Response of Barley to Bio Fertilization with *Mycorrhiza* and *Azotobacter* under Supplemental Irrigation Conditions at the North Western Coast of Egypt

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ABSTRACT

In order to evaluate the response of grain yield, yield compounds, quality and water use efficiency of barley cv. Giza 126 cultivar to irrigation water regimes and biofertilization inoculation, field experiment was conducted in the Experimental Farm of Maryout Experimental Station, Desert Research Center, Egypt, during two successive growing seasons 2017/18 and 2018/19. The experimental design was a split plot, whereas the main plots involved by irrigation water regimes and the sub-main plots involved by biofertilization treatments, with three replicates. The obtained results indicated that yield, yield attributes and N, P and K contents in grains of barley *i.e.* plant height, spike length, number of spikes/m^2, number of grains/spike, 1000-grain weight, grain yield ha^{-1}. The contents of nitrogen, phosphorus percentage in barley grains and water use efficiency significantly increased with increasing irrigation water applications and by biofertilizers treatments. However, the number of spikelets/spike, and potassium percentage in grains was not significantly affected by irrigations water regimes and/or biofertilizers treatments. Water use efficiency (kg m^{-3}) for grain yield significantly increased with increasing irrigation water application with biofertilizers treatments in the two growing seasons. The highest values of all studded traits were recorded by applying the three times irrigation in the two seasons. Regarding biofertilizers inoculation effects, results showed that the maximum values of most studied traits were recorded by inoculating with both Mycorrhiza and Azotobacter together as a combination treatment for both seasons except plant height, which produced highest values, by inoculating with Mycorrhiza and Azotobacter in the first season and by using Azotobacter alone in the second one. On the other side, maximum value of nitrogen percentage in grains were recorded by treating the plant with Azotobacter alone in the two seasons. The results clearly showed that barley plants which irrigated by the three irrigations and inoculated by Mycorrhiza and Azotobacter together, as a combination treatment, produced the highest yield, yield components and water use efficiency at the North Western Coast of Egypt.

Key words: Barley, Mycorrhiza, Azotobacter, supplemental irrigation, sandy loam, rainfed.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is grown across a wide range of environments as a rainfed or irrigated crop. It is considered as one of the most common suitable cereal crops which can survive and grow over extensive range of soils and under many adverse climatic conditions. The economically valued product is grain, which is used for food and feed, but also for manufacturing processing. It ranks fourth in the world's cereal production after wheat, rice and maize. It is one of the most important cereal crops grown in many developing countries, where it is often exposed to drought stress at later stages of development (Ceccarelli et al., 2007; Sharafi et al., 2011).

Barley originates from the Eastern Mediterranean Region where plants involvement many abiotic stresses in the field. Its production has become further intense and complex in recent years. As a result, it is necessary to carry out experiments to estimate the response of barley plants to a variety of adversative conditions, such as low and high solar energy, high temperature and salinity, shortage or excess of water in soil, which affects photosynthesis and yield development (Kalaji et al., 2012).

Water scarcity is a main global environmental problem of the 21st century (Srinivasan et al., 2012). Globally, agriculture consume about 80–90 % of all source of freshwater used by humans, and most of that water is used for crop production (Morison et al., 2007). Insufficient water is the main limitation to barley production world-wide. The production of barley under drought is correlated with yield potential and this has become an urgency area of research. Barley is grown widely as a rainfed crop in semi-arid regions of the world, where large variations occur in the amount and frequency of rainfall events.

The recommended number of irrigations at the vegetative and the reproductive stages of barley need to be applied correctly and timely for well yields. Water use efficiency (WUE) defined as the ratio of produced yield to total seasonal water use considers as an important factor in describing the role of biological fertilizers in reducing the effect of drought on yield

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(Blum, 2009). Therefore, it could be used as a criterion for yield improvement under drought stress and as an indication of the ability of biofertilizers to preserve water under stress conditions (Fang et al., 2010; Dong et al., 2011).

Biofertilizers have the potential to improve the health and productivity of plant life and reduce the applied inorganic chemical fertilizers. Most biofertilizers consists of microbes that are involved in the decomposition of organic matter and the breakdown of minerals into a soluble form to become available to plants. It is based on the use of natural products including fertilizers, decaying the remains of organic matter, animal manure, crop residues, and microorganisms such as fungi and bacteria. They are used to enhance fixation of nutrients in the rhizosphere, improve soil fertility, produce growth stimulants for plants, provide biological control, recycle nutrients, biodegrade organic substances, and promote mycorrhiza symbiosis (Carvajal-Muñoz and Carmona-Garcia, 2012).

