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EFFICIENCY OF BIOFERTILIZERS IN SUBSTITUTING MINERAL FERTILIZERS AND IMPROVING DROUGHT TOLERANCE IN BARLEY

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ABSTRACT

Two pot-experiments were conducted during 1998/99 and 1999/2000 seasons to examine the efficiency of biofertilizer as a substitute for chemical fertilizers and as means of improving drought stress tolerance in barley H. vulgare L. Biofertilizer-inoculated (with half NPK dose) and non-inoculated (with full NPK dose) treatments were applied to five barley genotypes (Giza 123, Giza 125, Rehan 97, Morocco and a wild species, H. marinum L.) under three moisture levels (100, 70 and 40%) of field capacity (FC) in five replications. Chemical constituents, vegetative and yield attributes as well as proline and chlorophyll contents were estimated.

There was no significant difference between biofertilizer-inoculated (with half NPK dose) and non-inoculated control (with full NPK dose) in both vegetative or yield attributes. This indicated that biofertilizers could be efficient in reducing chemical fertilizers. Significant differences were found between the three levels of moisture and barley genotypes in both vegetative and yield attributes.

Biofertilizer-inoculation treatment increased some yield components under mild stress (70% FC) but not under severe stress conditions (40% FC).

Giza 123 and Rehan 97 had relatively high values for most vegetative and yield attributes as well as chemical constituents, which refers to differential response of barley genotypes under drought stress and biofertilizer inoculation.

Key words: *Barley, Biofertilizer, Chemical constituents, Drought, Proline, Yield.*

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the efficient winter drought stress tolerant crops that can be very useful in arid and semi arid areas as grain or a forage crop. In 2003, the harvested area of barley in the world reached 57,237,858 hectares, which produced 141,503,090 tons. While, the area allotted for barley in Egypt reached 33,007 hectares which produced 100,797 tons in 2003 (FAO, 2003). Barley is mainly grown under rainfed

conditions in regions that are characterized by low and highly variable rainfall. Therefore drought stress is a major concern in these regions.

On the other hand, mineral fertilizers have become a major source of pollution for ground water. There is a worldwide tendency towards reducing mineral fertilizers and substituting them with unconventional fertilizers such as those of microorganism origin. Many researchers found that bio-chemical fertilizers have an improving effect on growth and yield of several crops (Abd-Alla *et al* 1994, Pasricha *et al* 1996 and Ozturk *et al* 2003).

Rashad and Ismail, (2000) and Rashad and Ragab (2003) found that bio-chemical fertilizers combined with NPK application in different cereal crops gave equally or better growth and yield compared with the mineral NPK under heat stress and drought stress, respectively. These results showed that biofertilizers were potentially good means for improving drought tolerance.

The objectives of this investigation were to: (1) examine the efficiency of biofertilizer as a substitute for mineral fertilizers and (2) test the efficiency of biofertilizers as means of improving drought stress tolerance among barley genotypes.

MATERIALS AND METHODS

Two pot-experiments were conducted during 1998/1999 and 1999/2000 seasons in the greenhouse of Plant Physiology Dept., Faculty of Agriculture, Cairo University, Giza. The experiments included four cultivar stocks and one wild type. The cultivated stocks included two cultivars from ICARDA (Morocco and Rehan) and two Egyptian commercial cultivars (Giza 123 and Giza 125). The wild species (*Hordeum murinum* L.) was collected from Wadi Sudr, South Sinai. Two fertilization treatments were applied; (1) 20 grams per pot of commercial NPK as a control (full dose) and biofertilizer + half the dose of NPK (10 grams/pot). The NPK commercial fertilizer contained 46% N, 15 % P_2O_5, and 48% K_2O. Pots were kept at different water regimes maintaining 100%, 70% and 40% of field capacity (FC) using a moisture meter.

The pots were set in a completely randomized design (CRD) in 5 replications in the greenhouse of the biotechnology lab, Plant Physiology Dept., Faculty of Agriculture, Cairo University. Each pot represented all treatments combination.

