coenzymes, nucleic acids, ribosomes, chlorophyll, cytochrome and some vitamins. Thus, N supply to the plant will influence the amount of protein, cell size, leaf area and photosynthetic activity (Diacono *et al.,* 2013). N fertilizer causes positive effect on the number of grains spike^{-1}, spike weight, 1000-grain weight and grain yield of wheat (Campuzano *et al.,* 2012 and Liu and Shi, 2013). Namvar and Khandan, (2013) found that high rates of N fertilization and biofertilizer (*Azotobacter sp*. and *Azospirillium sp*.) inoculation increased grains number spike^{-1}, 1000-grain weight, grain yield, biological yield and grain protein content of wheat plant.

The current investigation aimed at assessing the effect gamma irradiation, different nitrogen rates and biofertilizers on nitrogen utilization as well as some plant characteristics, yield and yield composition of barley (*Hordeum vulgare* L.) c.v Giza 123 grown on a sand soil.

MATERIALS AND METHODS

A field experiment on barley was conducted at El-Khattara region El-Sharkia Governorate, Egypt during winter season 2009 / 2010 to investigate the effect of gamma-irradiation as well as the effect of nitrogen fertilization and biofertilization of barley plants (*Hordeum vulgare* L.) c.v Giza 123, grown in a sandy soil. The chemical analysis of soil of the experimental field (30cm depth) showed sand, silt and clay as 91.8, 6.0 and 7.6%, respectively (sand in texture), having EC in its saturation extract of 0.77 dS m^{-1} and contents of $CaCO_3$ and organic matter of 7.5 and 7.8 g kg^{-1}, respectively. Available macronutrients were 18.5 mg N kg^{-1} (mineral N extracted by 2M KCl) 8.19 mg P kg^{-1} (extracted by Na-bicarbonate 0.5 M) and 29.4 mg K kg^{-1} (extracted by 1.0 M NH_4 OAc, pH 7.0) as described by Jackson (1958) Page *et al.* (1982) and Black *et al.* (1982).

Prior to sowing, seed inoculation was carried out using biofertilizers of nitrogen fixing bacteria (NFB) and phosphorus dissolving bacteria (PDB). The first group of NFB: NFB1 are *Azospirillum lipoferum* and *Bacillus polymxa* in the form of the commercial biofertilizer “Cerealin”. The second group NFB2 are *Azospirillium braselence* + *Azotobacter chroccocum* combined with PDB (i.e., phosphorus dissolving bacteria of *Bacillus megatherium*) are in a form of the commercial biofertilizer Microbin. Both produced by the Egyptian Ministry of Agriculture as inocula carried on organic, peat like substances to treat seeds. Seed inoculation was performed by mixing barley grains with the appropriate Cerealin and Microbin using Arabic gum as adhesive material. The coated grains were then air dried in shade for 30 minutes and sown immediately on 22^{th} of October 2009.

The experiment was a 3-factor factorial split-split plot in a randomized complete block design with three replications. The plot area was 5 m^2 (2.5 X 2 m). Main plots, were assigned to irradiation, none, 20 and 40 Gy gamma irradiation, irradiation facility used was, cobalt 60 gamma chamber 4000-A-India, Egyptian Atomic Energy Establishment, (EAEE), Inshas, Egypt. Sub-plots were assigned to N: 0,119, 238 and 298 kg N ha^{-1} in form of ammonium sulphate, AS (205 g N kg^{-1}) in three equal splits: 20 days after sowing, "DAS" (immediately after thinning), 40 and 60 DAS. Sub–sub plots were assigned to biofertilizers: none, Cerealin, Microbin and Cerealin + Microbin. Soil was supplied with phosphorus in form of Calcium superphosphate (67.6 g P kg^{-1}) at a rate of 31 kg P ha^{-1} during seed bed preparation; and with potassium 119 kg K ha^{-1} as potassium sulphate (400 g K kg^{-1}) in two equal doses 30 and 45 days after planting. Harvest was done on, 25^{th} of April 2010.

Dry matter and grain yield

At harvest, ten plants were taken randomly from each plot and tagged for yield assessment. Number of spikes, grain weight $spike^{-1}$ and 1000-grain weight were measured. Plants were harvested, air dried, then straw yield, Mg ha^{-1} and grain yield, Mg ha^{-1} were measured. The following parameters were determined: (1) N, P and K content and uptake by plant (straw and grains). (2) Grain protein content was calculated by multiplying grain N content by 5.83 (Baker, 1979). (3) Grain protein yield in kg ha^{-1} {protein content g kg^{-1} x grain yield Mg ha^{-1}}. (4) Harvest index % by {grain yield / grains + straw yield) x 100}. (5) Nitrogen harvest index (NHI) = Grain nitrogen uptake / Total nitrogen uptake (after, Nyborg *et al.,* 1995).

Methods of Analysis

Macronutrients content in plant were determined in aliquots of digested solutions resulting from the digestion of grains and straw samples by a mixture of concentrated sulphuric and perchloric acids after drying in an oven at 70° C as described by Ryan *et al.* (1996).

RESULTS AND DISCUSSION

Effect of treatments on growth parameters and yield of barley

Growth parameters

Table 1 reveals that the growth parameters of number of spikes m^{-2}, grain weight $spike^{-1}$ and 1000-grain weight significantly increased due to gamma irradiation, N fertilization and biofertilization solely or in combinations. Farag and El-Khawaga (2013) reported that gamma irradiation of sesame and N-application increased the 1000-seed weight. Namvar and Khandan (2013) reported that number of spikes *per* m^2, number of grain *per* spike and the 1000-grain weight of wheat increased significantly by N-fertilization and biofertilizer inoculation. These results are in agreement with those of Sary *et al.* (2009) and Kandil *et al.* (2011). There was no significant difference between the two gamma irradiation doses of 20 and 40 Gy for all parameters. As for N effect, there was the following descending order: N238 > N298 > N179 > N0 for grain weight $spike^{-1}$ and 1000-grain weight. As for the number of spikes *per* m^2, the order was N238 > N179 > N298 > N0. Regarding the response to biofertilization, the main effect followed a descending of: Cerealin + Microbin > Microbin > Cerealin > none for number of spikes *per* m^2 and 1000-grain weight; the order for grain weight *per* spike was: Cerealin + Microbin > Cerealin > Microbin > none.

The highest increase in number of spikes *per* m^2 (198%) and grain weight *per* spike (173%) were recorded in plants treated with N238 + (Cerealin+ Microbin) irradiated with gamma dose 40Gy. The treatment of N238 + (Cerealin+ Microbin) irradiated with 20Gy gamma irradiation caused highest increase in 1000-grain weight (104%).

Straw and grain yields

The data of straw and grain yield of barley plants are presented in Table 2. The obtained results exhibited significant increases due to application of N, biofertilization, irradiation and their combinations compared to the non-treated plants. Low doses of gamma rays increase enzymatic activation, which result in stimulating cell division, and affects germination, and vegetative growth **(**Ashri, 2007). The favorable effect of nitrogen fertilizer may be due to N stimulation of plant growth, which would increase the amount of light energy intercepted by leaves and increase photosynthetic pigments and photosynthesis, and in turn increase synthesized metabolites and consequently leaves and seeds (Wortman *et al.,* 2011). Growth promoting substances (phytohormones) which would be produced by these organisms play a key role in plant growth and promote seed germination and root elongation. Root development and proliferation of plants in response to biofertilizer activities enhance water and nutrients uptake (Kandil *et al.,* 2011) and Joshi *et al.,* 2012). These results agree with those obtained by, Siam *et al.* (2013) and Piccinin *et al.* (2013).

