J. of Soil Sciences and Agricultural Engineering, Mansoura Univ., Vol. 16 (2): 17 - 30, 2025

Journal of Soil Sciences and Agricultural Engineering

Journal homepage & Available online at: www.jssae.journals.ekb.eg

Evaluation of Barley Water Relations and Productivity on Clay Soils at the North Nile Delta as Impacted by Irrigation Technique and Biochemical Fertilization

Khalifa, R. M. *

Soils and water Department -Faculty of Agriculture -Damietta University -Damietta --Egypt

ABSTRACT

A two-year winter study at Sakha Agricultural Research Station, Kafrelsheikh Governorate, evaluated irrigation and fertilization strategies for optimizing barley production, water relations, and economic returns. Three irrigation turnoffs: at 100%(S1), 90% (S_2) and 85% (S_3) of the strip length (SL). Fertilization treatments; B1 (100% R_{NP}), B2 (75% R_{NP} + 50% (*Biofertale* + rhizobacterien), and B_3 (50% R_{NP} + 100% biofertilizers).Results showed S_1 required the highest seasonal water application, while S_2 and S_3 saved 7.31% and 10.88% water, respectively, versus S_1. Despite reduced irrigation, S_3 increased grain yield by 8.48% and 7.90% over S_1 in consecutive seasons. Fertilizer strategy B_3 outperformed B_1, boosting grain yield by 19.18% and 20.57%. The S_3B_3 combination achieved peak water productivity, enhancing irrigation efficiency for grain and straw yields. This synergy reduced water consumption while maximizing application efficiency, leading to the highest net income and economic returns per water unit.S_3B_3 also conserved groundwater, saving water and mineral fertilizer use. The integration of biofertilizers in B_2 and B_3 reduced reliance on synthetic inputs, supporting sustainable practices without compromising yield. Financially, S_3B_3 delivered superior cost-effectiveness for biological and grain yields, emphasizing its viability for resource-limited settings.The study underscores the potential of combining deficit irrigation (S_3) with biofertilizer-augmented nutrition (B_3) to balance water savings, yield enhancement, and profitability. By optimizing irrigation turnoff points and substituting mineral fertilizers with bioalternatives, farmers can achieve sustainable barley production, addressing water scarcity and environmental concerns. These strategies offer a scalable model for improving agricultural resilience in similar semi-arid regions.

Keywords: Barley ; Bio-chemical fertilizers ; turn off irrigation ; Economic return; groundwater contribution

INTRODUCTION

The fourth most important grain crop in Egypt is barley (*Hordeum vulgare L.*). Unlike other grains, it can withstand harsh environmental conditions. According to FAOstat, 2021, it is cultivated in 0.06 Mha in Egypt, yielding 6.2 Mt of production at an average of 3.6 $Mgha^{-1}$.. In this regard, Egypt's barley productivity is on average in the top 70 nations.

One of the most important and significant grain crops in the world is barley (*Hordeum vulgare L.*). Barley is regarded as the primary food supply in many North African nations and grows in a variety of habitats and places across the globe, from the high elevations of the Himalayas to the Middle Eastern deserts. The primary cereal crop in many dry regions of the world, it is also regarded as a moderately stress-tolerant plant and plays a crucial role in the livelihoods of many farmers in these areas (Kohistani, *et al*., 2019 and Masrahi *et al*., 2023). The most valuable and significant byproduct of the barley plant, which is utilised for food and fodder, are grains. Animals frequently eat straw, and it can also occasionally be added to compost. Manufacturing also makes use of grains. Although barley is a key grain crop in many developing nations and ranks fourth in the world in terms of grain production behind wheat, rice, and maize, barley plants are frequently subjected to drought stress at various phases of growth (Fatemi *et al*., 2022 and Zaib *et al*., 2023) .

The most crucial element influencing the pattern and approach to exploiting agricultural land is water. According to Singh *et al*., (2023) and Suna *et al*., (2023), the amount of productivity is contingent upon the availability of water and its suitability for agriculture. Water scarcity is the most significant worldwide environmental issue of the twenty-first century (Awad-Allah *et al*., 2022). About 80–90% of the freshwater resources utilised by humans worldwide are consumed by agriculture, with the majority of this water going towards crop production (Abdelhameid *et al*., 2019; Mishra, 2023; Tiwari *et al*., 2023).

Because there are few renewable freshwater resources and precipitation mostly falls on a small strip of coastal areas, Egypt has water stress, just like several other parts of the world. One of Egypt's biggest obstacles to crop production is the lack and restriction of water resources. To achieve this goal, it is necessary to refine new approaches and strategies that are very successful in cutting and rationalising irrigation water use (Abdelraouf *et al*. 2020 a, b ; Awad-Allah, *et al*., 2022;Elshamy *et al*., 2020 and ELshafie *et al*., 2021). One of these techniques is turned-off irrigation from strip length (strip irrigation) as a popular form of surface irrigation, strip irrigation works well for growing wheat or barley, particularly in clay soils. The wetting front is permitted to extend to the tail end of the boundary under the conventional irrigation methods used by the local farmers, which causes greater water loss through deep percolation. The irrigation front should therefore be halted before the end of the cultivated border, a process known as stop irrigation, in order to maximise the

---

*** Corresponding author.**
E-mail address: dr_ramykhalifa@yahoo.com
DOI: 10.21608/jssae.2025.273433.1265

benefits of horizontal water movement in such clay soils. The water front will advance to irrigate more cultivated area after the stop irrigation event, and then it will halt. This process is regarded as a straightforward, easy, and efficient method of conserving water. Furthermore, less water will seep into the drainage system in the region (El-Hadidi *et al*., 2016 and Khalifa *et al*., 2018 on wheat; Khalifa (2019) on faba bean; and Khalifa (2024) on canola).

The recommended number of irrigations must be applied at the appropriate and timely stages of barley growth, whether vegetative or reproductive, to generate a good and high yield. According to Pardo *et al.* (2022), biological fertilizers are crucial in mitigating the impact of drought on barley yield. As a result, yield serves as both a standard for development under drought stress and a measure of how well biofertilizers conserve water in drought-stressed environments (Abdelhameid *et al*., 2019 and Sharma *et al*., 2022).

Biofertilizers are receiving a lot of attention and have become a viable alternative to applying chemical inputs to meet fertilizer needs. By enhancing soil fertility and health, their use in agriculture as an alternative to chemical fertilizers has both economic and ecological advantages (Soltan *et al*., 2018 and Fayed *et al*., 2021). the function of AMF and microbes like as biofertale is to transform inaccessible minerals and organic molecules into forms that plants can use. Additionally, they strengthen the root system, lengthen the roots, and increase root biomass, all of which contribute to increased plant growth and production (Abdelhameid *et al*., 2019). According to Thirkell *et al.* (2017), barley, like other cereal crops, is linked to this common fungus, which can improve plant uptake of soil nutrients and water and boost nutrient availability.

A growing number of research show the value of AMF inoculation and its capacity to lessen the negative consequences of abiotic stressors, such as drought (Bernardo *et al*., 2019 ; Kamali *et al*., 2020 and Jerbi *et al*., 2022). In support of this, Thalooth *et al.* (2012) reported that, in comparison to the control under water stress conditions, the application of phosphate solubilising bacteria as a bio-fertilizer (phosphoreine or biofertale) resulted in a notable improvement in the yield and yield components of the barley crop. Several other studies have also demonstrated that the application of arbuscular mycorrhizal fungus in semi-arid areas enhanced the uptake of certain nutrients, resulting in a rise in barley yield and its constituent parts (Masrahi *et al*., 2023).

In sustainable agriculture, the relationship between deficit irrigation (DI) and biofertilizers has drawn a lot of attention as scientists look for ways to work together to improve crop resilience in water-limited environments. Biofertilizers, especially plant growth-promoting rhizobacteria (PGPR) and arbuscular mycorrhizal fungi (AMF), improve nutrient uptake, promote root elongation and soil spread, and alter stress-responsive phytohormones to reduce drought stress. According to recent research, crop yields can be maintained or even increased while water use is decreased by combining biofertilizers with DI techniques. According to Alotaibi *et al.* (2024), the application of biofertilizers increased plant resistance to drought stress, as evidenced by an increase in a number of attributes when biofertilizer treatments were used. Begum *et al.* (2019) show how AMF can increase maize's water-use efficiency under DI. Abd El-Azeem, S., & Bucking, H. (2023) and Abdelaal *et al*. (2024). showed that by reducing the negative impacts of drought stress, the environmentally friendly application of AMF can enhance wheat plant growth and grain yield. The significance of AMF in agricultural production and optimising wheat grain yield is demonstrated by these findings. Mycorrhiza fungi have been shown to improve resilience to water stress and scavenge free radicals by enhancing enzymatic antioxidant activities (Gholinezhad *et al*., 2020).