The pots (30 cm in diameter) were filled with a mixture of clay and sand in a 1:1 (V:V) ratio. Soil chemical analysis of the clay soil using atomic absorption (Jackson, 1962 and Allen *et al.*, 1974) showed that it

contained 4.43, 4.03 , 6.29 and 0.63 meq./L Ca, Mg, Na and K , respectively with a pH 7.4.

All pots were irrigated to saturation before planting. Sowing dates were December 5th and 12th for the first and second seasons, respectively. Each pot received 20 equidistantly distributed and properly covered seeds of barley, then pots were watered again. All pots received one irrigation after emergence. Field capacity was measured after two weeks with a moisture meter and the irrigation was applied at the appropriate times in the three water regimes.

Ten seedlings were allowed to grow and the remaining seedlings were thinned after two weeks of planting. The half and the full doses of the commercial NPK fertilizer were divided into two parts, which were applied after two weeks and at late jointing.

Biofertilizer application treatment

The bacterial inoculum was a mixture of: *Bacillus megaterium* var. *phosphaticum* (which changes P^{+++} to more available P^{++}), *Azotobacter chroccocum* and *Azosperillum brasilense* (the latter two species fix nitrogen in the soil). This inoculum was carried on beatmoss and it was provided by the plant microbiology lab., Faculty of Agriculture, Cairo University.

The bacterial biofertilizer was mixed with the upper layer of the soil prior to planting and watering in a rate of 25 g for each kilogram of soil. A second boosting dose of the biofertilizer in the form of liquid suspension (containing approximately 10^{-5} to 10^{-6} colony forming units /ml) was mixed with soil surface at late jointing stage.

Measurements

Growth parameters

Growth parameters including plant height, root length, number of tillers/plant, fresh and dry weights of roots and shoots were measured in one sample collected at late jointing stage (after 60 and 70 days from planting in the first and second seasons, respectively). Two plants were carefully dug out of each pots to determine the above growth parameters.

Chemical constituents

Phosphorus content in dry shoots and roots was determined colormeterically using chlorostannous reduced molybdophosphoric blue color method according to Chapman and Parker (1961). Potassium and sodium were determined by using flame photometer as described by (A.O.A.C. 1975). Reducing, non-reducing, total sugars, and nitrogen were

also determined in both samples as mg / g dry weight of leaves. Hot ethanol extract from leaves was used for determination of total free amino acids using ninhydrine reagent (Moore and Stein 1954). In addition, hot ethanol extract was used for measuring reducing, non-reducing and total sugars by using the phosphomolybdic acid methods (A.O.A.C. 1975). For determination of total nitrogen and subsequently protein, the modified Micro-Keldahl apparatus of Parnas and Wagner as described by Van Shouwenburg and Walinga (1987) was used.

Chlorophyll a, b and carotenoids content in fresh leaves of all genotypes were measured using a spectrophotometer at wavelength of 662, 646 and 447 nm for chlorophyll a, b and carotenoids, respectively. The pigment contents were calculated using the formula adopted by Wettestein (1957). Proline content in fresh leaves was determined according to the method described by Bates *et al* (1973).

Cell viability (as an indicator of killing time for fresh leaf tissues, i.e. the more time needed to kill the tissue under certain temperature compared to the control, the more drought- tolerant the tissue) was also estimated. Two leaf discs from each pot were collected and placed in a test tube containing 2 ml of Triphenyl Tetrazolium Chloride (TTC) solution (1%) and were incubated at 45 °C for different periods of time as described by Towill and Mazur (1974).

Yield and yield components

At maturity, remaining plants in each pot (5-6 plants) were harvested separately for the following measurements: number of tillers per plant, number of spikes per plant, spike length, spike weight per plant, number of kernels per plant, weight of kernels per plant (grain yield/plant) and weight of 100 kernels.