Microorganisms play a fundamental role in the natural N, P and K cycles. The use of N_2-fixers, phosphate and potassium solubilizers contribute in improving uptake of plant nutrients (Afifi et al., 2014). Beneficial microorganisms, therefore, are a tool that optimize plant growth and nutrient uptake. The beneficial effect of symbiotic nitrogen fixer *Azotobacter chrococum* as free living N_2-fixing is attributed to fix atmospheric nitrogen, vitamins, and synthesis of phytohormones, inhibiting plant ethylene synthesis, enhancing stress resistance and improving nutrient uptake (Massoud et al., 2013).

Arbuscular mycorrizal fungi (AMF) have the facility to form symbiotic association with plants that benefit both partners through acquisition and absorption of nutrient especially phosphorus from soil (Barea et al., 2011). AM fungi interrelate with other soil microbes like free nitrogen fixer and the biochemical cycling of elements to the host plants. As well as, the role of Azotobacter as plant growth promoters (PGPRs), is to convert unavailable minerals and organic compounds into forms available to plants .In addition, they act also to increase the root length, root biomass and development the root system which leads to an increase in plant growth and yield (Gupta et al., 2002; Soliman et al., 2015).

Gaps remain in knowledge of how yield attributes (grain yield, yield components) and WUE on barley respond to various irrigation regimes in arid high pH sandy loam soils. Therefore, the main objective of this study was to evaluate the effect of different irrigation regimes and biofertilizers treatments on the grain yield, yield components and water use efficiency of barley, and find out the appropriate system of irrigation regime for the increasing production of barley under the conditions of North Western Coast of Egypt.

MATERIAL AND METHODS

Field experiment was carried out during two successive winter growing seasons of 2017/2018 and 2018/2019 in the experimental farm of Maryout Experimental Station (30˚ 59′ 57.12″ N and 29˚ 46′ 59.16″ E), Desert Research Center, Egypt to study the effect of four irrigation water regimes (rainfed only - one irrigation at tillering stage - two irrigations (one at tillering stage and one at potting stage) - three irrigations (one at tillering stage, one at potting stage and one at grain-setting stage) and four treatments of biofertilizers inoculation (without *Mycorrhiza* or/and *Azotobacter* - *Mycorrhiza fungi*- *Azotobacter chroococum* - *Mycorrhiza* and *Azotobacter* together) on the yield, yield attributes, quality and water use efficiency of barley (*Hordeum vulgare* L.) Giza 126cultivar under supplemental irrigation conditions at the North Western Coast of Egypt. Barley seeds were sowed on November 28th 2017 and November 17th 2018 at a rate of 140 kg ha^{-1} in the first and second season, respectively.

The experimental land area was ploughed and prepared by two vertical disking and field leveling. Soil analysis showed that the soil texture is sandy loam with pH of 8.6. Soil samples were taken just before the sowing date for determination some physical and chemical analysis and the results are shown in Table 1. The experimental layout was a split plot design according to Gomez et al. (1984) with three replicates. The main plots were devoted to water irrigation regimes and the sub-plots were devoted to biofertilizer inoculation. Each sub-sub plot included 50 rows (5 m long and 3 m wide and 10 cm between rows) and an area of 15 m^2. The experimental site was divided into four sections. The barley seeds were treated with *Mycorrhizae*, *Azotobacter* and with both *Mycorrhizae and Azotobacter*, while other part of seeds was not inoculated biologically. The all treatments were then irrigated immediately. The irrigation water was added by flood method. Calcium superphosphate (15.5% P_2O_5) was applied during soil preparation at a rate of 36 kg P_2O_5 ha^{-1}. Nitrogen fertilizer was applied at a rate of 143 kg N ha^{-1} as ammonium nitrate (33.5 % N) in two equal doses, before the first and the second irrigations. Potassium fertilizer was added at a rate of 60 kg K_2O ha^{-1} in the form of potassium sulphate (48% K_2O) before the third irrigation. All agricultural practices were applied at all treatments except water regime. Generally, the barley next was subjected to the recommended package of agronomic and plant protection regime of MALR to obtain a healthy crop.

At harvest on April 14th of 2018 and May 2th of 2019, plant height, spike length, number of spikes/m^2, number of spikelets/spike, number of grains/spike, 1000–grain weight, grain yield ha^{-1}, and water use efficiency (WUE) were calculated.

Rhizosphere soil samples were collected at plant harvest growth stage and analyzed for the determination of phosphatase activity; disodium phenyl phosphate served as enzyme substrate (Öhlinger, 1996). The most probable number (MPN) of Azotobacters was determined after incubating the tubes at 28+2C° for 7 days, on a modified Ashby's medium (Abd-el-Malek and Ishac, 1968). The estimates of numbers of Azotobacters by MPN technique was calculated using Cochran's tables (Cochran, 1950).

Separation of Arbuscular Mycorrhizal (VAM):

Different spores of mycorrhizae were isolated from soil pre-inoculated with mycorrhiza (*Glomus macrocarpium*) by wet-sieving and decantation method as described by Gerdeman and Nicolson (1963). The VAM inocula was mixed with pure sand and kept in the refrigerator to be used in the inoculation.