According to Alsunuse *et al.* (2021), mycorrhizal plants outperformed nonmycorrhizal plants in terms of biomass and tissue P content at the lowest soil moisture level (-1.5 MPa) across all soil P and moisture levels.

Therefore, the current study aimed to holistically evaluate the synergistic impacts of strategic irrigation termination points (100%, 90%, and 85% of strip length) and integrated fertilization regimes—progressively substituting mineral NPK with biofertilizers (BioI and BioII)—on barley productivity, water resource efficiency, economic viability, and groundwater contributions in water-scarce agroecosystems. By analyzing interactions between irrigation precision, biofertilizer-mineral combinations, and groundwater utilization, the research sought to identify optimal practices for enhancing yield, conserving water and fertilizers, improving irrigation effectiveness, and maximizing financial returns, ultimately advancing sustainable winter barley production under resource-constrained conditions."

MATERIALS AND METHODS

In order to investigate the effects of irrigation strip length and bio-chemical fertilizers on barley production and its water relations, as well as the contribution of groundwater and financial returns, field experiments were carried out at the experimental farm of Agricultural Research station (Sakha), Governorate of Kafr El-Sheikh , over the course of two consecutive winter seasons in 2015/2016 and 2016/2017. According to Kahlown *et al.* (2005), the groundwater table depth of 78 cm is regarded as a shallow water table and may help meet the irrigation water requirements of barley crops. Table (1) displays the physical and chemical characteristics of the experimental field's soil (Klute, 1986; Page *et al*., 1982). Table (2) displays the Sakha station's Agro-meteorological data for the two research seasons.

In the first and second seasons, barley (Giza 123 cultivar were obtained from Giza Agriculture Research station) was drilled as a winter crop on November 25 and November 20, respectively, at a rate of 60 kg fed^{-1}. For every season, there were four irrigations. As a phosphate dissolving bacterium, biofertale (*Bacillus megatherium* var. phosphaticum) is used as an inoculating bacterium. It has the ability to produce a soluble phosphate by excreting organic acids, which lowers pH and causes the bonds of phosphate to dissolve, making them available for plant growth. and rhizobacterien (*Azotobacter chroococum* and *Azospirillum braensesil*) were registered with the Ministry of Agriculture's Biofertilizers unit Egypt after being adsorbed on peatmoss power as a carrier. In both seasons, 300 g fed^{-1} of each biofertilizer was applied. Before planting, barley grains were mixed for the inoculation, and in both seasons, irrigation was carried out directly. With the exception of the researched treatments (the duration of irrigation run treatments and bio-chemical fertilisers), all agronomic procedures for the crop in the analysed region were adhered to.

A split-plot with three repetitions was used for the experiment, and the main plots were assigned at random to the following irrigation strip length treatment durations(S): S_1=turn off the irrigation when water reach to the end of the strip long 100% of irrigation strip length (SL) (check treatment) S_2 = turn off irrigation at 90% of the irrigation strip length (SL) is when irrigation stops. S_3= turn off the irrigation at 85% of the irrigation strip length.

To prevent water from moving laterally, ditches that were 1.5 meters wide were used to separate the major plots. Each planted strip was 100 m in length and 7.5 m in width, for a total area of 750 m^2 for each irrigation treatment (strip), and land leveling 0.1% slope was performed. The volume of applied water was determined using the following formula: IW=irrigation time × discharge rate, and irrigation water was applied through a weir with a water discharge rate of 4L sec^{-1} m^{-1} width at 10 cm as effective head above the crest: $Q = 1.84\ L\ H^{1.5}$ (Masoud, 1979), where Q is the discharge rate ($m^3\ sec^{-1}$), L is the weir's length edge (cm), and H is the height of the water column above the weir crest (cm).

The following subplots were assigned at random to biochemical fertilizer technique(B): B_1= Applying the suggested rate at 100% of NP (100% RNP as control) B_2= Using 50% of the mix of biofertale (Bio1) + rhizobacterien (BioII) in combination with 75% RNP + inoculation barley grains B_3= Applying 50% RNP and 100% of the biofertale (Bio1) + rhizobacterien (BioII) mix to inoculation barley grains

The size of the subplot was 82.5 m^2, measuring 11 m in length and 7.5 m in breadth. When preparing the seedbed, phosphorus fertilizer was applied as calcium superphosphate (15.5% P_2O_5) at the prescribed dosage of 10.05 kg P fed^{-1}. In the form of ammonium nitrate (33.5%)N, nitrogen fertiliser was applied at the prescribed rate of 75 kg N fed^{-1} in two equal doses prior to the first irrigation after planting and the second one prior to the subsequent watering. The appropriate dose of K was administered to all plots at a rate of 19.92 kg K fed^{-1} in the form of potassium sulphate (48% K_2O). For the first and second seasons, harvesting occurred on April 25 and 27, respectively. Plant height (cm), spike length (cm), number of grains $spike^{-1}$, 1000 grain weight (g), grain and straw yields (kg fed^{-1}), and biological yield (Mg fed^{-1}) were the yield characteristics of barley that were measured.

Table 1. Physical and chemical characteristics of the experimental site's soil prior to barley plant cultivation (mean of the two seasons)

a- Chemical characteristics

Depth of soil,cm	*pH (1:2.5)	**EC ds m^{-1}	Sodium adsorption ratio	Soluble cations mmolc L^{-1}**				Soluble anions mmolc L^{-1}**			
				Ca^{+2}	Mg^{+2}	Na^{+1}	K^{+1}	CO_3^{-2}	HCO_3^{-1}	Cl^{-1}	SO_4^{-2}
0-15	8.14	4.43	9.17	7.75	9.43	26.87	0.25	0.00	5.75	16.70	21.58
15-30	8.07	4.64	8.78	8.55	10.47	27.03	0.35	0.00	5.75	17.65	23.00
30-45	8.10	4.85	9.21	8.60	10.86	28.74	0.30	0.00	6.54	18.33	23.63
45-60	8.11	5.16	10.17	8.86	10.60	31.74	0.40	0.00	6.54	20.64	24.42
Mean	-	4.77	9.33	8.44	10.34	28.60	0.33	0.00	6.15	18.33	23.23

***in Soil water suspension was used to determine it. **in Soil paste extract was used to determine**

b-Physical characteristics

Depth of soil	Particle size distribution			Textural class	IR $cmhr^{-1}$	Bulk density Mg m^{-3}	Total porosity, %	*Soil water constants, %		
	Clay%	Silt%	Sand%					FC	PWP	AW
0-15	56.90	26.62	16.48	clayey	0.84	1.282	51.62	45.26	24.16	21.10
15-30	54.31	28.12	17.57	clayey		1.363	48.57	43.95	23.10	20.85
30-45	53.26	28.88	17.86	clayey		1.371	48.26	39.36	21.24	18.12
45-60	50.63	29.84	19.53	clayey		1.392	47.47	36.88	21.15	15.73
Mean	53.78	28.37	17.86	clayey		1.352	48.98	41.36	22.41	18.95

FC= field capacity PWP= wilting point AW= available water * the gravimetric method was used to determine

Table 2. Average weather data for the Kafr El-Sheikh region throughout the course of the two barley crop growth seasons**

Variables	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
			1st season (2015/2016)			
Maximum Air temperature, c^o	24.4	19.7	18.40	22.58	24.50	30.03
Minimum Air temperature, c^o	14.42	8.36	6.35	9.35	11.60	18.62
Mean od Air temperature, c^o	19.41	14.03	12.38	15.97	18.05	24.33
Maximum Relative humidity%	87.0	88.6	85.6	85.0	81.5	81.6
Minimum Relative humidity%	64.2	67.2	62.5	53.1	58.3	41.8
Mean od Relative humidity%	75.6	77.9	74.05	69.05	69.9	61.7
Wind speed at 2m height (km h^{-1})	2.38	2.41	2.88	2.45	2.63	3.63
Pan Evaporation, mm/ month	244.6	250.4	252.4	251.9	359.2	593.8
Rainfall mm/month	-	25	43.22	-	13.2	-
			2nd season (2016/2017)			
Maximum Air temperature, c^o	24.9	19.3	18.2	19.7	21.7	26.6
Minimum Air temperature, c^o	17.9	10.8	5.7	10.2	17.9	21.6
Mean od Air temperature, c^o	21.4	15.1	12.0	15.0	19.8	24.1
Maximum Relative humidity%	77.9	85.4	87.3	85.8	84.9	79.4
Minimum Relative humidity%	56.8	65.1	62.9	60.1	60.4	50.8
Mean od Relative humidity%	67.4	75.3	74.7	73.0	72.7	65.1
Wind speed at 2m height (km h^{-1})	2.33	2.70	2.16	2.47	3.49	3.72
Pan Evaporation, mm/month	198.1	156.4	136.2	214.4	295.4	463.8
Rainfall mm/month	-	21.34	16.46	16.26	-	10.6

(Novica, 1979) Effective rainfall (ER) = incident rainfall × 0.7 Source: Sakha Agriculture Research Station meteorological station, located at 310 07-N latitude and 300 57-E longitude, with an elevation of roughly 6 meters above mean sea level**

Execution data collected

The quantity of water used for irrigation

The following formula was used to calculate the seasonal water application in accordance with Giriappa (1983): as follows: WA=ER+IW+GWC, where, ER is the amount of effective rainfall, GWC is the amount of soil moisture contribution to consumptive use from the shallow ground water table, Iw is the quantity of water delivered by irrigation, and Wa is the amount of water applied.