Data analyses

Data were subjected to statistical analyses of variance by using SAS procedure PROC GLM (SAS Institute, Inc. 1996). Means of genotypes, inoculation treatments, water regimes, and their interactions were separated using Duncan's Multiple Range Test at 0.05 probability level. Drought susceptibility indices comparing grain yield of genotypes under control (100% FC) compared to yield under 70% and 40% FC were measured according to Fischer and Maurer (1978) as follows:

Susceptibility index (SI) = $1-(Yd/Yp)/D$

Where, Yd = yield under stress conditions, Yp = yield under control conditions and D= stress intensity = 1- (mean Yd of all genotypes/mean Yp of all genotypes).

Homogeneity tests for error variances of both seasons indicated the possibility of conducting combined analysis over season for yield components. However, vegetative samples over seasons were significantly different for most traits, therefore they were presented separately.

RESULTS AND DISCUSSION

Efficiency of biofertilizers as a substitute for mineral fertilizers

Vegetative attributes

For the vegetative attributes (Table 1), the means of main factors (i.e. genotypes, biofertilizer treatments and water regimes) generally showed that no significant difference was found between inoculated + half NPK and non-inoculated control in all vegetative attributes in both seasons. This means that inoculation with biofertilizers compensated for nutrients required by plants.

Also no significant differences were found among water regimes in plant height, shoot and root dry weights in both seasons. On the other hand, significant differences were found among the genotypes, where Rehan 97 was superior in all vegetative attributes during the first season, while Giza 125 was the highest in root and shoot dry weights during the second season. It is worth noting that Giza 125 had vigorous vegetative growth in both seasons, which resulted in lodgings of plants.

Table 1. Effect of biofertilizer, water regimes and genotypes on some vegetative attributes during 1998/99 and 1999/2000 seasons.

	Pl. height cm		Shoot dry wt		Root dry wt	
	98/ 99	99 /00	98/ 99	99 /00	98/ 99	99 /00
Biofertilizer						
Inoculated	49.9	51.4	1.0	2.6	0.3	0.8
Non-inoculated	50.2	52.9	1.2	2.5	0.3	0.8
LSD (0.05)	NS	NS	0.2	NS	NS	NS
Water regime						
100FC	51.9	52.6	1.1	2.6	0.3	0.8
70FC	50.5	52.5	1.1	2.5	0.2	0.6
40FC	47.9	51.4	1.0	2.5	0.3	0.9
LSD (0.05)	1.8	NS	NS	NS	NS	NS
Genotypes						
Giza123	48.4	51.8	0.7	2.0	0.2	0.6
Giza125	50.7	54.0	1.1	3.2	0.3	1.4
Morocco	51.1	51.9	0.8	2.2	0.3	0.4
Rehan97	52.6	47.4	1.8	2.4	0.4	0.9
Wild	47.7	55.7	1.0	2.8	0.2	0.7
LSD (0.05)	2.4	3.1	0.3	0.4	0.1	0.3

In addition, Rehan 97 had the highest values for shoot and root dry weights under all water regimes during the first season, while both Rehan 97 and Giza 125 were superior in shoot fresh and dry weights during the second season. It is noteworthy that the shoot and root dry weights in Rehan 97 were generally the highest in value under 40% FC in both seasons (1.8, 2.8 and 0.4, 1.1 g for shoot and root dry weight per plant in the two seasons, respectively).

Chemical constituents

Table (2) represented the shoot and root content of some chemical constituents as affected by biofertilizer inoculation treatment, different moisture levels and five different barley genotypes during 1998/1999 and 1999/2000 seasons. There was no major differences between the inoculated + half NPK and non-inoculated treatment (with full NPK dose) in all nutrient and total sugars in both the shoots and the root except for shoot N during the first season. N concentration was higher by one unit in non-inoculated compared to inoculated treatment. From these results, it can be concluded that biofertilizers + half NPK were as good as full dose of NPK for compensation for plant requirement from major nutrients. These results also highly coincide with those found in vegetative attributes.