Table1: Yield components of barley as affected by gamma irradiation, biofertilizers and N rates

N-Rate (N) kg N ha^{-1}	Biofertilizer (B)	Gamma irradiation dose, Gy (G)											
		0	20	40	Mean	0	20	40	Mean	0	20	40	Mean
		Number of spikes (m^2)				Grain weight spike^{-1} (g)				1000-grain weight (g)			
N0	Without	157	234	276	222	0.83	0.97	1.04	0.94	32.8	33.7	34.6	33.7
	Cerealin	281	299	303	294	0.90	1.00	0.97	0.96	33.9	36.5	37.0	35.8
	Microbin	310	320	324	318	1.00	1.04	1.08	1.04	35.1	37.2	36.6	36.3
	Cer.+ Mic.	326	338	369	344	1.02	1.12	1.16	1.10	35.9	37.7	37.2	36.9
	Mean	269	298	318	295 d	0.94	1.03	1.06	1.01 d	34.4	36.3	36.3	35.7 d
N179	Without	251	286	289	275	1.07	1.10	1.19	1.12	34.7	36.5	36.2	35.8
	Cerealin	315	339	329	328	1.23	1.36	1.40	1.33	37.8	39.0	39.4	38.7
	Microbin	326	406	378	370	1.47	1.57	1.65	1.56	38.7	39.6	41.7	40.0
	Cer.+ Mic.	331	425	389	382	1.50	1.66	1.587	1.58	38.2	40.5	41.9	40.2
	Mean	306	364	346	339 b	1.32	1.42	1.46	1.40 c	37.4	38.9	39.8	38.7 c
N238	Without	263	288	296	282	1.26	1.48	1.39	1.37	39.5	51.2	44.6	45.1
	Cerealin	331	368	349	349	1.30	1.59	1.70	1.53	41.7	49.0	54.8	48.5
	Microbin	347	429	411	396	1.39	2.02	1.98	1.80	46.5	55.7	60.5	54.2
	Cer.+ Mic.	336	438	468	414	1.57	1.97	2.27	1.94	48.9	66.9	61.9	59.2
	Mean	319	381	381	360 a	1.38	1.76	1.83	1.66 a	44.2	55.69	55.4	51.8 a
N298	Without	259	268	276	268	1.13	1.35	1.29	1.25	36.5	44.4	46.5	42.4
	Cerealin	279	318	336	311	1.36	1.65	1.75	1.59	39.5	47.4	43.6	43.5
	Microbin	341	385	397	374	1.45	1.55	1.60	1.53	44.2	51.4	52.5	49.4
	Cer.+ Mic.	325	379	388	364	1.40	1.48	1.54	1.47	41.3	53.9	52.0	49.1
	Mean	301	338	349	329 c	1.33	1.51	1.55	1.46 b	40.4	49.3	48.6	46.1 b
Grand mean (G)		299 b	345 a	349 a		1.24 b	1.43 a	1.47 a		39.0 b	45.0 a	45.0 a	
F – test		G:	**	N:	**	G:	**	N:	**	G:	**	N:	**
		B:	**	GxN:	**	B:	**	GxN:	**	B:	**	GxN:	**
		GxB:	**	BxN:	**	GxB:	NS	BxN:	**	GxB:	**	BxN:	**
		GxNxB:	**			GxNxB:	NS			GxNxB:	**		

Cer.: Cerealin; Mic.: Microbin; NS: Not significant

Means of biofertilizer

Whitout	262 d	1.17 c	39.2 d
Cerealin	321 c	1.35 b	41.6 c
Microbin	365 b	1.48 a	45.0 b
Cerealin+Microbin	376 a	1.52 a	46.3 a
Grand mean	331	1.38	43.0

Interaction effects of nitrogen fertilization rates and biofertilizer inoculation were significant for yields of straw, grains and grains + straw at all doses of gamma irradiation especially 40Gy which was superior to 20Gy gamma ray. A descending order characterized the effects of N fertilization on straw and grain yield as follows: N298 > N179 > N238 > N0 for straw yield and N238 > N298 > N179 > N0 for grain yield. As for the main effect of biofertilizer inoculation on grain yield; the order was: Cerealin + Microbin > Cerealin > Microbin > without. For straw yield, the main effect shows no significant difference.

The maximum (grains + straw) and grain yields (19.0 and 9.28 Mg ha^{-1}, respectively) were achieved due to application of N238 + (Cerealin + Microbin) when irradiated with 40Gy gamma ray and the corresponding increments over the non-treatment plants were 164 and 176%, respectively. With respect to straw yield, the greatest value (10.2 Mg ha^{-1}) was observed due to addition of N179 + (Cerealin + Microbin) with 40Gy gamma ray irradiation giving increases of 166% over the non-treated.

Table2: Grains and straw yield (Mg ha^{-1}) as well as harvest index (%) of barley as affected by gamma irradiation, biofertilizers and N rates

N-Rate (N) kg N ha^{-1}	Biofertilizer (B)	Gamma irradiation dose, Gy (G)											
		0	20	40	Mean	0	20	40	Mean	0	20	40	Mean
		(Grains + straw) yield (Mg ha^{-1})				Straw yield (Mg ha^{-1})				Grains yield (Mg ha^{-1})			
N0	Without	1.28	5.76	5.28	4.11	0.96	3.04	2.88	2.29	0.32	2.72	2.40	1.81
	Cerealin	1.76	7.04	8.00	5.60	1.04	3.84	4.48	3.12	0.72	3.20	3.52	2.48
	Microbin	1.84	8.00	7.84	5.89	1.12	4.48	4.64	3.41	0.72	3.52	3.20	2.48
	Cer.+ Mic.	1.44	6.08	7.20	4.91	1.04	3.36	3.84	2.75	0.40	2.72	3.36	2.16
	Mean	1.58	6.72	7.08	5.13 c	1.04	3.68	3.96	2.89 d	0.54	3.04	3.12	2.23 c
N179	Without	6.56	7.52	16.8	10.3	3.68	4.48	8.80	5.65	2.88	3.04	8.00	4.64
	Cerealin	7.20	10.1	18.6	12.0	3.68	5.92	9.92	6.51	3.52	4.16	8.64	5.44
	Microbin	9.92	9.44	18.9	12.8	5.92	4.80	10.1	6.93	4.00	4.64	8.80	5.81
	Cer.+ Mic.	7.52	11.7	18.5	12.5	3.84	4.64	10.2	6.24	3.68	7.04	8.32	6.35
	Mean	7.80	9.69	18.2	11.9 b	4.28	4.96	9.76	6.33 b	3.52	4.72	8.44	5.56 b
N238	Without	8.96	6.40	11.2	8.85	5.12	2.88	6.72	4.91	3.84	3.52	4.48	3.95
	Cerealin	10.2	9.92	16.8	12.3	5.44	3.20	8.80	5.81	4.80	6.72	8.00	6.51
	Microbin	9.28	11.4	15.4	12.0	5.12	5.28	7.68	6.03	4.16	6.08	7.68	5.97
	Cer.+ Mic.	9.12	13.4	19.0	13.9	5.60	5.92	9.76	7.09	3.52	7.52	9.28	6.77
	Mean	9.39	10.3	15.6	11.8 b	5.32	4.32	8.24	5.96 c	4.08	5.96	7.36	5.80 a
N298	Without	7.68	10.7	12.8	10.4	4.64	5.60	6.72	5.65	3.04	5.12	6.08	4.75
	Cerealin	9.44	14.4	16.2	13.3	6.08	8.16	7.84	7.36	3.36	6.24	8.32	5.97
	Microbin	9.76	12.3	15.8	12.6	6.40	7.36	7.68	7.15	3.36	4.96	8.16	5.49
	Cer.+Mic.	12.0	14.9	14.7	13.9	6.08	8.00	8.32	7.47	5.92	6.88	6.40	6.40
	Mean	9.72	13.1	14.9	12.6 a	5.80	7.28	7.64	6.91 a	3.92	5.80	7.24	5.65 ab
Grand means (G)		7.12 c	9.94 b	13.9 a		4.11 c	5.06 b	7.40 a		3.02 c	4.88 b	6.54 a	
F - test		G:	**	N:	**	G:	**	N:	**	G:	**	N:	**
		B:	**	GxN:	**	B:	**	GxN:	**	B:	**	GxN:	**
		GxB:	**	BxN:	**	GxB.:	**	BxN:	**	GxB.:	**	BxN:	**
		GxNxB: **				GxNxB: **				GxNxB: **			
						Means of biofertilizer							
Whitout				8.41 c				4.63 b				3.79 d	
Cerealin				10.8 b				5.88 a				5.10 b	
Microbin				10.8 c				5.71 a				4.94 c	
Cerealin+Microbin				11.3 a				5.87 a				5.42 a	
Grand mean				10.3				5.52				4.81	