Determination of root colonization percentage and number of spores per gram was carried out according the method described by Phillips and Hayman (1970). Giovannetti and Mosse (1980) intersect method was used to estimate the VAM infection percentage, using the equation:

$$Root\ colonization\ \% = \frac{No.\ of\ positive\ intersect\ points}{Total\ number\ of\ observed\ intersect\ points}$$

Bio dependency (BD) is the increase of yield or yield components which refer to the bio-inoculation and it is calculated as follows:

$$Yield\ Bio-Dependency\ (\%) = \frac{Yield\ (Inoculated) - Yield\ (UnInoculated)}{Yield\ (UnInoculated)}\ x\ 100$$

Water use efficiency (kg m^{-3}) on grain basis was calculated by dividing the grain yield (kg ha^{-1}) by quantity of water applied (m^3 ha^{-1}) (sum of rainfall and quantity of water added by irrigation) during the growth period (Stanhill, 1987) as follows:

$$WUE\ \left(\frac{kg}{m^3}\right) = \frac{Grain\ yield\ \left(\frac{kg}{ha}\right)}{Applied\ water\ \left(\frac{m^3}{ha}\right)}$$

The milled grains was wet-digested with H_2SO_4-H_2O_2 (Lowther, 1980) and the following determinations were carried out as follows:

Nitrogen percentage was determined by using the modified micro-Kjeldahl method according to A.O.A.C. (1980), phosphorus percentage was determined by using Vanado molybdate phosphoric method (Page et al., 1982), and potassium percentage was determined by using Flam-photometer according to (Page et al., 1982).

Soil moisture was measured by the gravimetric method for samples collected from the experimental site. Amount of irrigation water to be applied in each irrigation was determined using the following equation:

$$d = \frac{(\theta_{vFC} - \theta_{vPWP})}{100} * D * P$$

Where, d: amount of water applied, mm; θ_{vFC}: volumetric moisture content at the field capacity %; θ_{vPWP}: volumetric moisture content before irrigation %; D: depth of soil to be irrigated, cm, and P: plant cover ratio.

The obtained data in both seasons of study were subjected to analysis of variance as a factorial experiment in split plot design. L.S.D. method was used to differentiate between means according to (Snedecor and Cochran, 1969).

Table 1. The main physical and chemical properties of the experimental soil

Soil depth (cm)	Particle size distribution			Texture class	Chemical analysis						
	Sand (%)	Silt (%)	Clay (%)		pH	EC dS/m	$CaCO_3$ (%)	Water soluble Cations (meq/l)			
								Ca	Mg	K	Na
0-15	57	28	15	sandy loam	8.5	0.85	15.9	1.6	1.4	1.3	4.5
15-30	61	27	12	sandy loam	8.6	1.60	23.2	3.4	2.1	1.1	10.0

RESULTS AND DISCUSSION

Irrigation regimes are one of the very important factors which can significantly affect the crop growth and yield. Determination of the optimum irrigation regime for barley is very critical for better crop yields. So, a correct decision on the irrigation regime should be based on a thorough understanding of the environmental factors influencing barley growth, development, yield and quality. The present investigation provided considerable information useful in applying different water regimes on productivity and water use efficiency of barley crop under conditions of the North Western Coast of Egypt.

Weather data:

The total rainfall in Nov.-May period was 89.1 mm and 97.2 mm in 2017/2018 and 2018/2019, respectively (Table 2). The mean temperature was 18.7 °C in the first season and 16.7 °C in the second season. The mean relative humidity was 67.5% in the first season and 68.0% in the second season (Table 3). The soil moisture at field capacity was 21.4% and soil moisture at permanent wilting point was 8.5%.

Phosphatase enzyme:

Phosphatase activity recorded significant increase due to mixed biofertilization and rainfed treatment (Table 4). In the case of rainfed, the highest phosphatase activity was 0.37 and 0.40 mg phenol/g soil/24h at the first (2017/2018) and second (2018/2019) growing seasons, respectively, while mixed biofertilization treatment recorded the highest phosphatase activity as 0.50 and 0.53 mg phenol/g soil/24h at the first and second growing seasons, respectively. George et al., (2002) stated that phosphatase enzyme is capable of mineralizing organic phosphorus into inorganic phosphates that provides high phosphate availability for plant.

Mycorrhizal infection and number of spores:

The root colonization of barley plants and number of spores / g soil in the rhizosphere soil were affected by water regime and microbial inoculation (Table 4).

Table 2. The quantity of precipitation (mm) during the two growing seasons

Month growing season	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
2017/2018	20.86	8.69	40.98	11.60	1.27	5.63	0.02	89.05
2018/2019	20.71	33.43	10.13	11.71	16.91	4.26	0.01	97.16

Source: Weather Underground, Best Forecast (2017/2018 and 2018/2019).