To the end of the planned irrigation run, various stations spaced 10 meters apart were stalked along each agricultural border. The time it took to reach the water front was noted at the start of the watering event and at the conclusion of each station's irrigation. As a result, the time it took for the water to vanish at each station was also noted from the start of irrigation. Each station's irrigation water progress, recession, and opportunity periods were also noted.

Consumption of Water (CW)

The soil moisture % was calculated (on a weight basis) prior to, 48 hours following, and at harvest in order to calculate the actual amount of water consumed by the developing plants. Samples of soil were collected every 15 cm down to a total depth of 60 cm. According to Hansen *et al*. (1979), this straightforward approach for determining consumptive use is based on actual crop-water consumed (ETc) or soil moisture depletion (SMD).

$$CW = \sum_{i=i}^{i=4} \frac{\theta 2-\theta 1}{100} * Dbi * Di \,,$$

Where: CW is the water consumption in the effective root zone (60 cm) in centimeters.

θ_1 is the percentage of soil moisture prior to the subsequent irrigation, and θ_2 is the gravimetric percentage of soil moisture 48 hours following irrigation.

Di is the soil layer depth (15 cm).

For each layer, Dbi is the bulk density (Mg m^{-3}) of the soil, and i is the number of soil layers (1-4).

Efficiency of water consumption (EWC)

The following is how efficiency of water consumption (EWC) values were determined using Doorenbos and Pruitt's (1975) methodology:

$$EWC= CW/WA *100,$$

Where: Efficiency of water Consumptive Use (%) = EWC

CW = Consumptive Use Total (m^3 fed^{-1}).

WA is equal to water applied (m^3 fed^{-1}).

productivity of water consumption (PWC)

Crop yield (grains and straw, kg fed^{-1}) per cubic metre of water consumption is the standard definition of productivity of water consumption (PWC). (Ali *et al*., 2007) was used to calculate it.

$$PWC= Y/CW$$

PWC= productivity of water consumption (kg m^{-3} water consumed)

Y= grains and straw yields (kg fed^{-1})

and

CW= Consumption of Water (m^3 fed^{-1}).

Productivity of applied water (PAW)

Productivity of applied water (PAW), is generally defined as crop yield (grains and straw kg fed^{-1}) per cubic meter of water applied. It was calculated according to (Ali *et al*, 2007).

$$PAW = Y/WA \,,$$

Where: Y= (grain & straw) yields kg fed^{-1}, and

WA= seasonal applied water (m^3 /fed)

PAW= productivity of applied water (kg /m^3 WA)

WAE, or water addition efficiency*:*

$$WAE= (Da – (Dp+ R0)/Da * 100,$$

Where Da = applied water (cm), Dp = deep percolation (cm), and R0 = runoff (cm), was the formula used in accordance with Downy (1970).

WDE, or water distribution efficiency:

According to James (1988), it was computed as follows:

$$WDE = (1- y/d) * 100.$$

Where d is the average depth of soil water stored throughout the irrigation strip length during irrigation, y is the average numerical departure from -d, and WDE is the water distribution efficiency.

Contribution to water requirement of Barley crop made by groundwater table (CGW)

It was computed in this way: When crop evapotranspiration (ETc) equals ET0×Kc, CGW is equal to

$$ETc-SMD/ETc \times 100.$$

Blaney and Cridle, Pan evaporation (Dorrenbos and Pruitt, 1975), and Penman Montieth (Allen *et al*., 1998) were the three methods used to derive ET0, SMD=soil moisture depletion=CW . Average values were computed and taken into account in the computation.

An economic assessment: It was computed using the FAO, 2000 equation, which includes:

Total income minus total costs is *net income (L.E fed^{-1}). * Net income (L.E fed^{-1}) / applied water (m^3 fed^{-1}) = net income from water unit (L.E m^{-3}) * Net income (L.E. fed^{-1}) divided by total cost (L.E. fed^{-1}) equals economic efficiency.

Statistical examination:

In accordance with Gomez and Gomez (1984), the collected data was statistically analysed, and treatment means were compared using the Duncan's multiple range test at 0.05 and 0.01 probability levels. All statistical analyses were carried out using SAS software.

RESULTS AND DISCUSSION

Applying seasonal water and conserving water

Irrigation water (IW), effective rainfall (ER), and contribution of ground water to crop water need (CGW) make up the three components of the quantity of seasonal water used for barley crops. In comparison to other irrigation strip length treatments during the first and second seasons, the data presented in Table 3 clearly demonstrates that the highest values of seasonal water applied were 2320.08 m3 fed^{-1} (55.24 cm) and 2315.04 m^3 fed^{-1} (55.12 cm) under turn off the irrigation at 100% of irrigation strip length (S_1). However, under turn off the irrigation at 85% of irrigation strip length (S_3) in the two growing seasons, the lowest values of seasonal water applied were 2071.44 m^3 fed^{-1} (49.32 cm) and 2059.68 m^3 fed^{-1} (49.04 cm), respectively. The longer irrigation process duration under irrigation strip length treatment (S_1) and, consequently, the higher volume of water applied, may be the reason for the seasonal increase in water application under (S_1) as compared to (S_2 and S_3) treatments. Due to increased rainfall (R) and contribution of ground water (CGW) during the first season, as Table 3 makes evident, there was a greater amount of seasonal water applied (WA) in the first season as opposed to the second. As a result, the two seasons' average water application was in the following descending order: $S_1>S_2> S_3$.

The greatest water savings, 248.64 m^3 fed^{-1} (10.72%) and 255.36 m^3 fed^{-1} (11.03%), were seen with turn off the irrigation at 85% of irrigation strip length (S_3) during the first and second seasons, respectively, when compared to turn off the irrigation at 100% of irrigation strip length (S_1) as a check treatment. However, with turn off the irrigation at 90% SL (S_2) and turn off the irrigation at 85% SL (S_3), the average water savings for the two growing seasons were 167.58 m^3 fed^{-1} (7.47%) and 252 m^3 fed^{-1} (10.88%), respectively. The greatest crop output would allow for the horizontal extension of agriculture and the watering of additional crops using the water that is saved.

These findings are very consistent with those of Moursi *et al.* (2014), EL-Hadidi *et al.* (2016), and Khalifa (2016&2019), who found that irrigation of wheat or faba beans at 85% of border or furrow length resulted in a moderate amount of water applied, therefore saving irrigation water, as opposed to irrigation at 100% of border or furrow length, which resulted in the highest amount of water applied.

Table 3. Effects of irrigation strip length treatments on barley crop seasonal water addition (SWA), water conservation across the two growing seasons

Irrigation strip length treatments (S)	Water components						Seasonal Total water addition (SWA)		Water conservation	
	IW		ER		CGW					
	cm	m^3fed^{-1}	cm	m^3fed^{-1}	Cm	m^3fed^{-1}	cm	m^3fed^{-1}	m^3fed^{-1}	%
					1st season					
S1	49.11	2062.62	5.70	239.40	0.43	18.06	55.24	2320.08	-	-
S2	44.45	1866.90	5.70	239.40	1.17	49.14	51.32	2155.44	164.64	7.10
S3	42.22	1773.24	5.70	239.40	1.40	58.80	49.32	2071.44	248.64	10.72
					2nd season					
S1	49.99	2095.80	4.54	190.68	0.59	24.78	55.12	2315.04	-	-
S2	45.79	1923.18	4.54	190.68	0.73	30.66	51.06	2144.52	170.52	7.37
S3	43.65	1833.30	4.54	190.68	0.85	35.70	49.04	2059.68	255.36	11.03
					The over mean values of the two seasons					
S1	49.55	2081.1	5.12	215.04	0.51	21.42	55.18	2317.56	-	-
S2	45.12	1895.04	5.12	215.04	0.95	39.90	51.19	2149.98	167.58	7.24
S3	42.94	1803.27	5.12	215.04	1.13	47.25	49.18	2065.56	252.0	10.88

IW= irrigation water ER= effective rainfall CGW= contribution of ground water SL=Irrigation strip length
(S_1)=Turn off the irrigation at 100% SL, (S_2)=Turn off the irrigation at 90% SL (S_3)=Turn off the irrigation at 85% SL

Consumption of water (CW)