Harvest index

Values of harvest index as affected by gamma irradiation, N fertilization and biofertilizer inoculation whether applied solely or in combinations are shown in Table 3. Grain harvest index, varied between 25.0 % to 67.7%. The plants treated with N238 + Cerealin under gamma irradiation dose of 20Gy gave the highest value while those of the non-treated gave the lowest value.

Gamma irradiation increased the harvest index. Difference between the 20 and 40Gy were an average not significant. As for the N rates, the main effect followed the order: N238 > N179 > N298 > N0. Main effect of biofertilizers shows a slight increase over the non-biofertilized with no significant differences between Cerealin and Cerealin + Microbin or between Microbin and the non-biofertilized.

Grain protein content and grain protein yield

It can be seen from results presented in Table 3 that the protein content of barley grains significantly increased owing to application of gamma irradiation, N fertilization and biofertilizers inoculation. Siam, *et al.* (2013) pointed out that protein content in wheat grain increased with high rates of mineral N fertilizer up to 238 kg N ha^{-1}. Rahimi and Abdallah (2011) stated that gamma irradiation increased protein content of wheat grain and that 25 and 50Gy gamma irradiation produced the highest grain protein content. Namvar and Khandan (2013) reported that inoculation with *Azotobacter sp.* and *Azospirillium sp*. increased wheat grains protein content by 10%. The current results are in agreement with those reported by Abedi *et al.* (2010) and Rana *et al.* (2012). The main effect of irradiation shows increases and that the 20Gy dose was superior to the 40Gy dose. As for N fertilization, the main effect shows increases and that there were significant differences among the N rates; application of N238 was not different from the N298 treatment in majority of protein content. A descending order characterized the effects of biofertilization on protein content and is as follows: (Cerealin + Microbin) > Cerealin ≥ Microbin > non-biofertilized.

The highest increase in protein content (71%) was recorded in the plants treated with N298 + (Cerealin + Microbin) + 20Gy. The second highest (66%) was in plants of N238 + Cerealin + 20Gy.

Regarding the grain protein yield, results followed a trend rather similar to that of protein content.

The increase in protein yield could be attributed to the integrated effect of nitrogen plus bio effect of microorganisms such as N_2 fixing bacteria and P-dissolving bacteria increasing available nutrients for plant growth and accordingly maximizing the biological yield and grain quality of barley (Ewees and abdel Hafeez, 2010). Also, exudation of plant growth regulators such as auxins, gibberellin and cytokinin by *Azotobacter sp.* and *Azospirillium sp*. bacteria (Vessy, 2003) contribute to such positive effect. The maximum protein yield of (1117 kg ha^{-1}) was achieved due to N238 + Cerealin + Microbin with 40Gy gamma irradiation.

Results given in Table 4 reflected significant increases in the N concentration and uptake as affected by application of the treatments for straw and grain. The highest N content in straw and grain (11.85 and 24.9 g kg^{-1}, respectively) were produced by plants supplied by N298 + (Cerealin + Microbin) in combination with 20Gr gamma irradiation.

Table 3: Harvest index (%), grain protein content (g kg^{-1}) and grain protein yield (kg ha^{-1}) of barley as affected by gamma irradiation, biofertilizers and N rates

N-Rate (N) kg N ha^{-1}	Biofertilizer (B)	Gamma irradiation dose, Gy (G)											
		0	20	40	Mean	0	20	40	Mean	0	20	40	Mean
		Harvest index (%)				Grain protein content (g kg^{-1})				Grain protein yield (kg ha^{-1})			
N0	Without	25.0	47.2	45.5	39.2	85	98	92	91	27	265	219	170
	Cerealin	40.9	45.5	44.0	43.5	97	106	99	101	70	337	346	251
	Microbin	39.1	44.0	40.8	41.3	102	110	105	106	74	386	334	265
	Cer.+ Mic.	27.8	44.7	46.7	39.7	104	114	107	108	42	310	358	237
	Mean	33.2	45.4	44.2	40.9 d	97	107	100	101 c	53	325	314	231 c
N179	Without	43.9	40.4	47.6	44.0	92	102	95	96	265	310	760	445
	Cerealin	48.9	41.2	46.5	45.5	102	105	99	102	359	436	856	550
	Microbin	40.3	49.2	46.6	45.3	104	113	108	108	417	524	951	631
	Cer.+ Mic.	48.9	60.2	45.0	51.4	110	115	111	112	404	813	918	712
	Mean	45.5	47.7	46.4	46.5 b	102	109	103	105 b	361	521	871	584 b
N238	Without	42.9	55.0	40.0	46.0	104	107	105	105	399	374	471	415
	Cerealin	47.1	67.7	47.6	54.1	110	141	124	125	527	946	994	822
	Microbin	44.8	53.3	49.9	49.3	121	130	122	124	500	790	939	743
	Cer.+ Mic.	38.6	56.1	48.8	47.9	115	138	120	125	406	1038	1117	854
	Mean	43.3	58.0	46.6	49.3 a	112	129	118	120 a	458	787	880	708 a
N298	Without	39.6	47.9	47.5	45.0	100	105	103	103	306	537	626	490
	Cerealin	35.6	43.3	51.4	43.4	113	132	126	124	378	825	1049	751
	Microbin	34.4	40.3	51.6	42.1	114	136	115	122	381	675	942	666
	Cer.+Mic.	49.3	46.2	43.5	46.3	110	145	120	125	646	994	768	803
	Mean	39.7	44.4	48.5	44.2 c	109	130	116	118 a	428	758	846	677 a
Grand mean (G)		40.4 b	48.9 a	46.5 a		105 c	119 a	109 b		325 c	598 b	728 a	
F - test		G: **		N: **		G: **		N: **		G: **		N: **	
		B: **		GxN: **		B **		GxN: **		B: **		GxN: **	
		GxB: **		BxN: **		GxB: **		BxN: **		GxB: **		BxN: **	
		GxNxB: **				GxNxB: **				GxNxB: **			

Harvest index % = (grain yield / grains + straw yield) x 100

Means of biofertilizer			
Whitout	43.6 b	99 c	380 c
Cerealin	46.6 a	113 b	594 b
Microbin	44.5 b	115 b	576 b
Cerealin+Microbin	46.3 a	118 a	651 a
Grand mean	45.3	111	550

4

Nitrogen content and uptake

This indicates that the addition of mineral N at high rate in presence of Cerealin and Microbin has more availability and solubility for plant and increases the ability of plant roots to uptake more elements in plant tissues by increasing the levels of nutrients in rooting zone (Hassan *et al.,* 2009).

The main effects of gamma irradiation, N-fertilization and biofertilization show the following: 40Gy > 20Gy; N238 ≥ N298 > N179 > N0 and (Cerealin + Microbin) > Cerealin ≥ Microbin >without.