Table 3. Weather parameters of Maryout during 2017/2018 and 2018/2019 growing seasons

Period date	First season (2017/2018)				Second season (2018/2019)			
	Mean T C°	Dew point (C°)	Relative humidity	Wind speed (km/h)	Mean T C°	Dew point (C°)	Relative humidity	Wind speed (km/h)
1-10/12/2017	17.46	10.64	65.90	11.57	16.22	11.47	74.04	15.86
11-20/12/2017	18.45	13.08	72.05	12.42	16.52	11.79	74.77	14.18
21-30/12/2017	16.03	10.77	72.27	14.52	14.98	10.06	73.15	12.44
1-10/1/2018	15.38	10.21	72.29	15.87	12.26	6.97	71.55	17.92
11-20/1/2018	15.18	8.67	66.77	15.44	12.64	7.43	71.96	16.06
21-30/1/2018	14.56	8.15	66.60	17.25	13.22	5.67	63.56	12.45
1-10/2/2018	17.14	12.16	74.29	8.73	14.32	8.26	68.89	10.54
11-20/2/2018	15.23	10.13	72.85	11.23	13.08	7.28	69.98	12.51
21-30/2/2018	16.85	9.98	66.21	10.68	15.34	8.44	66.86	17.74
1-10/3/2018	18.57	12.06	68.32	11.78	14.90	9.08	69.41	12.20
11-20/3/2018	17.95	11.76	69.76	10.59	15.75	10.26	71.19	15.74
21-30/3/2018	18.65	10.50	61.20	15.15	16.88	11.16	70.42	16.70
1-10/4/2018	18.48	12.14	67.91	13.73	17.34	11.62	70.50	12.35
11-20/4/2018	22.38	13.92	62.06	11.45	17.84	11.00	66.31	16.75
21-30/4/2018	21.49	13.44	62.50	16.11	20.03	10.87	58.44	14.47
1-10/5/2018	22.99	16.45	67.98	16.39	20.55	12.92	63.28	15.00
11-20/5/2018	23.84	16.46	65.61	16.30	23.26	14.34	59.50	12.35
21-30/5/2018	25.76	17.22	61.03	13.12	25.65	16.06	59.30	13.35

The percent of root colonization was higher due to the rainfed and the inoculation with mixed treatments (36.25 in the two seasons for rainfed and 51.5 and 54.0 for mixed infection) compared to non-inoculated plants. On the other side, the number of spores per gram soil were 13.7 and 14.2 in the two seasons for rainfed and 15.05 and 15.03 for mixed infection. These results agreed with those obtained by Bahadori et al. (2013) who found that mixed inoculation have a positive effect on increasing root colonization and numbers of VAM spores. Also, Garbaye (1994) reported that bacteria produce phytohormones and cohabit in the rhizosphere with VAM fungi and these might stimulate the plant-fungus interaction.

Azotobacter counts:

Table (4) showed that there are high variations of Azotobacter counts between all treatments in barley rhizosphere soil in both the two growing seasons. The highest Azotobacter counts are recorded with rainfed water regime (39.0 and 43.3×10^{-4} cfu / g dry soil) and with mixed biofertilizer treatment (39.5 and 48.8×10^{-4} cfu / g dry soil). These data agreed with those found by Aye (2011) who reported that the mixture of biofertilizers produce the best result.

Effect of irrigation regimes on yield parameters:

The data presented in Table (5) showed that irrigation treatments significant affected the plant height, spike length, number of spikes/m^2, number of grains/spike, 1000-grain weight and grain yield ha^{-1}. of barley, while, the number of spikelets/spike did not has significant effect with irrigation treatments in the two growing seasons. Three times (Optimum irrigation regime) due to irrigating barley plants increased the previous studied traits by 23.51, 12.90, 26.91, 12.89, 44.96, 107.56, 5.41 and 6.12 %, respectively in the first season, and by 14.19,11.23, 10.39, 10.64, 15.90 ,40.64, 4.26 and 7.22 %, respectively, in the second season compared with the control (rainfed irrigation). These increases due to increasing irrigation water applied which enhanced the roots growth and uptake of nutrients which in turn has positively effects on barley yield and its components.

The obtained results in Table 5 indicate the significant stimulation of irrigation of plants grown under rainfed conditions in the arid and semi-arid regions of the world. It seems that water deficit limits contribution of photosynthesis in formation of grain yield (Al-Khateeb, 2006; El Hwary and Yagoub, 2011; Shrief and El-Mohsen, 2014) and drought is the most important abiotic stress and also is a major restriction to barley and other agricultural production in arid and semi-arid regions. Thus, drought reduces more than 50% of yields for most major crops such as wheat (Wang et al., 2012) and barley (Shrief and El-Mohsen, 2014).