Similar to the trend of seasonal water application, the barley plant's seasonal crop water consumption. Water consumption is directly related to the water condition of the soil, which is already influenced by the quantity of water used for irrigation. The data shown in Table (4) and Fig. (1) demonstrate that the application of bio-chemical fertilizers and irrigation strip length treatments had a discernible impact on the monthly and seasonal values of water consumptive usage. Under all treatments, it was observed that the monthly water consumption of the barley crop was low in November and December and increased over time to reach its highest values in March and April in both seasons. In addition, turn off the irrigation at 100% of irrigation strip length (S_1) during the first and second seasons yielded the greatest seasonal mean values of water consumptive use, 1557.78 m^3 fed^{-1} (37.09 cm) and 1552.74 m^3 fed^{-1} (36.97 cm), respectively, when compared to other treatments (S_2 and S_3). This is because the greatest amount of water was applied to (S_1). In the meantime, turn off the irrigation at 85% of irrigation strip length (S_3-treatment) produced the lowest consumptive usage values in both seasons, 1479.66 m^3 fed^{-1} (35.23 cm) and 1470 m^3 fed^{-1} (35 cm), respectively. Increasing the amount of soil moisture available to barley plants in their root development zone clearly increased ETC. These outcomes might be the consequence of high soil evaporation rates when soil moisture availability is high. On the other hand, poor vegetative development could result in less transpiration from plants under water stress, and the dry soil surface would also result in less evaporation, Abdou and Emam (2016). The results of EL-Hadidi *et al.* (2016) and Abdou *et al.* (2023) are in perfect agreement with these findings.

Regarding the impact of using biochemical fertilisers, water consumption figures were impacted in both seasons under all irrigation strip length treatments when biofertilizers partially replaced mineral fertilisers. Additionally, statistics indicate that the use of biofertilizers (a combination of biofertale and rhizobacterien) and a decrease in NP-mineral rates resulted in a minor increase in barley's CW in both seasons when compared to the recommended NP-mineral (B1). Therefore, the combination of B3 (applying 50% of RNP+100% of the mixture of biofertale + rhizobacterien) and S1-treatment (turn off the irrigation at 100% of irrigation strip length) produced the highest water consumption values in both seasons, measuring 1559.54 m^3 fed^{-1} (37.37 cm) and 1561.14 m^3 fed^{-1} (37.17 cm), respectively. The application of these biofertilizers may therefore be the cause of the higher seasonal values of water consumptive use under B2 and B3 treatments when compared to B1 (recommended NP). This is because these biofertilizers encourage healthy plant growth and formation, which in turn causes the plants to consume more water to make up for water losses through transpiration. These results were consistent with other research that demonstrated that mycorrhizal fungus or biofertilizers enhanced plants' ability to absorb water under drought. Furthermore, a number of studies have shown that higher water content in plants that have been inoculated with biofertilizers is linked to either the capacity of soil-growing hyphae to expand the host plant roots' absorption area and low-potential water absorption from the rhizosphere or the plant's capacity to regulate water loss through stomata regulations in order to conserve water during extreme drought conditions. These results are very consistent with those of Khalifa (2019), Fiorilli *et al.* (2022), and Alotaibi *et al*., (2024).

Table 4. The monthly and seasonal water consumption of barley plants over the two growing seasons as influenced by fertilisation and irrigation strip length treatments

Treatments		Monthly water consumption, cm						Seasonal water consumption	
Irrigation strip length (S)	Biochemical fertilization (B)	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	cm.	m^3 fed^{-1}
			1st season						
S_1	B_1	0.76	3.75	5.80	7.02	10.76	8.63	36.72	1542.24
	B_2	0.76	3.89	5.91	7.10	10.84	8.68	37.18	1561.56
	B_3	0.76	3.90	5.95	7.14	10.89	8.73	37.37	1569.54
Mean		0.76	3.85	5.89	7.09	10.83	8.68	37.09	1557.78
S_2	B_1	0.74	3.63	5.67	6.66	10.36	8.48	35.54	1492.68
	B_2	0.74	3.70	5.70	6.74	10.45	8.53	35.86	1506.12
	B_3	0.74	3.74	5.82	6.77	10.50	8.58	36.16	1518.72
Mean		0.74	3.69	5.75	6.72	10.44	8.53	35.85	1505.70
S_3	B_1	0.74	3.58	5.65	6.48	10.14	8.33	34.92	1466.64
	B_2	0.74	3.61	5.72	6.55	10.24	8.43	35.29	1482.18
	B_3	0.74	3.64	5.75	6.58	10.29	8.48	35.49	1490.58
Mean		0.74	3.61	5.71	6.54	10.22	8.41	35.23	1479.66
			2nd season						
S_1	B_1	1.26	3.87	5.73	6.42	10.91	8.59	36.78	1544.76
	B_2	1.26	3.90	5.79	6.46	10.98	8.64	36.96	1550.64
	B_3	1.26	3.93	5.82	6.49	10.99	8.67	37.17	1561.14
Mean		1.26	3.90	5.78	6.46	10.96	8.63	36.97	1552.74
S_2	B_1	1.24	3.81	5.61	6.11	10.46	8.42	35.61	1495.62
	B_2	1.25	3.84	5.64	6.14	10.49	8.45	35.78	1502.76
	B_3	1.26	3.87	5.67	6.15	10.51	8.50	35.93	1509.06
Mean		1.25	3.84	5.63	6.13	10.49	5.46	35.77	1502.34
S_3	B_1	1.22	3.74	5.46	5.93	10.22	8.23	34.80	1461.60
	B_2	1.22	3.74	5.49	5.96	10.28	8.32	35.01	1470.42
	B_3	1.23	3.77	5.49	5.97	10.33	8.40	35.19	1477.98
Mean		1.23	3.75	5.48	5.95	10.27	8.32	35.00	1470.00

B_1= 100% of R_{NP} B_2=75% of R_{NP} +50% of mix of BioI+ BioII B_3= 50% of R_{NP} + 100% of mix of BioI +Bio II (S_1)=Turn off the irrigation at 100% SL (S_2)=Turn off the irrigation at 90% SL (S_3)=Turn off the irrigation at 85% SL

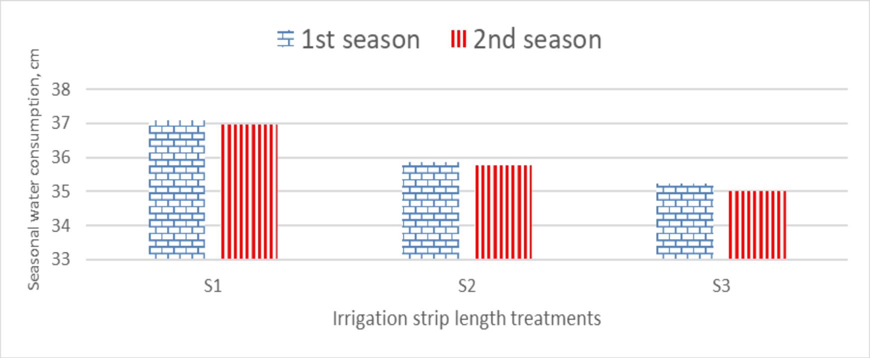

Fig. 1. Impact of irrigation strip length treatments on Seasonal water consumption of barley crop during the two growing seasons

(S_1)=Turn off the irrigation at 100% SL (S_2)=Turn off the irrigation at 90% SL (S_3)=Turn off the irrigation at 85% SL

water efficiencies for barley crop

productivity of water consumption (PWC)

The findings shown in Table (5) and Fig. (2) demonstrate that the administration of biochemical fertilizers and irrigation strip-length treatments had a clear impact on the productivity of water use. In the first and second seasons, the highest mean PWC values for grain yield (1.39 and 1.37 kg m^{-3}) and straw yield (1.49 & 1.52 kg m^{-3}) were seen with turn off the irrigation at 85% of irrigation strip length (S_3). In contrast, S_1-treat produced the lowest PWC values for grain yield (1.22 and 1.20 kg m^{-3}) and straw yield (1.34 and 1.33 kg m^{-3}) in both seasons. The over-mean PWC values for barley grain and straw yields throughout the two seasons were found to be in the following declining order: S_3>S_2> S_1.