Highest N uptake by straw (110 kg ha^{-1}) was obtained under applied treatment N179 + Cerealin with 40Gy gamma ray which caused an increase of 244%, while the highest N uptake by grain (191 kg ha^{-1}) was recorded in the plants treated with N238 + (Cerealin + Microbin) with 40 Gy gamma ray representing an increase of 208%.

Efficiency of applied N

Efficiency of the applied nitrogen for the different bio and irradiation treatments were calculated and the results are shown in Table 5.

Table 5: Nitrogen harvest index, NHI (kg kg^{-1}) as affected by gamma irradiation, biofertilizers and N rates

N-Rate (N) kg N ha^{-1}	Biofertilizer (B)	Gamma irradiation dose, Gy (G)			
		0	20	40	Mean
N0	Without	0.41	0.66	0.69	0.59
	Cerealin	0.60	0.64	0.65	0.63
	Microbin	0.58	0.62	0.62	0.60
	Cer.+ Mic.	0.43	0.65	0.66	0.58
	Mean	0.51	0.64	0.65	0.60 c
N179	Without	0.60	0.61	0.61	0.60
	Cerealin	0.62	0.60	0.57	0.60
	Microbin	0.56	0.68	0.63	0.62
	Cer.+ Mic.	0.67	0.78	0.64	0.69
	Mean	0.61	0.67	0.61	0.63 b
N238	Without	0.60	0.70	0.59	0.63
	Cerealin	0.64	0.82	0.67	0.71
	Microbin	0.65	0.72	0.70	0.69
	Cer.+ Mic.	0.55	0.75	0.67	0.66
	Mean	0.61	0.75	0.66	0.67 a
N298	Without	0.58	0.65	0.68	0.63
	Cerealin	0.54	0.62	0.73	0.63
	Microbin	0.54	0.64	0.72	0.63
	Cer.+ Mic.	0.63	0.64	0.63	0.63
	Mean	0.57	0.64	0.69	0.63 b
Grand mean (G)		0.57 b	0.67 a	0.65 a	
F – test		G:	**	N:	**
		B:	**	GxN:	**
		GxB.:	*	BxN:	**
		GxNxB:	**		

Means of biofertilizer	
Whitout	0.61 b
Cerealin	0.64 a
Microbin	0.64 a
Cerealin+Microbin	0.64 a
Grand mean	0.63

Nitrogen harvest index, (NHI)

NHI which is the N uptake in grains in relation to the N-uptake in grains + straw followed a trend of increase up to N238 followed by a decrease at N298. The main effects of gamma irradiation, N rates and biofertilizer treatments showed a descending increase in the order: 20Gy ≥ 40Gy; N238 ≥ N298 = N179 > N0; Cerealin ≥ Cerealin + Microbin ≥ Microbin ≥ without. Alves *et al.,* (2003) found no significant effect of N applications or bio inoculation on NHI values for soybeans. The lowest value of NHI (0.41 kg kg^{-1}) was recorded for the untreated plants. Low NHI indicates low N translocation from shoots to grains and this might be because of the high N requirements of barley plants inoculated with Cerealin that received 238 kg N ha^{-1} and irradiated with 20Gr gamma ray recorded the highest NHI value (0.82 kg kg^{-1}) indicating 36.7% increase compared with the same treatment which received N179 and this indicates high translocation of N from shoots to grains.

Response curve

Fig. 1 presents the response of barley grain yield to nitrogen fertilization under three levels of gamma irradiation (A) and Biofertilization (B). As seen in the Fig.1 (A), the grain yield increased with increasing N rate up to 238 kg N ha^{-1} with 0Gy irradiation and 20Gy gamma ray irradiated and then decreased gradually. Under 40Gy irradiation, it increased with increasing N rate up to 179 kg N ha^{-1} then decreased the rate of increase with 40Gy gamma ray in combination with nitrogen rates was higher than the other irradiation of 20Gy gamma ray.

The biofertilization increased grain yield when N was increased up to N238 and then decreased. The rate of increase in grain yield for the Cerealin + Microbin with N rates application was higher than the other bio treatments.

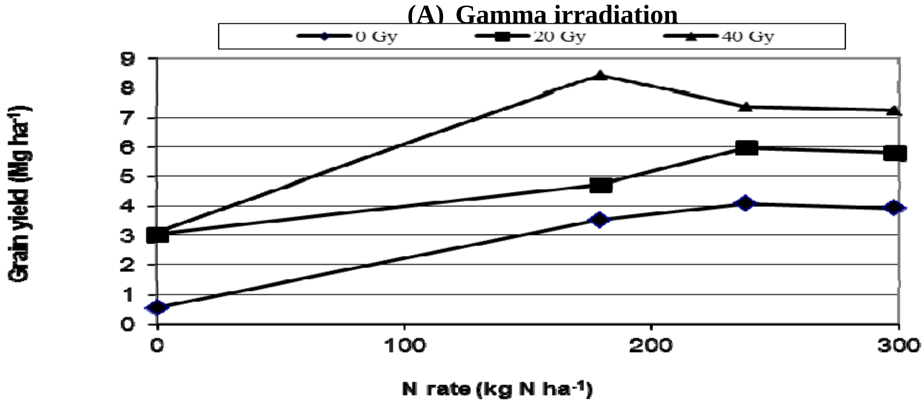
Phosphorus uptake

Phosphorus content and uptake by barley straw and grain increased significantly as a result of N application, biofertilization and irradiation (Table 6) singly or in combinations. The positive effect of biofertilization is due to increased availability of P (Metwally, 2000). These findings are in agreement with those reported by El-Sebaey (2006) and Ibrahim *et al.* (2008).

The main effects of gamma irradiation, N application and biofertilization showed a descending increase for P uptake by grains in the order: 40Gy > 20Gy; N238 ≥ N179 ≥ N298 > N0 and Cerealin + Microbin > Microbin ≥ Cerealin > without.

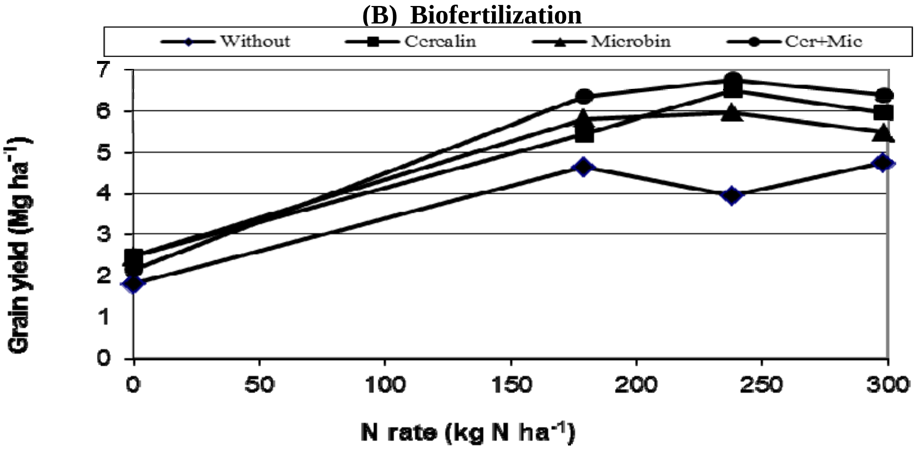
The highest P contents of 2.35 and 6.87 g kg^{-1} in straw and grains, respectively were observed due to N238 + Microbin with 20Gy gamma ray and N179 + Cerealin irradiated with 40Gy gamma ray, respectively. The highest P uptake values for straw and grains (15.71 and 59.16 kg ha^{-1}, respectively) were obtained in plants treated with N238 + (Cerealin + Microbin) with 40Gy gamma ray and N179 + Cerealin with 40Gy gamma ray, respectively.