Similar trend was found for water regimes, where no differences were detected in chemical constituents in both the shoot and the roots, except for shoot N during the first season, where it was the highest at 70 % FC. On the other hand, differences were detected among genotypes in shoot and root content of chemical constituents, particularly in N, K, and Na.

Comparing proline, chlorophyll a, b and carotein (in fresh leaves) between inoculated and non-inoculated treatment, we found that all except proline were not different. Proline content was relatively higher in non-inoculated full dose NPK. It was found earlier that shoot N was the only nutrient that was higher in non-inoculated compared to inoculated treatment. Plants probably tend to absorb the more readily available nutrients, particularly under stress conditions. This probably was the reason for the relatively increased proline content under non-inoculated full NPK treatment. Proline content was lower under 40% FC compared to both 100% FC and 70% FC, while the differences in chlorophyll a, b and carotein were small. For the genotypes, both Morocco and Rehan 97 had the highest proline content, while the wild species had the highest content of chlorophyll a, b and carotein.

Table 2. Effect of biofertilizers, water regimes and genotypes on chemical contents in shoots and root during 1998/99 and 1999/2000 seasons

Shoot	N		P		K		Na		Sugars		Proline	Chloro A	Chloro B	Carotein
	98/ 99	99 /00	98/ 99	99 /00	98/ 99	99 /00	98/ 99	99 /00	98/ 99	99 /00	98/ 99	98/ 99	98/ 99	98/ 99
Biofertilizer														
Inoculated	10.9	5.9	0.5	0.4	2.5	2.4	0.9	0.9	0.7	0.5	53.7	27.7	16.8	8.0
Non-inoculated	11.9	6.0	0.5	0.4	2.6	2.3	1.0	0.9	0.6	0.5	58.4	28.4	17.1	8.2
Water regime														
100FC	10.6	6.2	0.5	0.4	2.5	2.4	0.9	0.9	0.6	0.5	58.1	28.1	15.8	7.6
70FC	12.0	5.6	0.5	0.4	2.6	2.4	1.1	0.8	0.6	0.5	57.8	28.9	17.5	8.4
40FC	11.6	5.9	0.5	0.4	2.5	2.4	0.9	0.9	0.6	0.5	52.2	29.0	17.6	8.4
Genotypes														
Giza 123	10.0	4.7	0.5	0.4	2.4	2.9	0.7	1.2	0.7	0.5	52.5	25.8	15.7	7.5
Giza 125	11.2	5.9	0.5	0.4	2.6	2.2	1.1	0.6	0.6	0.5	51.6	30.2	18.3	8.7
Morocco	12.8	6.2	0.5	0.4	2.5	2.5	1.1	1.2	0.6	0.5	64.9	26.4	15.8	7.6
Rehan 97	10.2	6.0	0.6	0.4	2.7	2.3	1.1	0.8	0.7	0.4	60.4	25.3	15.4	7.3
Wild	13.0	6.9	0.5	0.4	2.5	2.0	0.9	0.6	0.6	0.5	50.7	32.4	19.7	9.4
Root														
Biofertilizer														
Inoculated	8.0	5.1	0.4	0.3	2.6	2.9	0.7	0.7	0.5	0.3				
Non-inoculated	8.0	5.4	0.3	0.3	2.9	2.8	0.9	0.7	0.5	0.3				
Water regime														
100FC	8.0	5.4	0.4	0.3	2.8	2.8	0.8	0.7	0.5	0.3				
70FC	7.9	5.1	0.4	0.3	2.6	2.8	0.9	0.7	0.5	0.3				
40FC	8.3	5.3	0.4	0.3	2.9	2.8	0.8	0.6	0.5	0.3				
Genotypes														
Giza 123	8.1	4.3	0.4	0.3	2.7	3.0	0.7	0.8	0.5	0.3				
Giza 125	7.7	5.2	0.3	0.2	2.9	3.1	0.8	0.7	0.5	0.3				
Morocco	7.7	5.7	0.4	0.3	3.2	2.6	1.5	0.8	0.5	0.3				
Rehan 97	8.4	5.9	0.3	0.2	2.4	3.0	0.6	0.9	0.5	0.3				
Wild	8.4	5.2	0.4	0.3	2.6	2.5	0.5	0.5	0.5	0.3				