Effect of bio-fertilizers on yield parameters:

Table (5) showed that, biofertilization significant increased yield and yield components (plant height, spike length, number of spikes/m^2, number of grains/spike and 1000-grain weight and water use efficiency) of barley plants grown in both seasons, except number of spikelets/spike. The highest mean values of spike length, (11.35 and 12.22 cm), number of spikes/m^2 (208.15 and 222.26), number of grains/spike (44.41and 44.81), 1000-grain weight (46.48 and 52.43 g) and grain yield ha^{-1}, (4.10 and 4.98 ton) were obtained by barley plants inoculated by both Mycorrhiza and Azotobacter together during the two growing seasons. On the other side, the highest value of plant height (89.47 cm) was recorded by using Mycorrhiza and Azotobacter together in the first season, whereas in the second season, the highest value (96.61 cm) were detected by applying Azotobacter only. These findings are in agreement with those obtained by Najafi et al., (2012) who found positive effects of microorganism symbiosis on barley root growth and water and nutrition absorption. In addition, Raklami et al., (2019) pointed out a positive impact of biofertilizers and interest of adoption of innovative practices improving crops productivity and soil fertility. Berhanu et al., (2013) reported that there was a positive effect of using Mycorrhizae and Azotobacter on wheat crop yield. They believe Azotobacter stimulates hair root growth and, therefore, more longitudinal growth of the fungi mycelium and their penetration into the deeper layers of soil that increases plant nutrient availability increases.

Effect of the interactions

It is clear from Tables 4 and 5 that, yield, yield components and water use efficiency for the second growing season expressed higher values than those obtained in the first season. This might be due to the high quantity and regular distribution of precipitations during the second season (Table, 2). In addition, it is also due to early cultivation during the second season and plant adaptation as well i.e. growth stage, adaptation of barley plants to meteorological factors that suitable to physiological process and increasing plant life period. Moreover, up to 46 % of precipitation was concentrated in January (40.98 mm) as shown in Table (2) of the first season which useless for vegetation. The difference between the two seasons for grain yield, yield components and water use efficiency also, may have been caused by different environmental conditions between the two seasons (Table, 3).

Table 4. The values of Mycorrhizal infection %, Mycorrhiza No of spore/g soil, Azotobacter densities and Phosphatase enzyme in 2017/2018 and 2018/2019 growing seasons as influenced by irrigation water regimes and biofertilization inoculation.

Treatments	Mycorrhizal Infection (%)		Mycorrhiza No. of spore/g soil		Azotobacter densities x10^4 (cfu/g dry soil)		Phosphatase enzyme (mg phenol/g soil/24h)	
	17/18	18/19	17/18	18/19	17/18	18/19	17/18	18/19
Irrigation water regimes (A):								
Rainfed only	36.25	36.25	13.70	14.18	39.00	43.25	0.37	0.40
One irrigation at tillering stage	31.25	31.25	12.95	12.98	25.25	32.50	0.31	0.30
Two irrigations (one at tillering + one at potting stage)	31.50	34.75	12.18	12.35	20.50	28.50	0.35	0.38
Three irrigations (one at tillering + one at potting + one at grain-seating stage)	25.75	25.00	11.13	10.58	14.75	22.00	0.32	0.28
L.S.D. (0.05)	N.S	0.016	0.016	0.016	0.016	0.016	0.02	0.02
Biofertilization (B):								
Non-inoculating	12.75	13.00	8.58	9.03	19.75	24.25	0.29	0.33
Mycorrhiza	40.25	41.75	14.80	14.93	18.25	21.75	0.46	0.47
Azotobacter	20.25	18.50	11.13	11.10	22.00	31.50	0.19	0.25
Mycorrhiza + Azotobacter	51.50	54.00	15.05	15.03	39.50	48.75	0.50	0. 53
L.S.D. (0.05)	16.56	0.011	0.011	0.011	0.011	0.011	0.01	0.01
Interaction: AxB	*	*	*	*	*	*	*	*

Table 5. Average values of yield and yield components of barley as affected by irrigation and bio fertilization in 2017/2018 and 2018/2019 growing seasons.