(A) Gamma irradiation



Grain yield (0 Gy gamma ray) = $0.53 + 0.256x - 4.731x^2$ $R^2 = 0.997$
Grain yield (20 Gy gamma ray) = $3.01 + 0.013x - 1.042x^2$ $R^2 = 0.944$
Grain yield (40 Gy gamma ray) = $3.16 + 0.049x - 0.0001x^2$ $R^2 = 0.965$

(B) Biofertilization



Grain yield (Without bio) = $1.85 + 0.020x - 3.76x^2$ $R^2 = 0.906$
Grain yield (Cerealin) = $2.45 + 0.027x - 4.94x^2$ $R^2 = 0.972$
Grain yield (Microbin) = $2.48 + 0.031x - 7.23x^2$ $R^2 = 0.999$
Grain yield (Cer. + Mic.) = $2.16 + 0.038x - 7.92x^2$ $R^2 = 0.999$

Fig.1:Response of grain yield (kg ha^{-1}) of barley to nitrogen rates as affected by gamma irradiation doses (a) and biofertilization (b)

Potassium uptake

As shown in Table 7, K content and uptake in straw and grains followed a rather similar as trend of that for N and increased significantly owing to application of gamma irradiation, nitrogen application and biofertilization. As for the effect of irradiation with gamma ray, the mail effect shows 40 Gy > 20Gy gamma ray. The main effect of biofertilization shows: Microbin + Cerealin > Microbin > Cerealin > without biofertilization. The Main effect of N shows the order: N238 ≥ N179 ≥ N298 > N0 for K content in straw; N179 > N298 ≥ N238 > N0 for K content in grains; N298 > N179 > N238 >N0 for K uptake by straw. The pattern concerning response of K-uptake in grains is N179 ≥ N298 ≥ N238 > N0.

The maximum values of K uptake by straw and grain (62.87 and 35.06 kg ha^{-1}, respectively) were obtained due N238 + (Cerealin + Microbin) with 40Gy gamma ray for straw and N179 + Microbin irradiated with 40Gy gamma ray, for grains. Increases were 173% and 213%, respectively over the non-treated.

7

2

CONCLUSION

The nitrogen rate of 238 kg N ha^{-1} when applied in combination with biofertilizers for plants irradiated with 20 or 40Gy gamma ray was superior to the other rates for enhancing barley yield and nutrient uptake. Biofertilization using N_2-fixing bacteria with or without P-dissolving bacteria could reduce requirements of chemical N-fertilizer with no toxic substances accumulating in the food chain. Reducing chemical fertilizer play a great role to protect environment from chemical pollution.

REFERENCES

Abedi, T., Alemzadeh, A. and Kazemeini, S.A. (2010). Effect of organic and inorganic fertilizers on grain yield and protein banding pattern of wheat. Australian J. Crop Sci., 4(6): 384–389.

Alves, B.J.R., Boddey, R.M. and Urquiaga, S. (2003). The success of BNF in soybean in Brazil. Plant and Soil, 252: 1 – 9.

Artik, C. and Peksen, E. (2006). The effects of gamma irradiation on seed yield and some plant characteristics of faba bean (*Vicia faba* L.) in M2 generation. (Turkish) Ondokuz Mays Universties, Ziraat Fakultesi Dergisi, 21(2): 195 – 203.

Ashri, A. (2007). Sesame (*Sesamum indicum* L.). In: R.J. Singh, Ed, Genetics resources chromosome engineering, and crop improvement. Oilseed Crops: 231 – 289, CRC Press, Boca Raton, Fl, USA.

Baker, D. (1979). Report on cereal foods. J. Assoc. of Anal. Chem. 62: 369 – 370.

Black,C.A., Evans, D.D., White, I.I. Ensminger, L.E. and Clark, F.E. (1982). “Methods of soil analysis”. Amer. Soc. Agron. Inc., Ser. 9 in Agron., Madison , Wisconsin.

Campuzano, G.E., Slafer, G.A. and Miralles, D.J. (2012). Differences in yield, biomass and their components between triticale and wheat grown under contrasting water and nitrogen environments. Field Crops Res., 128: 167–179.

Daneshmand, N.G., Bakhshandeh, A. and Rostami, M.R. (2012). Biofertilizer affects yield and yield components of wheat. Inter. J. Agric., 2(6): 699–704.

Diacono, M., Rubino, P. and Montemurro, F. (2013). Precision nitrogen management of wheat; a review. Agronomy for Sustainable Development, 33(1): 219–241

El-Kramany, M.F., Ahmed, M.K.A., Bahr, A.A. and Kabesh, M.O. (2000). Utilization of biofertilizers in field crop production. 13- Effect of organic manuring, chemical and biofertilizers on yield and nutrient content of sesame grown in newly reclaimed soil. Egypt. J. Appl. Sci., 15(11): 137 – 155.

El-Sebaey, M.M. (2006). Effect of inorganic, organic and bio-fertilizer on wheat plant grown in new cultivated land. Zagazig J. Agric. Res., 33(5): 863 – 876.

Ewees, M.S.A. and Abdel Hafeez, A.A.A. (2010). Response of Maize grain to a partial substitution of N-mineral by applying organic manure, bio-inoculation and elemental sulphur as an alternative strategy to avoid the possible chemical pollution. Egypt. J. Soil Sci., 50(1): 141 – 166.

FAO (2012). “Food and Agric. Organization” of the United Nations Statistical. Statistical Year Book.

Farag, I.A.A. and El-Khawaga, A.A.H. (2013). Response of sesame to gamma irradiation and nitrogen fertilizer levels on newly reclaimed sandy soils. Zagazig J. Agric. Res., 39(6): 1083 – 1092.

Hassan, M.A., El-Tohamy, M.A. and Ali, A.A. (2009). Effect of manure, rock phosphate and Microbein bio-fertilizer as partial substitutes for mineral fertilizers on onion grown on a sandy soil. Egypt J. Soil Sci., 49(2): 295 – 310.

Jackson, M.L. (1958). “Soil Chemical Analysis” .Prentice - Hall, Inc., Englewood Califfs, New Jersy .

Joshi, R.A., Prasanna, R., Shivay, Y.S. and Nain, L. (2012). Biofortification of wheat through inoculation of plant growth promoting rhizobacteria and cyanobacteria. Euro. J. Soil Biology, 50: 118 – 126.

Jyoti, P.M., Sukalyan, C.S.K., Subrata, P., Jiin-Shuh, J., Alok, C., Anindita, C. and Subhas, C.S. (2009). Effects of gamma irradiation on edible seed protein, amino acids and genomic DNA during sterilization. Food Chem., 114: 1237 – 1244.

Ibrahim, A.M., Mostafa, M.M., El-Garhi, A.I. and Youssef, N.N. (2008) Macronutrients uptake by maize plant and their availability in the soil as affected by organic fertilization under different sources and levels of nitrogen. Zagazig J. Agric. Res., 35(5): 1127 – 1142.

Kandil, A.A., El-Hindi, M.H., Badawi, M.A., El Morarsy S.A. and Kalboush, F.A.H.M. (2011). Response of wheat to rates of nitrogen, biofertilizers and land leveling. Crop & Enviro. 2(1): 46–51.

Kiong, A., Ling Pick A., Grace, S.H., and Harun, A.R. (2008). Physiological responses of *Orthosiphon stamineus* plants to gamma irradiation. Am. Eurasian J. Sustain. Agric., 2(2): 135 – 149.

Kizilkaya, R. (2008). Yield response and nitrogen concentrations of spring wheat (*Triticum aestivum* L.) inoculated with *Azotobacter chroococcum* strains. Ecological Engineering, 33(2): 150–156.