However, PWC for both grain and straw yield of the barley crop increased when mineral fertilizers were partially replaced by biofertilizers, as shown by the data in the same table. The highest PWC values (1.53 and 1.55 kg m^{-3}) for grain yield and (1.64 and 1.65 kg m^{-3}) for straw yield were found with B_3-treatment under (S_3) treatment in the first and second seasons, respectively. In the meantime, B_1-treatment under (S_1-treatment) produced the lowest PWC values (1.14 and 1.13 kg m^{-3}) for grain yield and (1.27 and 1.21 kg m^{-3}) for straw yield in both seasons. Additionally, it was noted that the over-mean PWC values for both grain and straw yield fell into the following descending order: B_3> B_2>B_1. .This could be because barley yielded more grain and straw during B_3 and B_2 treatments than under B_1 treatment. The results obtained by Moursi *et al*., (2015) and Paredes *et al*., (2017) are in good agreement with these findings. As the least transportable element in the soil, phosphorus obstructs and inhibits plant growth when soil water and P levels fall in dry soil. Different defence mechanisms can be used by biofertilizers to lessen the impacts of stress (Zare *et al*., 2023; Wei *et al*., 2023). One of these processes is enhanced phosphatase secretion by biofertilizers (biofertale and AMF), which raises the efficiency of P absorption , Francis *et al*., (2023) and Cheng *et al*.,(2023). The union of fungal hyphae increases the exposed surface of the roots, and the roots' depth increases as well, allowing the roots to absorb enough water and mineral supplements from the dry soil, Wahab *et al*., (2023).

Productivity of applied water (PAW)

The highest mean values of PAW for barley grain and straw yields were recorded (S_3-treatment), as shown by the illustrative data in Table (5) and Fig. (2). These were found to be (0.99 and 1.0 kg m^{-3}) for grain yield and (1.06 and 1.11 kg m^{-3}) for straw yield during the first and second seasons, respectively. In both seasons, S_2-treatment was the next highest mean value. In contrast, the first and second seasons under (S_1-treatment) showed the lowest PAW values (0.82 and 0.80 kg m^{-3}) for grain yield and (0.90 and 0.89 kg m^{-3}) for straw yield, respectively. Additionally, the data in the same table demonstrate that applying biofertilizer in place of some chemical fertilizer increased PAW in both seasons when compared to the recommended dose of NP (B_1). In contrast, the B_3 treatment produced the highest PAW values, which were 1.10 and 1.11 kg m^{-3} for grain yield and 1.18 and 1.19 kg m^{-3} for straw yield in both seasons, respectively. These findings concur with those of EL-Mantawy and Khalifa, (2018); and Khalifa, (2019).

Table 5. Impact of biochemical fertilizer application and irrigation strip length treatments on productivity of irrigation water (PAW) and productivity of water consumption (PWC) for barley crop grain and straw yields across the two growing seasons

Treatments		1st season				2nd season				The overall mean values through the two seasons			
		PWC, kg m^{-3}wc		PAW, kg m^{-3}wa		PWC, kg m^{-3}wc		PAW , kg m^{-3}wa		PWC, kg m^{-3}wc		PAW, kg m^{-3}wa	
Irrigation strip length (S)	Bio chemical fertilization (B)	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
S_1	B_1	1.14	1.27	0.76	0.84	1.13	1.21	0.75	0.80	1.14	1.24	0.76	0.82
	B_2	1.18	1.27	0.79	0.86	1.18	1.30	0.79	0.87	1.18	1.29	0.79	0.87
	B_3	1.33	1.47	0.90	1.00	1.30	1.48	0.87	1.00	1.32	1.48	0.89	1.06
Mean		1.22	1.34	0.82	0.90	1.20	1.33	0.80	0.89	1.21	1.34	0.81	0.90
S_2	B_1	1.23	1.44	0.85	1.00	1.20	1.44	0.84	1.01	1.22	1.44	0.85	1.01
	B_2	1.34	1.58	0.94	1.10	1.28	1.52	0.89	1.07	1.31	1.55	0.92	1.09
	B_3	1.41	1.58	1.00	1.12	1.42	1.64	0.99	1.15	1.42	1.61	1.00	1.14
Mean		1.33	1.53	0.93	1.07	1.30	1.53	0.91	1.08	1.32	1.53	0.92	1.08
S_3	B_1	1.29	1.33	0.91	0.94	1.23	1.40	0.87	1.00	1.26	1.37	0.89	0.97
	B_2	1.35	1.49	0.96	1.07	1.32	1.52	0.94	1.09	1.34	1.51	0.95	1.08
	B_3	1.53	1.64	1.10	1.18	1.55	1.65	1.11	1.19	1.54	1.65	1.11	1.19
Mean		1.39	1.49	0.99	1.06	1.37	1.52	1.00	1.11	1.38	1.51	0.98	1.08

B_1= 100% of R_{NP} B_2=75% of R_{NP} +50% of mix of BioI+ BioII B_3= 50% of R_{NP} + 100% of mix of BioI +Bio II (S_1)=Turn off the irrigation at 100% SL (S_2)=Turn off the irrigation at 90% SL (S_3)=Turn off the irrigation at 85% SL

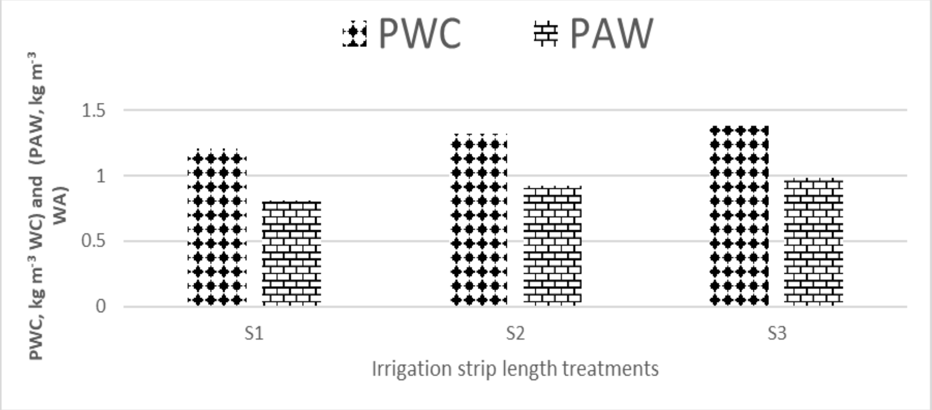

Figure 2. Impact of irrigation strip length treatments on average productivity of water consumption (PWC) and productivity of applied water (PAW) for barley crop grain production over the course of two growing seasons
(S_1)=Turn off the irrigation at 100% SL (S_2)=Turn off the irrigation at 90% SL (S_3)=Turn off the irrigation at 85% SL

Efficiencies of irrigation water

Efficiency of water consumption (EWC)

One metric that shows how well plants can use the soil water stored in the effective root zone is the efficiency of consumption. The highest EWC values (83.45 and 80.19%) were observed during the first and second seasons, respectively, under the S3 treatment, according to data reported in Table (6) and Fig. (3). Therefore, growing plants could benefit from using a larger amount of irrigation water if the amount of water applied for irrigation is reduced. Conversely, the S_1-tratment produced the lowest EWC values in both seasons (75.53 and 74.03%, respectively). In contrast, the B_3 treatment produced the highest EWC values, which were determined to be (84.06 and 80.62) percent in the first and second seasons, respectively. It is clear that replacing mineral fertilizers with biofertilizers increased EWC in both seasons. These results are in line with those of Moursi *et al*., (2015) and Khalifa, (2016 and 2019).

WAE stands for water addition efficiency.

According to data in Table (6) and Figure (3), the S_3-treatment had the highest water addition efficiency values (72.06 and 71.57%) in the first and second seasons, respectively, followed by the S_2-treatment. However, turn off the irrigation at 100% of the irrigation strip length (S_1-treatment) produced the lowest WAE values in both seasons (62.27 and 61.41%, respectively). During both seasons, it was found that increasing turn off the irrigation at 85% of irrigation strip length resulted in higher mean values of water addition efficiency. In all seasons, the effectiveness of water addition was unaffected by the use of mineral and biofertilizers. These findings partially concur with those of Moursi *et al*., (2015) and EL-Hadidi *et al*., (2016).

Water distribution efficiency (WDE)

According to the data in Table (6) and Figure (3), the S_2 treatment had the highest water distribution efficiency values (80.15 and 80.95%) in both seasons, followed by the S_1 treatment. In contrast, the S_3 treatment had the lowest water distribution efficiency values (74.58 and 74.81%) in both seasons. The data collected clearly shows that the efficiency of water distribution in both seasons was unaffected by the application of either mineral or biofertilizers. These findings concur with those of Khalifa, (2016 and 2019).