Treatments	Plant height (cm)		Spike length (cm)		No. of spikes/m^2		No. of pikelets/spike		No. of grains / spike		1000 grain weight (g)		Grain yield (ton ha^{-1})	
	17/18	18/19	17/18	18/19	17/18	18/19	17/18	18/19	17/18	18/19	17/18	18/19	17/18	18/19
Irrigation (A):														
Rainfall	78.61	89.27	9.59	11.31	172.19	203.35	16.92	16.96	40.71	41.65	36.63	47.68	2.38	3.80
1	85.39	93.64	11.11	12.06	193.33	213.04	16.97	16.98	43.85	44.17	42.99	50.82	3.44	4.60
2	93.97	100.20	11.98	12.50	211.30	219.09	16.91	17.01	45.93	46.03	49.98	53.98	4.62	5.18
3	97.09	101.94	12.35	12.58	218.52	224.47	16.96	17.01	45.96	46.08	53.10	55.26	4.94	5.35
New L.S.D. (0.05)	1.91	1.79	0.22	0.05	2.45	2.21	N.S.	N.S	0.09	0.46	0.27	0.37	0.06	0.07
Biofertilization (B):														
Without	87.36	95.39	11.15	11.99	186.81	206.35	16.92	16.96	43.48	43.84	44.07	50.80	3.44	4.38
Mycorrhiza	88.98	96.47	11.24	12.11	198.13	214.21	16.94	17.00	44.27	44.59	46.01	52.22	3.87	4.75
Azotobacter	89.26	96.61	11.29	12.13	202.26	217.13	16.96	16.99	44.31	44.69	46.14	52.29	3.96	4.83
Myco. + Azot.	89.47	96.58	11.35	12.22	208.15	222.26	16.94	17.01	44.41	44.81	46.48	52.43	4.10	4.98
L.S.D. (0.05)	1.78	0.87	0.17	0.10	1.87	1.43	N.S.	N.S	0.08	0.23	0.19	0.24	0.04	0.04
Interaction: AxB	*	*	*	*	*	*	N.S	N.S	*	*	*	*	*	*

Comparing the mean values of grin yield for all treatments, the results showed that inoculation with VAM+Azoto, with three irrigation treatment is considered as the best treatment under the experimental conditions to produce the highest grain yield of barley (5.09 ton ha^{-1}). Without inoculation under rainfed water treatment the lowest grain yield (2.18 ton ha^{-1}) was produced under experiment conditions. (Fig. 1). These data are in agreement with the finding by Heitman et al. (2018).

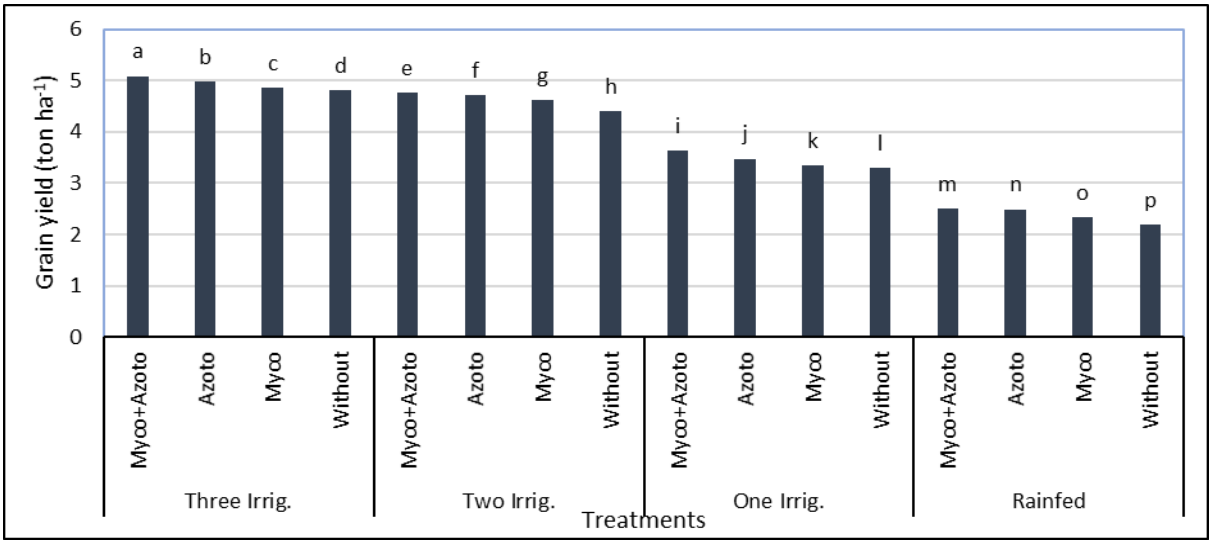

Fig. 1. Comparing the mean values of grain yield under irrigation water regimes and bio-fertilizers treatments.

Grains nutrient content:

Results in Table (6) showed that grains nitrogen concentration were much higher in the inoculated plants than uninoculated ones. The three-irrigation treatment with Mycorrhiza+Azotobacter inoculation treatment significantly recorded the highest grains nitrogen contents (1.95 and 1.95; 1.96 and 2.02 %) for the two seasons, respectively. The relative increases were 5.4, 6.6 and 4.3, 11.6% compared with rainfed and uninoculated treatment, respectively. Chen et al. (2018) reported that the contribution of VAM fungi to plant nitrogen nutrition varies widely in diverse symbiotic systems, but VAM fungi can transfer substantial amounts of nitrogen to their hosts. On the other hand, applied three irrigations with mycorrhiza+Azotobacter significantly increased the grain phosphorus concentration by 6.12 and 16.67% for 1st season and 7.22 and 12.37% for 2nd season.