Kovacs, E. and Keresztes, A. (2002). Effect of gamma irradiation and UV-B/C radiation on plant cell. Micron., 33: 199 – 210.

Liu, D. and Shi, Y. (2013). Effects of different nitrogen fertilizer on quality and yield in winter wheat. Advanced J. Food Sci. Tech., 5(5): 646–649.

Metwally, S.G. (2000). Fertilizer use efficiency of wheat as affected by microbial inoculation and soil conditions. Ph.D. Thesis Soils Dept., Fac. Agric., Mansoura Univ.

Namvar, A., Khandan, T. and Shojaei, M. (2012). Effects of bio and chemical nitrogen fertilizer on grain and oil yield of sunflower (*Helianthus annuus* L.) under different rates of plant density. Annals of Biological Research, 3(2): 1125–1131.

Namvar, A. and Khandan, T. (2013). Response of wheat to mineral nitrogen fertilizer and biofertilizer (*Azotobacter sp.* and *Azospirillium sp*.) inoculation under different levels of weed interference. Ekologija, 59(2): 85 – 94.

Nyborg, M., Solberg, E.D., Izaurralde, R.C., Malhi, S.S. and Molina-Ayala, M. (1995). Influence of long term tillage, straw and fertilizer on barley yield, plant N uptake and soil-N balance. Soil & Tillage Res., 36: 165 – 174.

Page, A.L., Miller, R.H. and Keeney, D.R. (1982). Methods of Soil Analysis. Part 2: Chemical and Microbiological Properties, 2^{nd} ed. Agronomy Society of America. Madison, WI.

Piccinin, G.G., Braccini, A.L., Dan, L.G.M., Scapim C.A., Ricci, T.T. and Bazo, G.L. (2013). Efficiency of seed inoculation with *Azospirillum brasilense* on agronomic characteristics and yield of wheat. Industrial Crops and Products, 43:393–397.

Rahimi, M.M. and Abdallah B. (2011). Influence of gamma irradiation on some physiological characteristics and grain protein in wheat (*Triticum aestivum* L.). World Applied Sci. J., 15 (5): 654 – 659.

Rana, A., Joshi, M., Prasanna, R., Shivay, Y.S. and Nain, L. (2012). Biofertification of wheat through inoculation of plant growth promoting rhizobacteria and cyanobacteria. Euro. J. Soil Biology, 50: 118–126.

Ryan, J., Garabet, S., Harmsen, K. and Rashid, A. (1996). “A soil and plant analysis”. Manual Adapted for the West Asia and North Africa Region. ICARDA, Aleppo, Syria, 140.

Saini, V.K., Bhandari, S.C. and Tarafdar, J.C. (2004). Comparison of crop yield, soil microbial C, N and P, N-fixation, nodulation and mycorrhizal infection in inoculated and non-inoculated sorghum and chickpea crops. Field Crops Res., 89:39 – 47.

Sary, G.A., El-Naggar, H.M., Kabesh, M.O., ElKramany, M.F. and Akhoum, G.Sh.H. (2009). Effect of bio-organic fertilization and some weed control treatments on yield and yield components of wheat. World J. Agri. Sci., 5(1): 55–62.

Siam, H.S., Shaban, Kh.A. and Mahmoud, S.A. (2013). Evaluation of applying different mineral nitrogen sources on soil fertility and wheat productivity under saline conditions. J. Appl. Sci. Res., 9(4): 3146 – 3156.

Snedecor, G.W. and Cochran, W.G. (1971). “Statistical Methods”. 6^{th} edition. Iowa State University Press, Ames. Iowa, U.S.A.

Vessey, J.K. (2003). Plant growth promoting rhizobacteria as biofertilizers. Plant and Soil. 255:571–586.

Wortman, S.E., Davis, A.S., Schutte, B.J. and Lindquist, J.L. (2011). Integrating management of soil nitrogen and weeds. Weed Sci., 59: 162 170.

إستجابة الشعير النامي في الأرض الرملية (*Hordeum vulgare* L.) لتشعيع البذور بأشعة جاما ، التسميد النيتروجيني و الحيوي

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يعد معاملة التقاوي قبل الزراعة بأشعة جاما واحدة من أهم الطرق الفعالة لتحسين انتاجية المحاصيل و مكوناتها وكذلك تركيبها الكيماوي لذلك تم إجراء تجربة حقلية بإستخدام تصميم القطع المنشقة مرتين التامة كاملة العشوائية والمحتوية علي ثلاث مكررات وذلك بمحطة البحوث الخاصة بكلية الزراعة جامعة الزقازيق بمنطقة الخطارة –محافظة الشرقية خلال الموسم الشتوي ٢٠١٠/٢٠٠٩ م. تم توزيع حبوب الشعير المعاملة بجرعات التشعيع بأشعة جاما بثلاث معدلات (٠ ، ٢٠ و ٤٠ جراي) في القطع الرئيسية بينما أشتملت القطع المنشقة الأولي علي معاملات التسميد النيتروجيني بسلفات الأمونيوم من خلال أربع معدلات (٠ ، ١١٩ ، ٢٣٨ و ٢٩٨ كيلو جرام ن الهكتار-١) و القطع المنشقة الثانية عوملت بأربع معاملات للتسميد الحيوي (بدون ، السريالين ، الميكروبين و السريالين + الميكروبين) وقد أوضحت النتائج المتحصل عليها ما يلي:- أزداد محصول الشعير ومكوناتة و كذلك محتوي القش و الحبوب من النيتروجين و الفسفور و البوتاسيوم معنوياً نتيجة المعاملة بأشعة جاما ، التسميد النيتروجيني بمعدلاته و التسميد الحيوي. إزداد معنوياً عدد السنابل للمتر المربع ، وزن الحبوب للسنبلة ، المحصول البيولوجي ، محصول الحبوب ، النيتروجين الممتص للحبوب ، الفسفور الممتص للقش و البوتاسيوم الممتص للقش وأعطت جميعها أعلي قيم نتيجة للمعاملة ن ٢٣٨ + (السريالين + الميكروبين) مع معاملة التشعيع الجامي بجرعة ٤٠ جراي. أعلي محصول للقش تم الحصول عليه نتيجة المعاملة ن ١٧٩ + (السريالين + الميكروبين) مع معاملة التشعيع الجامي بجرعة ٤٠ جراي. أعطت المعاملة ن ١٧٩ + السريالين مع معاملة التشعيع الجامي بجرعة ٤٠ جراي أقصي محتوي للنيتروجين الممتص بالقش ، محتوي الفسفور للقش و الحبوب و كذلك محتوي الفسفور الممتص للحبوب. أنخفضت كفاءة النيتروجين المستخدم بزيادة معدلات النيتروجين المضافة وأعطي المعدل المنخفض ن ١٧٩ في وجود الميكروبين مع معاملة التشعيع الجامي بجرعة ٤٠ جراي. إزداد محتوي البروتين ومحصوله معنوياً نتيجة للمعاملات المختلفة المستخدمة بالدراسة خاصة مع زيادة معدلات النيتروجين حتي ٢٩٨ كجم ن الهكتار-١ و التي أعطت أقصي محتوي للبروتين بالإشتراك مع الميكروبين و التشعيع الجامي ٤٠ جراي. من النتائج المتحصل عليها يوصي بأستخدام التسميد النيتروجيني بمعدل ٢٣٨ كجم ن للهكتار في وجود التسميد الحيوي مع تشعيع البذور قبل الزراعة بجرعات ٢٠ أو ٤٠ جراي حيث كانت الأفضل بالمقارنة بباقي المعاملات وأدت لتحسين أنتاجية وأمتصاص العناصر الغذائية بواسطة الشعير.