Table 6. Effect of irrigation strip length and biochemical fertilization treatments on water addition efficiency (WAE), water distribution efficiency (WDE) and efficiency of water consumption (EWC) in the two growing seasons

Treatments		1st season			2nd season			The over all mean values through the two seasons		
Irrigation strip length (S)	Biochemical fertilization (B)	WAE,%	WDE,%	EWC,%	WAE,%	WDE,%	EWC,%	WAE,%	WDE,%	EWC,%
S_1	B_1	62.27	79.77	74.77	61.41	79.96	73.71	61.84	79.87	74.24
	B_2	62.27	79.77	75.71	61.41	79.96	73.99	61.84	79.87	74.30
	B_3	62.27	79.77	76.09	61.41	79.96	74.49	61.84	79.87	75.30
Mean		62.27	79.77	75.58	61.41	79.96	74.03	61.84	79.87	74.78
S_2	B_1	67.67	80.15	79.96	67.15	80.95	77.77	67.41	80.55	78.77
	B_2	67.67	80.15	80.67	67.15	80.95	78.14	67.41	80.55	79.41
	B_3	67.67	80.15	81.35	67.15	80.95	78.47	67.41	80.55	79.91
Mean		67.67	80.15	80.66	67.15	80.95	78.13	67.41	80.55	79.40
S_3	B_1	72.06	74.58	82.71	71.57	74.81	79.73	71.82	74.70	81.22
	B_2	72.06	74.58	83.59	71.57	74.81	80.21	71.82	74.70	81.90
	B_3	72.06	74.58	84.06	71.57	74.81	80.62	71.82	74.70	82.34
Mean		72.06	74.58	83.45	71.57	74.81	80.19	71.82	74.70	81.82

B_1= 100% of R_{NP} B_2=75% of R_{NP} +50% of mix of BioI+ BioII B_3= 50% of R_{NP} + 100% of mix of BioI +Bio II
(S_1)=Turn off the irrigation at 100% SL (S_2)=Turn off the irrigation at 90% SL (S_3)=Turn off the irrigation at 85% SL

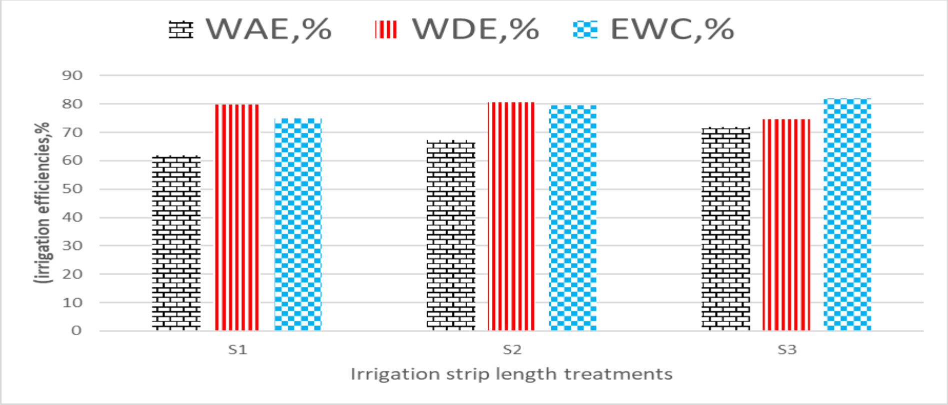

Fig. 3. Average water addition efficiency (WAE), water distribution efficiency (WDE), and efficiency of water consumption (EWC) values across the two growing seasons as influenced by irrigation strip length treatments.

Barley productivity and its constituents

Irrigation strip length treatments had a notable impact on barley yield parameters in both seasons, according to data in Tables (7 and 8) and Figs. (4 and 5). Except for plant height (cm) and spike length (cm) in the first season, all barley yield attributes were not significantly impacted by irrigation strip length treatments in either season. However, in the second season, irrigation strip length treatments had a highly significant impact on plant height (cm), straw yield (kg fed^{-1}), and biological yield (Mg fed^{-1}).

In both seasons, S3-treatment produced the highest yield and barley characteristics, followed by S_2-treatment. During the first and second seasons, the S_3-treatment yielded more grain (8.48 and 7.90%) and straw (5.54 and 9.06%) than the S_1-treatment. The higher barley grain and straw production results under irrigation strip length treatment (S_3) compared to (S_1) can be the result of more water being applied under S_1, which lowers the availability and uptake of soil nutrients. According to Morsi *et al*., (2014); and Khalifa, (2016 & 2019), irrigation of wheat or faba bean in the North Middle Nile Delta region until 85% of strip or furrow length is the appropriate irrigation treatment that demonstrated the highest grain yield and yield components. These results are in excellent agreement with those of these studies.

Additionally, inoculating maize grain with biofertilizers (PsB) (Bacillus Megatherium) has been shown to significantly improve maize production and yield components. Also, combining PsB with chemical fertilisers may help minimise environmental pollution, according to Abd EL-Rahman and EL-Shahawy, (2014).

With regard to the impact of bio-chemical fertilisation treatments, the data in the same tables indicate that, with the exception of 1000-grain weight (g) in the first season, all barley yield attributes increased significantly in both seasons. The superior B_3 treatment was followed in decreasing order by B_2> B_1 treatment. In both seasons, B_3-treatment resulted in higher grain yields (19.18 and 20.57%) and straw yields (18.10 and 18.94%) compared to B_1-treatment. Through their capacity to use free available solar energy and atmospheric nitrogen and water, biofertilizers may help to increase the efficiency of mineral fertilizers and reduce the extensive use of mineral fertilization, which may be the reason for the increase in barley grain and straw yields (Shakori and Sharifi, 2016 and Khalifa (2020, 2022 and 2024)). Furthermore, as N_2-fixing bacteria, soil microorganisms such as Azotobacter and Azosprillum may be able to help plants grow and produce large quantities of reproductive and biological organs, as well as increase their productivity and productive organs (Thirkell *et al*., 2017; Soltan *et al*., 2018 and Fayed *et al*., 2021). Therefore, because of their relative benefits, low fertilization costs, and decreased soil pollution, the above-mentioned fertiliser treatments—especially B_3 (which received half of the necessary amount of NP plus 100% of the combination of Biofertale+ rhizobacterien)—were deemed preferable.

Table 7. Barley production and its components in the first growing season as impacted by irrigation strip length and biochemical fertiliser application treatments

Treatments	Plant height, cm	Spike length, cm	No. of grain plant^{-1}	1000-grain weight, g	Grain yield, kg fed^{-1}	Straw yield, kg fed^{-1}	Biological yield Mg fed^{-1}
Irrigation strip length (S)							
S_1	89.29^{b}	9.53^{a}	47.29	58.33	1879.12	2086.0	3.980
S_2	95.18^{a}	9.03^{b}	47.31	60.00	1997.13	2313.89	4.310
S_3	95.97^{a}	8.83^{b}	49.47	61.43	2053.37	2201.56	4.255
F-Test	**	**	N.S.	N.S.	N.S.	N.S.	NS
Bio-chemical ferti (B)							
B_1	88.28^{C}	8.98^{b}	45.42^{b}	57.22	1823.27^{b}	2020.67^{c}	3.844^{b}
B_2	94.71^{b}	8.99^{b}	47.80^{ab}	59.67	1948.83^{b}	2193.33^{b}	4.142^{b}
B_3	97.45^{a}	9.42^{a}	50.62^{a}	62.89	2172.53^{a}	2386.45^{a}	4.559^{a}
F-Test	**	*	*	NS	**	**	**
Interaction (S×B)							
S_1×B_1	85.20^{c}	9.33^{a}	43.60^{bc}	55.0	1753.90	1960.0	3.714
S_1×B_2	88.40^{c}	9.77^{a}	48.80^{bc}	58.33	1833.73	1988.00	3.822
S_1×B_3	94.27^{b}	9.50^{a}	49.47^{bc}	61.67	2094.74	2310.0	4.405
S_2×B_1	93.27^{b}	9.23^{ab}	50.13^{ab}	58.33	1828.67	2156.0	3.985
S_2×B_2	94.60^{b}	8.70^{bc}	45.73^{bc}	60.0	2015.97	2380.0	4.396
S_2×B_3	97.67^{ab}	9.16^{ab}	46.13^{bc}	61.67	2146.76	2402.67	4.549
S_3×B_1	86.37^{c}	8.37^{c}	42.53^{c}	58.33	1887.20	1946.0	3.833
S_3×B_2	101.13^{a}	8.51^{c}	48.87^{bc}	60.67	1996.80	2212.0	4.209
S_3×B_3	100.40^{a}	9.60^{a}	56.27^{a}	65.33	2276.10	2446.67	4.723
F-Test	**	**	**	NS	NS	NS	NS

Table 8. Barley production and its components in the second growing season as impacted by irrigation strip length and biochemical fertiliser application treatments.