Data in Table (3) showed the effect of biofertilizer inoculation, water regimes and genotypes on cell viability, i.e. the ability of cells to stay alive for a longer period at a given temperature (45 °C). Data after 60 min. were not presented because the percentage of injury (killed tissue) was higher than 50% compared to the control.

Cell viability test showed that inoculated treatment with half NPK was not higher than full NPK in percentage of injury (dead tissue). On the contrary, this percentage was relatively lowered in biofertilizer-inoculated compared to non-inoculated during the first season at all times.

Water regimes affected the percentages of injury, where the control (100 % FC) was generally the lowest and the 40% FC was the highest. Differences were also found among the genotypes, where Giza 123 had the lowest values at 15 min in both seasons and at 30 min in the first season only.

Table 3. Effect of biofertilizer inoculation, water regimes and genotypes on cell viability (killing time) in barley in two seasons.

		1998/ 99			1999/ 00	
		15 min	30 min	60 min	15 min	30 min
Biofertilizer		% Dead tissue compared to the control				
Inoculated		56.6	95.9	160.6	64.4	139.0
Non - inoculated		60.4	124.8	185.9	63.3	131.6
Water regimes						
100 FC		49.7	90.6	154.8	54.6	128.4
70 FC		57.4	107.8	162.7	72.0	133.1
40 FC		68.3	132.8	202.2	64.9	144.5
Genotypes						
	Giza 123	15.5	34.4	57.6	32.8	111.1
	Giza 125	52.8	106.9	184.9	56.7	139.9
	Moracco	90.6	153.9	221.4	92.6	154.4
	Rehan 97	103.7	173.7	221.8	78.7	155.7
	Wild	29.9	82.9	180.3	58.4	115.6

Yield components

Generally, there was no significant difference between inoculated + half NPK and non-inoculated control in all yield components except in weight of 100 kernels (Table 4). This finding highly coincide with those found in both vegetative and chemical attributes. It confirms that biofertilizers can be an effective partial substitute for mineral fertilization.

There were significant differences among the three water regimes in all yield components except number of tillers and number of spikes per plant. Yield components were generally the highest at the control (100 % FC).

Analysis of variance showed that there were significant differences between genotypes in all yield components. No single genotype was superior in all the yield components. However, over all treatments, Giza 123 was superior in most components, where it had the highest number of tillers/plant, highest spike weight, weight of kernels per plant and weight of 100 kernels. While, Rehan 97 had the highest number of spikes per plant, number of kernels per plant and relatively high weight of kernels (1.32 g). On the other hand, Giza125 had the lowest values for number of kernels and weight of kernels per plant. It seems that Rehan 97 could utilize its superiority in vegetative growth and turn it into grain yield.

It may be noted that increased vegetative growth did not always reflect on grain yield. This is because increased vegetative growth sometimes was associated with observed plant lodging and consequently reduced yield. This was the case for Giza 125, where increased vegetative growth resulted in reduced yield.

There was a significant difference between the genotypes and water regime interactions in all yield components. Giza 123 scored the highest value in spike weight (3.27 g), number of kernels per spike (64.7) and weight of kernels per spike (2.42 g) at control (100 %FC). However, under stress conditions (40% FC), Giza 123 suffered significant losses in most of the above mentioned traits. On the other hand, Rehan 97 had intermediate yield at control (kernel weight = 1.43 g), but it did not loss significant yield under both 70 and 40% FC. Rehan 97 also had the lowest drought susceptibility index compared to other genotypes under both 70 and 40% FC.