The three-irrigation treatment and Mycorrhiza + Azotobacter bio-fertilizer treatment increased non-significantly potassium concentration in the grains by 1.59 and 1.01%; 0.43 and 1.73% as compared with rainfed and without bio-fertilizers in the two seasons, respectively. Govindarajulu et al., (2005) found that VAM fungi are able to deliver enough N for optimal plant growth and development and that inorganic nitrogen taken up by the fungi can be incorporated into amino acids that are further transferred to the plant. Earlier results of studies indicate that VAM fungi increase the root surface area that results increasing plant nutrient uptake (Zhang et al., 2016). Sary and Elsokkary (2019) found that application of effective microorganisms reduces the adverse effect of drought on NPK concentration in olives leaf.

Water use efficiency (WUE):

Grain water use efficiency (grain WUE) has the highest values as a result of mycorrhiza+Azotobacter inoculation treatment and significantly increased up to 0.22 and 0.28 kg m^{-3} as compared to uninoculated treatments in the two growing seasons (Table 6). The lower water treatment (rainfed) has the highest value of grain WUE which increased up to 1.22 and 2.39 kg m^{-3} in the two seasons as compared to three water applications treatment. Also, rainfed treatment increased with 0.12 and 1.60; 0.05 and 0.61 kg m^{-3} compared to two and one irrigation treatments in the two seasons, respectively. Mycorrhizal plants required less water than noncolonized plants to produce 1 kg of dry grains (Eulenstein et al., 2017). Mbava et al., (2020) confirmed that crop type had a significant effect on WUE with cereals producing an average of 2.37 kg dry grain per cubic meter (m^{-3}) of water.

Bio-Dependency

Bio-Dependency of grain yields take the same trend in the two seasons. The highest grain yield bio-dependency values were recorded under rainfed treatment. Figure (2) showed that the grain yield bio-dependency in the second season (2018/2019) significantly increased by 6.70, 14.08 and 14.88% under rainfed treatments and by 1.17, 3.52 and 5.87% under three irrigation applications for inoculation with Mycorrhiza, Azotobacter and Mycorrhiza+Azotobacter, respectively as compared to without inoculation treatment.

Table 6. Average values of N, P, and K percentage and water use efficiency of barley as affected by irrigation and bio-fertilization in 2017/2018 and 2018/2019 growing seasons.

Treatments	N (%)		P (%)		K (%)		W.U.E (kg/m^3)	
	17/18	18/19	17/18	18/19	17/18	18/19	17/18	18/19
Irrigation (A):								
Rainfall (control)	1.85	1.88	0.98	0.97	0.69	0.70	2.67	3.92
1	1.87	1.90	1.00	1.01	0.69	0.70	2.62	3.31
2	1.90	1.96	1.01	1.03	0.70	0.70	2.15	2.32
3	1.95	1.96	1.04	1.04	0.70	0.70	1.45	1.53
L.S.D. $_{(0.05)}$	0.05	0.02	0.02	0.02	N.S	N.S	0.08	0.07
Biofertilization (B):								
Without biofertilization	1.83	1.81	0.96	0.97	0.69	0.69	2.11	2.62
Mycorrhiza	1.86	1.89	1.01	1.04	0.70	0.70	2.19	2.72
Azotobacter	1.93	1.97	0.93	0.95	0.70	0.70	2.29	2.84
Mycorrhiza + Azotobacter	1.95	2.02	1.12	1.09	0.70	0.71	2.33	2.90
L.S.D. $_{(0.05)}$	0.03	0.03	0.01	0.03	N.S	N.S	0.08	0.07
Interaction: AXB	*	*	*	*	N.S	N.S	*	*