Treatments	Plant height, cm	Spike length, cm	No.of grain plant^{-1}	1000-grain weight, g	Grain yield, kg fed^{-1}	Straw yield ,kg fed^{-1}	Biological yield Mg fed^{-1}
Irrigation strip length (S)							
S_1	88.78b	8.75	46.49	56.67	1861.16	2058.42b	3.920b
S_2	94.22a	8.86	47.04	57.22	1946.84	2307.51a	4.255a
S_3	94.93a	8.91	50.10	60.56	2008.59	2244.81a	4.254a
F-Test	**	NS	NS	NS	NS	**	*
Bio-chemical ferti (B)							
B_1	87.80C	8.73b	46.78b	55.0a	1779.26b	2022.84c	3.803b
B_2	92.38b	8.61b	47.11b	57.22b	1891.74b	2182.00b	4.074b
B_3	97.76a	9.18a	49.69a	62.43a	2145.54a	2405.89a	4.551a
F-Test	**	**	*	**	**	**	**
Interaction (S×B)							
S_1×B_1	84.40d	8.76cde	44.67	53.33	1738.52	1862.0	3.601
S_1×B_2	84.73d	8.57ef	46.13	58.33	1823.08	2010.0	3.833
S_1×B_3	97.20ab	8.91bc	48.67	58.33	2021.88	2303.27	4.325
S_2×B_1	91.93bc	9.00b	48.47	55.0	1798.73	2153.87	3.953
S_2×B_2	95.27bc	8.67cdef	46.13	55.0	1917.59	2296.0	4.213
S_2×B_3	95.47bc	8.89cd	46.53	61.67	2124.08	2472.67	4.597
S_3×B_1	87.10d	8.41f	47.20	56.67	1800.54	2052.67	3.853
S_3×B_2	97.13^{ab}	8.59^{def}	49.07	58.33	1934.55	2240.0	4.174
S_3×B_3	100.60^{a}	9.73^{a}	53.87	66.67	2290.67	2441.73	4.733
F-Test	**	**	NS	NS	NS	NS	NS

Significant at the 0.01 and 0.5 levels of probability, respectively, and NS, *, and ** inconsequential. According to Duncan's Multiple Range Test, mean values representing the same letter in each column are not significant. SL is the irrigation strip length. Bio I = Biofertale Bio II = Rhizobactrien S_1=turn off the irrigation at 100% , SL S_2=turn off the irrigation at 90% SL S_3 = 85% irrigation is stopped. SL. B_1 = 100% of RNP B_2 = 75% of RNP + 50% of BioI+BioII mix B_3 = 50% of RNP + 100% of BioI+Bio II mix

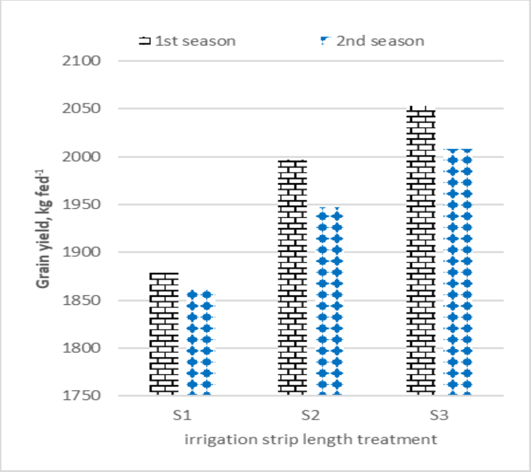

Fig. 4. Effect of irrigation strip length treatments on grain yield of barley crop in the two growing seasons.

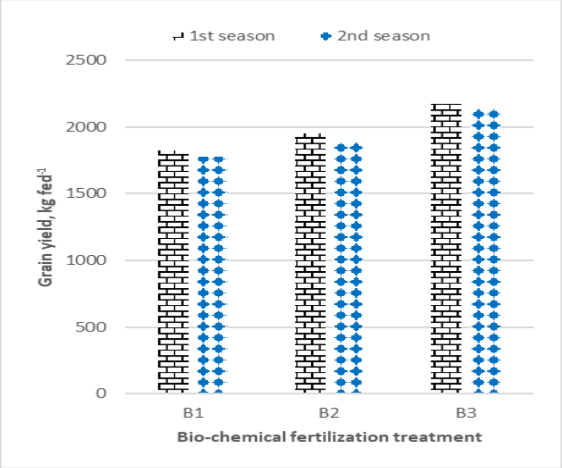

Fig. 5. Impact of applying biochemical fertilizers on barley crop grain output throughout the two growing seasons.

With the exception of plant height, spike length, and number of grains per plant, which showed extremely significant increases in both seasons, the interaction between irrigation strip length treatments and the use of biochemical fertilizers revealed negligible improvements in all previously indicated yield components Figs (6 and 7). In all seasons, the combination of S_3 and B_3 treatments produced the greatest values of all barley yield parameters. Abdel-Azeem and Hokam, (2014); Moursi *et al*., (2015); and Jerbi *et al*., (2022) produced findings that are consistent with these findings. According to their findings, biological fertilizers are particularly significant as suitable substitutes for mineral fertilizers since they enhance soil fertility, meet plant nutrition needs, and boost crop production. To minimise the negative effects of water stress and increase agricultural yield, water must be supplied through supplemental irrigation, delivered in enough amounts at the appropriate times, and other methods. One of these techniques is biological fertilization,. Attia , *et al*.,(2022). The findings of Najafi *et al.* (2012), who documented the beneficial effects of biofertilizers on barley roots that enhance growth, water absorption, and nutrition, are in line with these findings. The benefits of biofertilizers and the significance of using cutting-edge techniques that enhance soil fertility and crop yield were also noted in a number of studies (Raklami *et al*., 2019; Beslemes *et al*., 2023).

The effects of biofertilizers on hair root growth and penetration into the deeper soil layers, which improves plant nutrient availability and absorption, have been the subject of numerous prior research. Shi *et al.* (2023). Plant roots' interactions with AMF may be the cause of the subsequent increase in barley plants' growth and production, which could alter the expression of genes involved in biotic resistance and abiotic tolerance responses. Fiorilli, *et al*., (2022).

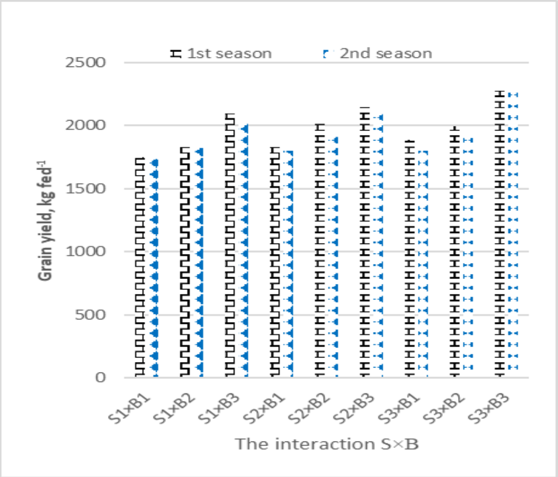

Fig 6. Effect of the interaction between irrigation strip length and biochemical fertilizer treatments on grain yield of barley crop in the two growing seasons.

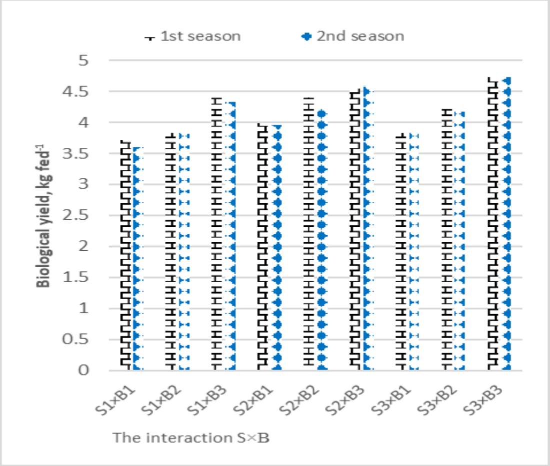

Fig. 7. Impact of the interaction between irrigation strip length and bio-chemical fertilizer treatments on barley crop biological yield throughout the two growing seasons.

S_1=turn off the irrigation at 100% , SL S_2=turn off the irrigation at 90% SL S_3 = 85% irrigation is stopped. SL. B_1 = 100% of RNP B_2 = 75% of RNP + 50% of BioI+BioII mix B_3 = 50% of RNP + 100% of BioI+Bio II mix

Contribution to water requirement of Barley crop made by groundwater table (CGW)

According to the data in Table (9) for both seasons, the ground water table's contribution to barley's water requirements increased as the turn off the irrigation strip length limit increased. Turn off the irrigation had an impact on the seasonal mean values of CGW; for the first and second seasons, the mean values for S1, S2, and S3 treatments were (0.43 and 0.59 cm), (1.17 and 0.73 cm), and (1.40 and 0.85 cm), respectively. In both seasons, it was shown that halt irrigation at 85% of irrigation strip length (S3-treat.) produced the highest CGW values (47.26 and 34.77%). However, in both seasons, turn off the irrigation at 100% of the irrigation strip length produced the lowest CGW values (13.76 and 24.40%). Additionally, data in Table (9) demonstrate that as the fraction of mineral fertilizers replaced by biofertilizers increased in both seasons, seasonal mean values of CGW declined. These findings are most likely explained by the fact that the water table's contribution reduced as irrigation water levels rose. As previously mentioned (see Table 3), the barley plant that got the least amount of irrigation water—that is, irrigation that stopped at 85% of the irrigation strip length (S3)—achieved the highest groundwater contribution percentage values in both seasons. These findings are somewhat consistent with those of Khalifa, (2019 and 2024); EL-Hadidi *et al.*, (2016); Karimove *et al.*, (2014) and Kahlown*et al.*, (2005) .