قام بتحكيم البحث

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Table 4: N content (g kg^{-1}) and N-uptake (kg ha^{-1}) by barley as affected by gamma irradiation, biofertilizers and N rates

N-Rate (N) kg N ha^{-1}	Biofertilizer (B)	Gamma irradiation dose, Gy (G)															
		0	20	40	Mean	0	20	40	Mean	0	20	40	Mean	0	20	40	Mean
		N-content (g kg^{-1})				N-uptake (kg ha^{-1})				N-content (g kg^{-1})				N-uptake (kg ha^{-1})			
		Straw								Grain							
N0	Without	7.10	7.70	5.90	6.90	6.82	23.4	17.0	15.7	14.5	16.8	15.7	15.7	4.64	45.7	37.7	29.3
	Cerealin	7.70	8.30	7.10	7.70	8.01	31.9	31.8	23.9	16.7	18.2	16.9	17.3	12.0	58.2	59.5	43.3
	Microbin	8.30	8.90	7.70	8.30	9.30	39.9	35.7	28.3	17.5	18.8	18.0	18.1	12.6	66.2	57.6	45.5
	Cer.+ Mic.	8.90	8.55	8.30	8.58	9.26	28.7	31.9	23.3	17.8	19.5	18.3	18.5	7.12	53.0	61.5	40.5
	Mean	8.00	8.36	7.25	7.87 c	8.34	31.0	29.1	22.8 c	16.6	18.3	17.2	17.4 c	9.10	55.8	54.1	39.6 c
N179	Without	8.30	7.70	9.45	8.48	30.5	34.5	83.2	49.4	15.8	17.5	16.3	16.5	45.5	53.2	130	76.4
	Cerealin	10.1	8.30	11.1	9.82	37.2	49.1	110.1	65.5	17.5	18.0	17.0	17.5	61.6	74.9	147	94.5
	Microbin	9.45	8.90	9.55	9.30	55.9	42.7	96.5	65.0	17.9	19.4	18.5	18.6	71.6	90.0	163	108
	Cer.+ Mic.	9.00	8.60	8.90	8.83	34.6	39.9	90.8	55.1	18.8	19.8	19.0	19.2	69.2	139	158	122
	Mean	9.20	8.38	9.75	9.11 b	39.6	41.6	95.1	58.7 b	17.5	18.7	17.7	17.9 b	62.0	89.4	150	100 b
N238	Without	8.90	9.45	8.30	8.88	45.6	27.2	55.8	42.9	17.8	18.3	18.0	18.0	68.4	64.4	80.6	71.1
	Cerealin	9.45	11.3	9.45	10.1	51.4	36.2	83.2	56.9	18.8	24.1	21.3	21.4	90.2	162	170	141
	Microbin	9.00	10.1	8.90	9.32	46.1	53.3	68.4	55.9	20.7	22.3	21.0	21.3	86.1	136	161	128
	Cer.+ Mic.	10.1	9.95	9.45	9.82	56.6	58.9	92.2	69.2	19.8	23.7	20.6	21.4	69.7	178	191	146
	Mean	9.35	10.2	9.03	9.52 a	49.9	43.9	74.9	56.2 b	19.3	22.1	20.2	20.5 a	78.6	135	151	122 a
N298	Without	8.30	8.90	7.70	8.30	38.5	49.8	51.7	46.7	17.2	18.0	17.6	17.6	52.3	92.2	107	83.8
	Cerealin	8.90	10.7	8.30	9.28	54.1	87.3	65.1	68.8	19.3	22.7	21.6	21.2	64.8	142	180	129
	Microbin	8.55	9.00	8.30	8.62	54.7	66.2	63.7	61.6	19.5	23.3	19.8	20.9	65.5	116	162	114
	Cer.+ Mic.	10.7	11.9	9.45	10.65	65.1	95.2	78.6	79.6	18.8	24.9	20.6	21.4	111	171	132	138
	Mean	9.10	10.1	8.44	9.21 b	53.1	74.6	64.8	64.2 a	18.7	22.2	19.9	20.3 a	73.5	130	145	116 a
Grand means		8.91 b	9.24 a	8.63 c		37.7 c	47.8 b	66.0 a		18.0 c	20.3 a	18.8 b		56.0 c	103 b	125 a	
F - test		G:	**	N:	**	G:	**	N:	**	G:	**	N:	**	G:	**	N:	**
		B:	**	GxN:	**	B:	**	GxN:	**	B:	**	GxN:	*	B:	**	GxN:	**
		GxB.:	NS	BxN:	**	GxB.:	**	BxN:	**	GxB.:	**	BxN:	**	GxB.:	**	BxN:	**
		GxNxB: **				GxNxB: **				GxNxB: **				GxNxB: **			

Means of biofertilizer				
Whitout	8.15 d	38.7 c	1.70 c	65.2 c
Cerealin	9.20 b	53.8 ab	1.93 a	102 b
Microbin	8.85 c	52.7 b	1.97 b	98.9 b
Cerealin+Microbin	9.45 a	56.8 a	2.01 a	114 a
Grand mean	8.91	50.5	1.90	95.0

Table 6. P-content (g kg^{-1}) and P-uptake (kg ha^{-1}) by barley as affected by gamma irradiation, biofertilizers and N rates

N-Rate (N) kg N ha^{-1}	Biofertilizer (B)	Gamma irradiation dose, Gy (G)															
		0	20	40	Mean	0	20	40	Mean	0	20	40	Mean	0	20	40	Mean
		P-content (g kg^{-1})				P-uptake (kg ha^{-1})				P-content (g kg^{-1})				P-uptake (kg ha^{-1})			
		Straw								Grain							
N0	Without	0.06	0.46	0.22	0.25	0.07	1.41	0.62	0.70	4.15	4.43	4.36	4.32	1.33	12.1	10.6	7.99
	Cerealin	0.11	0.86	0.56	0.51	0.12	3.31	2.49	1.97	4.32	4.68	5.39	4.79	3.11	15.0	18.9	12.3
	Microbin	0.26	0.98	0.64	0.63	0.29	4.37	2.95	2.54	4.43	5.90	6.66	5.66	3.19	20.8	21.4	15.1
	Cer.+ Mic.	0.16	0.88	0.61	0.55	0.16	2.94	2.36	1.82	4.49	6.00	6.75	5.74	1.80	16.3	22.8	13.6
	Mean	0.15	0.79	0.51	0.48 d	0.16	3.01	2.10	1.76 d	4.35	5.25	5.79	5.13 b	2.36	16.0	18.4	12.3 a
N179	Without	0.07	0.875	0.79	0.58	0.27	3.92	6.91	3.70	4.25	4.43	5.30	4.66	12.2	13.5	42.5	22.7
	Cerealin	0.14	1.329	1.16	0.88	0.50	7.89	11.6	6.65	5.30	5.90	6.86	6.02	18.7	24.6	59.2	34.1
	Microbin	0.22	1.991	1.39	1.20	1.33	9.56	14.1	8.31	5.59	6.12	6.52	6.08	22.4	28.4	57.4	36.0
	Cer.+ Mic.	0.19	1.865	1.32	1.12	0.71	8.69	13.5	7.64	5.65	6.24	5.58	5.82	20.8	43.9	46.6	37.1
	Mean	0.16	1.52	1.17	0.95 c	0.70	7.52	11.5	6.58 c	5.20	5.67	6.06	5.64 a	18.5	27.6	51.4	32.5 a
N238	Without	0.08	1.23	1.09	0.80	0.42	3.55	7.33	3.77	4.36	5.13	5.02	4.84	16.7	18.1	22.5	19.1
	Cerealin	0.11	1.99	1.58	1.23	0.60	6.37	13.9	6.94	5.41	5.34	5.26	5.33	26.0	35.9	41.9	34.6
	Microbin	0.30	2.35	1.69	1.45	1.53	12.5	13.1	9.04	6.34	6.46	5.59	6.13	26.4	39.3	43.1	36.2
	Cer.+ Mic.	0.20	2.12	1.61	1.31	1.10	12.4	15.7	9.75	6.20	6.28	5.74	6.07	21.8	47.2	53.3	40.8
	Mean	0.17	1.92	1.49	1.20 a	0.91	8.72	12.5	7.38 b	5.58	5.80	5.40	5.59 a	22.7	35.1	40.2	32.7 a
N298	Without	0.07	1.17	1.04	0.76	0.32	6.50	6.88	4.57	4.49	4.66	4.66	4.60	13.7	23.9	28.5	22.0
	Cerealin	0.11	1.66	1.47	1.08	0.66	13.5	11.6	8.61	5.30	6.52	5.22	5.68	17.8	40.7	43.7	34.1
	Microbin	0.26	1.85	1.54	1.22	1.68	13.6	11.8	9.03	5.95	6.87	5.40	6.07	20.0	34.1	44.2	32.8
	Cer.+ Mic.	0.30	1.77	1.46	1.18	1.82	14.2	12.2	9.40	5.59	6.49	5.58	5.89	33.1	44.6	35.9	37.9
	Mean	0.19	1.61	1.38	1.06 b	1.12	12.0	10.6	7.90 a	5.33	6.13	5.22	5.56 a	21.1	35.8	38.1	31.7 a
Grand means		0.17 c	1.46 a	1.14 b		0.72 c	7.78 b	9.19 a		5.11 b	5.72 a	5.62 a		16.2 c	28.3 b	37.0 a	
F - test		G:	**	N:	**	G:	**	N:	**	G:	**	N:	**	G:	**	N:	**
		B:	**	GxN:	**	B:	**	GxN:	**	B:	**	GxN:	*	B:	**	GxN:	**
		GxB.:	**	BxN:	**	GxB.:	**	BxN:	**	GxB.:	NS	BxN:	NS	GxB.:	**	BxN:	**
		GxNxB:	**			GxNxB :	**			GxNxB:	**			GxNxB:	**		
Means of biofertilizer																	
Whitout			0.60 d				3.19 c				4.61 c				18.0 c		
Cerealin			0.92 c				6.03 b				5.46 b				28.8 b		
Microbin			1.12 a				7.23 a				5.99 a				30.1 b		
Cerealin+Microbin			1.04 b				7.14 a				5.88 a				31.9 a		
Grand mean			0.92				4.53				5.49				27.2		