Efficiency of biofertilizers in improving drought tolerance

Vegetative attributes

Table (5) represents the interaction between water regimes and biofertilizer inoculation treatments on the main vegetative attributes of barley genotypes. The data showed that no significant difference was found between biofertilizer-inoculated and non-inoculated treatments in vegetative attributed at 100 % FC and 70% FC in both season and at 40% FC in the second season. However, at 40 % FC in the first season, both shoot and root dry weights were significantly higher in non-inoculated than biofertilizer-inoculated treatment. These results indicated that biofertilizers can be efficient in reducing the effect of drought stress on vegetative growth up to 70 % FC. At 40% FC, the effect of biofertilizers may be minimized due to lack of water, which is necessary for the growth and propagation of the microbes involved in the biofertilizers composition.

Table 4. Effects of biofertilizer inoculation, water regimes and genotypes on yield components over two seasons.

Biofertilizer	Tillers/ plant	Spikes/ plant	Spike Length cm	Spike wt/ plant g	No. Kernel /plant	Kernels wt/plant g	Wt 100 Kernels g
Inoculation	7.87	2.58	5.72	1.73	32.20	1.12	3.62
Non-inoculation	6.69	2.42	5.41	1.71	32.11	1.09	3.71
LSD (0.05)	0.48	NS	NS	NS	NS	NS	0.09
Water regimes							
100FC	7.33	2.50	5.38	1.96	38.40	1.35	3.85
70FC	7.00	2.43	5.43	1.44	27.50	0.90	3.51
40FC	7.50	2.57	5.88	1.76	30.57	1.07	3.64
LSD (0.05)	NS	NS	0.39	0.34	6.60	0.27	0.10
Gentoypes							
Giza123	8.56	2.39	5.72	2.20	38.61	1.44	3.88
Giza125	7.33	2.22	5.78	0.95	19.22	0.62	3.83
Morocco	7.11	2.28	5.28	1.49	30.28	1.02	3.43
Rehan97	6.89	3.00	5.19	1.88	42.67	1.32	3.45
Wild	6.50	2.61	5.86	2.08	30.00	1.13	3.73
LSD (0.05)	0.76	0.44	0.50	0.44	8.54	0.34	0.13

Table 5. Effect of biofertilizer and water regime interaction on vegetative attributes of barley genotypes in two seasons.

Water regime	Biofertilizer	Pl. height cm		Shoot dry wt (g)		Root dry wt (g)	
		98/ 99	99 /00	98/ 99	99 /00	98/ 99	99 /00
100FC	Inoculated	50.9	52.0	1.0	2.8	0.3	0.9
	Non-inoculated	52.9	53.2	1.1	2.4	0.3	0.8
70FC	Inoculated	50.9	50.9	1.1	2.3	0.3	0.7
	Non-inoculated	50.0	54.0	1.1	2.6	0.2	0.6
40FC	Inoculated	47.9	51.3	0.8	2.6	0.2	0.8
	Non-inoculated	47.9	51.5	1.3	2.3	0.4	1.0
LSD (0.05)		NS	NS	0.3	NS	0.1	NS

Chemical constituents

Table (6) showed that the differences in shoot content of N, P, K , Na and total sugars were obvious at 40% FC during the first season , where the shoot contents of these elements were almost the double in non-inoculated compared to inoculated treatments. While at 100 % FC and 70% FC the differences were minute during the first season. During the second season, the differences were minute at all three water regimes. Similar trend was found for the root content of chemical constituents.

These results indicated that biofertilizer inoculation were efficient in reducing the effect of water stress on the ability of barley plants to absorb required nutrient, specially up to 70% FC. Where water stress is severe (at 40% FC), the efficiency of biofertilizers in providing the plants with required nutrients can be reduced.