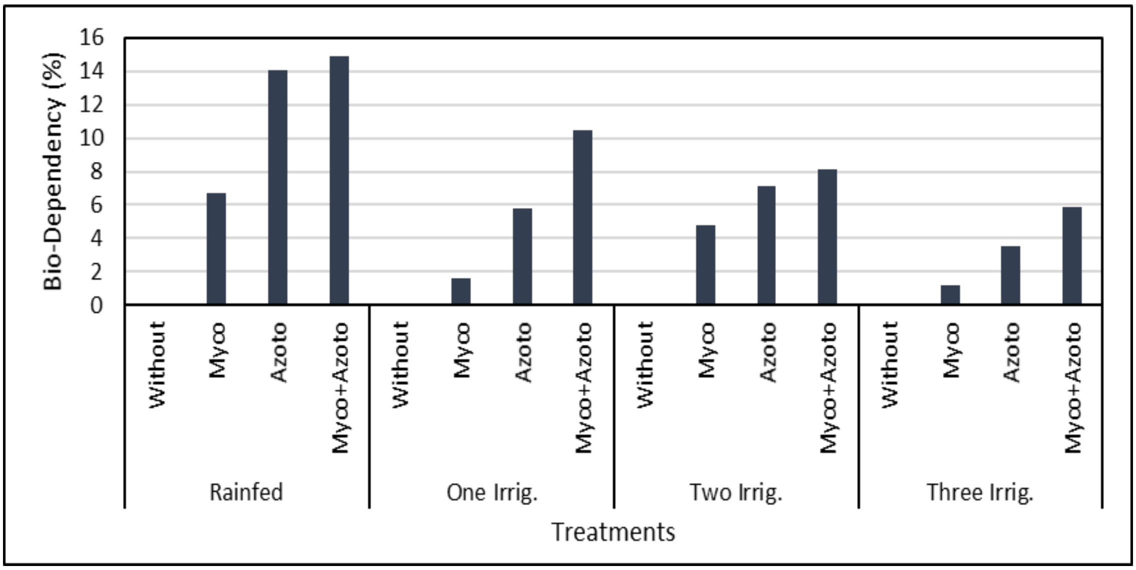

Fig. 2. Grain yield bio-dependency in 2018/2019 season as affected by water and biofertilizers treatments.

Elhindi et al., (2017) and Abdelhameid (2019) found that the high dependency on Mycorrhiza will improve plant growth, photosynthetic efficiency, gas exchange and water use efficiency under salinity stress. Also, the extraradical mycelium strategy of mycorrhiza resulted in protection of sensitive crop species against biotic and abiotic stresses and can be implemented in low- and high-input cropping systems (Brito et al., 2019).

CONCLUSIONS

The present study advises that the dual application of Mycorrhiza and Azotobacter was more effective than single inoculation for increasing the absorption of water and nutrients from the soil of low nutrients content. This could improve the production of barley yield and yield components cultivated in low fertile sandy loam soil. Development of a sustainable biofertilizers technology for maximum and environmentally friendly crop production and preserve soil sustainability is highly needed.

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الملخص العربي

استجابة الشعير للتسميد الحيوى تحت ظروف الرى التكميلى والمطرى بالساحل الشمالى الغربي بمصر

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يهدف البحث الى تقييم محصول الحبوب ومكوناته وكذا كفاءة استخدام المياه بواسطة نبات الشعير صنف جيزة ١٢٦ نتيجة المعاملات بكمية مياه الري والتسميد الحيوى، أجريت تجربة حقلية في المزرعة التجريبية لمحطة بحوث مريوط، مركز بحوث الصحراء، مصر. خلال موسمين زراعيين متتاليين٢٠١٨/٢٠١٧ و٢٠١٩/٢٠١٨ تحت نظام القطع المنشقة حيث كان العامل الرئيسى فيها هو عدد الريات والمعاملة التحت رئيسية هي التسميد الحيوى فى ثلاث مكررات. أشارت النتائج التي تم الحصول عليها أن محصول الحبوب ومكونات الانتاج (ارتفاع النبات وطول السنبلة وعدد السنابل/ م٢ وعدد الحبوب/ سنبلة ووزن ١٠٠٠ حبة) وكذلك تركيز عناصر النيتروجين والفسفور والبوتاسيوم في الحبوب واستخدام المياه قد زادت معنوياً مع زيادة كميات مياه الري والتسميد الحيوي. بينما لم تتأثر معنوياً عدد السنيبلات/ السنبلة وتركيز البوتاسيوم في الحبوب بكميات مياه الري أو معاملات التسميد الحيوي. كذلك زادت معنوياً كفاءة استخدام الماء (كجم م٣) لإنتاجية الحبوب مع زيادة كميات مياه الري والتلقيح بالتسميد الحيوي في كلا الموسمين. وقد سجلت جميع الصفات المدروسة مع إضافة ماء الري ثلاث مرات أعلى قيم وذلك في كلا الموسمين. فيما يتعلق بتأثير التلقيح بالسماد الحيوي، أظهرت النتائج أن أكبر قيم مقاسة لجميع الصفات المدروسة كانت في معاملة التلقيح باستخدام الميكوريزا والأزوتوباكتر معًا كلقاح مزدوج لكلا الموسمين باستثناء طول النبات الذي سجل أعلى القيم مع التلقيح بكلا الميكوريزا والأزوتوباكتر في الموسم الأول وبالتلقيح بالأزوتوباكتر في الموسم الثانى. على الجانب الآخر، تم تسجيل أعلى قيمة لتركيز النيتروجين في الحبوب مع معاملة الأزوتوباكتر بمفرده في الموسمين. وتشير نتائج الدراسة في مجملها ان نباتات الشعير المروية ثلاث مرات في الموسم مع مياه المطر والمسمدة بلقاح الميكوريزا والأزوتوباكتر معًا سجلت أعلى قيم للمحصول ومكوناته وكذلك كفاءة استخدام ماء الى في الساحل الشمالي الغربي لمصر.