Table 7: K content (g kg^{-1}) and K-uptake (kg ha^{-1}) by barley as affected by gamma irradiation, biofertilizers and N rates

N-Rate (N) kg N ha^{-1}	Biofertilizer (B)	Gamma irradiation dose (Gy)															
		0	20	40	Mean	0	20	40	Mean	0	20	40	Mean	0	20	40	Mean
		K-content (g kg^{-1})				K-uptake (kg ha^{-1})				K-content (g kg^{-1})				K-uptake (kg ha^{-1})			
		Straw								Grain							
N0	Without	2.73	3.35	4.14	3.41	2.62	10.2	11.9	8.25	1.17	1.37	2.60	1.71	0.37	3.72	6.30	3.46
	Cerealin	3.63	4.56	4.76	4.32	3.78	17.5	21.4	14.2	1.95	1.69	2.86	2.17	1.41	5.42	10.1	5.65
	Microbin	4.39	3.96	5.57	4.64	4.92	17.7	25.9	16.2	2.86	2.73	3.53	3.04	2.06	9.62	11.2	7.63
	Cer.+ Mic.	3.89	4.14	6.00	4.67	4.04	13.9	23.0	13.7	2.15	2.86	3.69	2.90	0.86	7.79	12.4	7.03
	Mean	3.66	4.00	5.12	4.26 b	3.84	14.8	20.6	13.1	2.03	2.16	3.17	2.46 c	1.18	6.64	10.0	5.94 b
N179	Without	3.80	4.22	4.65	4.22	14.0	18.9	40.9	24.6	2.21	2.47	2.99	2.56	6.37	7.52	24.2	12.7
	Cerealin	4.65	4.04	5.24	4.64	17.1	24.0	52.0	31.0	2.99	2.86	3.46	3.11	10.5	11.9	29.9	17.4
	Microbin	3.97	4.39	6.08	4.81	23.5	21.1	61.5	35.4	2.47	2.99	3.97	3.15	9.90	13.9	35.1	19.6
	Cer.+ Mic.	4.04	4.22	5.90	4.72	15.5	19.7	59.9	31.7	2.60	2.95	4.05	3.20	9.58	20.8	33.8	21.4
	Mean	4.11	4.22	5.47	4.60 a	17.5	20.9	53.6	30.7ab	2.57	2.82	3.62	3.00 a	9.10	13.5	30.7	17.8 a
N238	Without	2.86	4.39	4.85	4.03	14.7	12.7	32.7	20.0	1.69	2.21	2.60	2.17	6.50	7.79	11.7	8.67
	Cerealin	3.63	5.07	5.57	4.76	19.6	16.2	49.1	28.3	1.95	3.46	3.29	2.90	9.37	23.3	26.4	19.7
	Microbin	4.22	3.46	6.51	4.73	21.6	18.4	50.6	30.2	2.08	2.86	3.38	2.78	8.67	17.4	26.1	17.4
	Cer.+ Mic.	4.13	4.65	6.46	5.08	23.1	27.3	62.9	37.8	2.86	2.99	3.46	3.11	10.08	22.5	32. 2	21.6
	Mean	3.71	4.39	5.85	4.65 a	19.8	18.7	48.8	29.1 b	2.15	2.88	3.18	2.74 b	8.66	17.8	24.1	16.8 a
N298	Without	2.34	4.05	4.22	3.54	10.9	22.6	28.5	20.7	1.56	2.34	3.63	2.51	4.75	12.0	22.2	13.0
	Cerealin	4.56	4.39	4.90	4.62	27.7	35.8	38.6	34.1	1.95	2.60	3.13	2.56	6.56	16.3	26.1	16.3
	Microbin	3.29	5.49	5.74	4.84	21.1	40.3	44.0	35.1	2.04	2.86	4.05	2.99	6.84	14.2	33.2	18.1
	Cer.+ Mic.	4.42	5.57	5.66	5.22	26.8	44.7	47.1	39.6	2.08	3.13	4.31	3.17	12.33	21.5	27.6	20.5
	Mean	3.65	4.88	5.13	4.55 a	21.6	35.9	39.6	32.4 a	1.91	2.73	3.78	2.81 b	7.62	16.0	27.3	17.0 a
Grand mean		3.79 c	4.37 b	5.39 a		15.7 c	22.5 b	40.7 a		2.17 c	2.65 b	3.44 a		6.66 c	13.5 b	23.0 a	
F - test		G:	**	N:	**	G:	**	N:	**	G:	**	N:	**	G:	**	N:	**
		B:	**	GxN:	**	B:	**	GxN:	**	B:	**	GxN:	**	B:	**	GxN:	**
		GxB:	**	BxN:	**	GxB:	**	BxN:	**	GxB:	**	B x N:	**	GxB::	**	BxN:	**
		GxNxB: **				GxNxB: **				GxNxB: **				GxNxB: **			

	Means of biofertilizer			
Whitout	3.80 d	18.4 d	2.24 d	9.48 d
Cerealin	4.58 c	26.9 c	2.69 c	14.8 c
Microbin	4.76 b	29.2 b	2.99 b	15.7 b
Cerealin+Microbin	4.92 a	30.7 a	3.10 a	17.6 a
Grand mean	4.52	26.3	2.76	14.4