In addition, at 100 % FC, there was no difference between inoculated + half NPK and non-inoculated control in proline, chlorophyll a, b or carotein content. On the contrary the values were relatively higher at the inoculated treatment. At 70 % FC, proline content was higher at non-inoculated control. Proline content usually readily increases under stress conditions (Singh, *et al* 1973, Monneveux and Nemmar 1986, Narayan and Misra 1989, Emad El-Din 1990, Ali Dib *et al* 1994 and Bajii *et al* 2000, Rashad *et al* 2002). However, at 40 % FC, the difference was minimum between the two treatments. The reason for this difference at 70% FC is probably because full dose NPK makes elements necessary for building proline more available. While, at 40 % FC, plants usually get adapted after a period of time to the shortage of water and proline content tends to decrease.

Regarding the improving effect of biofertilizer on barley genotypes tolerance to water stress, data showed that at 100% FC (control) inoculation resulted in a reduced percentage of dead tissue at all times (particularly at 15 min.) during the first season. At 70 % FC, similar trend was found. However, at 40 % FC, opposite trend was found at 15 min. Reduced percentage of dead tissue is an indicator of stress tolerance. These results indicate that biofertilizers inoculation could have an improving effect for drought tolerance, particularly under mild drought stress.

Table 6. Effect of biofertilizer and water regime interaction on chemical constituents of barley genotypes in two seasons.

Shoot		N		P		K		Na		Total sugars	
Water regime	Biofertilizer	98/ 99	99 /00	98/ 99	99 /00	98/ 99	99 /00	98/ 99	99 /00	98/ 99	99 /00
100FC	Inoculated	11.28	16.83	0.49	1.14	2.36	6.72	0.95	2.41	0.65	1.28
	Non-inoculated	12.87	13.67	0.61	0.99	3.01	5.91	1.13	2.29	0.71	1.10
70FC	Inoculated	14.10	12.70	0.57	0.90	2.96	5.65	1.23	1.85	0.71	1.10
	Non-inoculated	13.12	15.65	0.59	1.01	3.03	5.88	1.32	2.21	0.69	1.22
40FC	Inoculated	7.58	16.13	0.38	1.02	2.13	6.25	0.66	2.04	0.52	1.22
	Non-inoculated	15.53	15.25	0.72	0.93	3.15	5.38	1.39	2.29	0.82	1.07
Root											
100FC	Inoculated	2.85	5.01	0.13	0.24	0.97	2.41	0.25	0.47	0.16	0.29
	Non-inoculated	2.12	4.15	0.09	0.20	0.71	2.10	0.19	0.49	0.12	0.24
70FC	Inoculated	2.11	3.42	0.11	0.18	0.61	2.16	0.17	0.53	0.14	0.22
	Non-inoculated	1.40	3.20	0.05	0.14	0.47	1.45	0.14	0.39	0.08	0.18
40FC	Inoculated	1.25	4.50	0.06	0.21	0.42	2.09	0.09	0.52	0.08	0.25
	Non-inoculated	3.47	5.35	0.14	0.24	1.05	3.13	0.28	0.72	0.20	0.31

Yield components

Table (7) showed the effect of biofertilizers under different water regimes on yield components. No significant differences were found between biofertilizer-inoculated + half NPK and non-inoculated full dose NPK control at 100% FC in all yield components, except 100 kernels weight. At 70 % FC all yield components was higher at the inoculated treatment compared to the non-inoculated. This increase in yield components was significant in number of kernels and weight of kernels per plant. At 40 % FC, opposite trend was found for spike weight, number and weight of kernels per plant, where non-inoculated control had higher values. These results indicate that biofertilizer inoculation has an improving effect on yield under mild stress (up to 70 % FC).

Table 7. Effect of biofertilizer and water regime interaction on yield components of barley over two seasons.

Water regime	Biofertilizer	Tillers/ plant	Spikes/ plant	Spike Length cm	Spike wt/ plant g	No. Kernel /plant	Wt 100 Kernels g	Kernels wt/plant g
100 FC	Inoculated	8.00	2.53	5.43	1.99	38.80	3.70	1.31
	Non-inoculated	6.67	2.47	5.33	1.92	38.00	3.99	1.39
70FC	Inoculated	7.67	2.60	5.70	1.73	33.80	3.53	1.21
	Non-inoculated	6.33	2.27	5.17	1.15	21.20	3.49	0.59
40FC	Inoculated	7.93	2.60	6.03	1.47	24.00	3.63	0.84
	Non-inoculated	7.07	2.53	5.73	2.06	37.13	3.66	1.29
LSD (0.05)		NS	NS	NS	0.68	12.92	0.25	0.51

Also, there were significant differences in drought susceptibility index (DSI) among genotypes and between biofertilizer inoculation treatments. DSI compares the yield performance under stress and non-stress conditions. DSI was generally lower in inoculated compared to non-inoculated control at 70% FC, while it was opposite to that at 40%FC, but these differences were not significant. It seems that inoculation treatment could improve drought tolerance under mild stress (70 % FC). However, under severe stress conditions (40%), inoculation treatment was not effective for improving drought tolerance.

From the results of this research it could be concluded that biofertilizers can be a good partial substitute for mineral fertilization under normal and mild stress conditions. Also, biofertilizers can have an improving effect on growth and yield of barley genotypes under mild stress and not under severe stress. There was a differential reponse of some barley genotype to biofertilizers, where Giza 123 and Rehan 97 had relatively

higher values for most evaluated traits compard to the other genotyeps. Therefore, barley genotypes should be evaluated for their ability to utilize (or their roots to interact with) bioferilizers before their application. Further field experiments may be required to confirm the results of this investigation.

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كفاءة استخدام الأسمدة الحيوية كبديل للأسمدة المعدنية و فى تحسين تحمل الشعير للجفاف

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أجريت تجربة فى موسمى ١٩٩٨/١٩٩٩ و ١٩٩٩/٢٠٠٠ باستخدام الأصص وذلك لاختبار مدى كفاءة الأسمدة الحيوية فى تحسين كفاءة تحمل الجفاف فى الشعير. اشتملت المعاملات على إضافة السماد الحيوى(+ نصف كمية السماد المعدنى الموصى بها) ومعاملة الكونترول (كل كمية السماد المعدنى الموصى بها) الى خمسة أصناف من الشعير وهى (جيزة ١٢٣ و جيزة ١٢٥ و Rehan97 و Morocco و أحد الطرز البرية) وذلك باستخدام ثلاثة مستويات من الرطوبة (١٠٠ و ٧٠ و ٤٠ % من السعة الحقلية) فى خمسة مكررات. تم تقدير المحتوى الكيماوى وصفات النمو الخضرية والمحصولية للنباتات بالإضافة الى محتوى البرولين والكلوروفيل.

أظهرت النتائج انه لم يكن هناك فرق بين معاملتى إضافة التسميد الحيوى مع نصف كمية السماد المعدنى ومعاملة الكونترول (كل الكمية السماد المعدنى) سواء فى صفات النمو الخضرى او صفات المحصول ، مما يشير الى فعالية الأسمدة الحيوية كبديل جزئى للأسمدة المعدنية. كما أظهرت النتائج وجود اختلافات معنوية بين مستويات الرطوبة فى كل من الصفات الخضرية وصفات المحصول وكانت هناك اختلافات معنوية بين الأصناف فى معظم الصفات المدروسة. أدى استخدام الأسمدة الحيوية الى زيادة بعض مكونات المحصول تحت مستوى الإجهاد الرطوبى المتوسط (٧٠ % من السعة الحقلية) ولكن ليس تحت مستوى الإجهاد المرتفع (٤٠% من السعة الحقلية). كما تشير نتائج هذا البحث الى قابلية بعض الأصناف دون الأخرى من الاستفادة من الأسمدة الحيوية خاصة تحت ظروف الجفاف والى ضرورة اختبار الأصناف المختلفة قبل التوصية باستخدام الأسمدة الحيوية معها.

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