Table 9. Contribution to water requirement of Barley crop made by groundwater table (CGW) as affected by irrigation strip length and Bio-chemical fertilization treatments over the course of the two growing seasons

Fertilization (B) Irrigation strip length treatments (S)	B_1		B_2		B_3		Seasonal mean of irrigation regimes	
	CGW,cm	CGW,%	CGW,cm	CGW,%	CGW,cm	CGW,%	CGW,cm	CGW,%
				1st season 2015/2016				
S_1	0.47	14.98	0.42	13.41	0.41	12.90	0.43	13.76
S_2	1.23	41.40	1.15	38.76	1.12	37.59	1.17	39.25
S_3	1.50	50.58	1.39	46.75	1.32	44.43	1.40	47.26
Seasonal average of fertilization	1.07	35.65	0.99	32.97	0.95	31.64		
				2nd season				
S_1	0.61	25.88	0.58	24.07	0.57	23.24	0.59	24.40
S_2	0.75	30.80	0.73	30.10	0.71	29.37	0.73	30.10
S_3	0.86	35.29	0.84	34.61	0.84	34.61	0.85	34.77
Seasonal average of fertilization	0.74	30.66	0.72	29.60	0.71	29.01		

B_1= 100% of R_{NP} B_2=75% of R_{NP} +50% of mix of BioI+ BioII B_3= 50% of R_{NP} + 100% of mix of BioI +Bio II

(S_1)=Turn off the irrigation at 100%SL (S_2)=Turn off the irrigation at 90%SL (S_3)=Turn off the irrigation at 85%SL

Economic assessment

The entire cost of producing barley, including both fixed and variable costs, was calculated using the local market price (L.E.) in Egypt. A few items are necessary for economic assessment in order to carry out the evaluation process (Table 10). The total cost of the various treatments under study varied depending on how much mineral and biofertilizer was used in each season. Based on the data collected, the S3 and B3 treatment combination produced the highest total income (7805.2 and 8397.8 LE fed^{-1}), net income (4567.7 and 5095.3 LE fed^{-1}), net income from water unit for grain yield (1.74 and 1.88 LE m^{-3}), and biological yield (2.21 and 2.47 LE m^{-3}) in the first and second seasons, respectively. The S_2 and B_3 treatment combination came in second in both seasons. Conversely, in both seasons, the combination of (S_1) and (B_1) produced the lowest values for the aforementioned criteria. Additionally, the data acquired indicates that during the first and second seasons, respectively, the combination of the (S_3) and (B_3) Treatments produced the highest values of economic efficiency (1.11 and 1.17) for grain yield and (1.41 and 1.54) for biological yield. In contrast, the combination of S1 and B_1-treatments produced the lowest economic efficiency values in both seasons, respectively. Therefore, based on economic evaluation, the impact of irrigation regimes while applying B_3 therapy on barley crops can be ranked in descending order: $S_3 > S_2 > S_1$.

Table 10. Barley crop economics as affected by bio-chemical fertilisation and irrigation strip length practices over the two growing seasons

Treatments		Income, LE.fed^{-1}		Total income LE.fed^{-1}	*Total cost LE.fed^{-1}	Net income LE.fed^{-1}	Applied water m^{3}fed^{-1}	Net income from water unit, LE. m^{-3}		Economic efficiency	
Irrigation strip length (S)	Bio-chemical fertilization(B)	Grain	Straw					Grain yield	Biological yield	Grain yield	Biological yield
						1st season					
S_1	B_1	5260.5	784.0	6044.5	3620	2424.5	2321.76	0.71	1.04	0.45	0.67
	B_2	5499.0	795.2	6294.2	3444	2850.2	2319.66	0.88	1.23	0.60	0.83
	B_3	6282.0	924.0	7206	3237.5	3968.5	2319.24	1.31	1.71	0.94	1.23
S_2	B_1	5485.5	862.4	6347.9	3620	2727.9	2157.96	0.86	1.26	0.52	0.75
	B_2	6048.0	952.0	7000.0	3444	3556	2154.60	1.21	1.65	0.76	1.03
	B_3	6439.5	961.1	7400.6	3237.5	4163.1	2153.34	1.48	1.93	0.99	1.28
S_3	B_1	5661.0	778.4	6439.4	3620	2819.4	2075.64	0.98	1.36	0.56	0.78
	B_2	5989.5	884.8	6874.3	3444	3430.3	2071.02	1.23	1.66	0.74	1.0
	B_3	6826.5	978.7	7805.2	3237.5	4567.7	2068.08	1.74	2.21	1.11	1.41
						2nd season					
S_1	B_1	5447.3	931.0	6378.3	3730	2648.3	2315.88	0.74	1.14	0.46	0.71
	B_2	5710.5	1005	6715.5	٣٥٣١,٣	3184.2	2314.62	0.94	1.37	0.62	0.90
	B_3	6335.6	1151.6	7487.2	٣٣٠٢,٥	4184.7	2314.20	1.31	1.80	0.91	1.26
S_2	B_1	5635.3	1077	6712.3	3730	2982.3	2145.36	0.89	1.39	0.51	0.80
	B_2	5724.6	1148	6872.6	٣٥٣١,٣	3341.1	2144.52	1.02	1.56	0.62	0.95
	B_3	6655.2	1236.3	7891.5	٣٣٠٢,٥	4589	2143.68	1.56	2.14	1.02	1.39
S_3	B_1	5644.7	1026.4	6671.1	3730	2941.1	2060.10	0.93	1.43	0.51	0.79
	B_2	6063	1120	7183.0	٣٥٣١,٣	3651.7	2059.26	1.23	1.77	0.72	1.03
	B_3	7176.9	1220.9	8397.8	٣٣٠٢,٥	5095.3	2059.26	1.88	2.47	1.17	1.54

***The price of both bio and mineral fertilisers and seeds, the cost of equipment for ploughing and levelling the land, labour costs for planting, fertiliser, irrigation, pesticides, manual weed control, and harvesting, and land rent for both seasons are all included in this. *Based on the local market pricing, the price of grain yield (ardab) is 450 LE in the first season and 470 LE in the second. In the first and second seasons, the price of one kilogramme of straw is 0.40 and 0.5 L.E., respectively. B_1 = 100% RNP, B_2 = 75% RNP + 50% BioI+BioII mix, and B_3 = 50% RNP + 100% BioI+Bio II mix(S_1) = 100%SL, (S_2) = 90%SL, and (S_3) = 85%SL are the points at which irrigation should be stopped.**

CONCLUSION

The consequences of the current study concluded that the application of biofertilizers under irrigation strip length treatments included turn off the irrigation at 100% (S1)normal irrigation conditions, 90% (S2), and 85% (S3)of strip length lack of irrigation water (drought), were very useful and effective in overcoming the harmful effects of drought and led to a significant and highly significant improvement in the growth and productivity of barley plants, their various characteristics, and the productivity of grain and straw crops. The use of bio-fertilization led to saving a half of the amount of chemical fertilizer, and this in turn leads to reducing the cost of production and increasing the net return. Accordingly, the importance of developing sustainable bio-fertilizer technology and increasing its application becomes clear to achieve maximum crop production in a healthy way, reduce pollution, preserve the environment, and sustain the soil.

Conflicts of interest that "There are no conflicts to declare".

Formatting of funding sources

This research did not receive any funding.

REFERENCES

Abd EL-Azeem, S. A. M. and Hokam, E. M. (2014). Effect of rhizobacteria and water quality on some soil properties and nutrient uptake of Barley under stress. 11th International Conf. of Egyptian Soil Science Society, 5-7 May, Kafelshiekh, Egypt.

Abd El-Azeem, S., & Bucking, H. (2023). Effectiveness of combined inoculation of rhizobacteria and arbuscular mycorrhizal fungi on wheat performance. *Egyptian Journal of Soil Science, 63(1), 35-45. doi: 10.21608/ejss.2022.168643.1546*

Abd EL-Rahman, L. A. and EL-Shahawy, A. S. (2014). Performance of phosphate solubilizing bacteria for improving yield and yield components of maize, in the presence some sources of phosphorus fertilizer. 11th Inter. Conf. of Egyptian Soil Science Society, 5-7 may 2014, Kafrelsheikh, Egypt.

Abdelaal, K., Alaskar, A. & Hafez, Y.(*2024).* Effect of arbuscular mycorrhizal fungi on physiological, bio-chemical and yield characters of wheat plants (*Triticum aestivum L.) under drought stress conditions. BMC Plant Biol 24, 1119 . https://doi.org/10.1186/s12870-024-05824-9*

Abdelhameid, N.M.; Kenawey, K. (2019). Response of Barley to Bio Fertilization with Mycorrhiza and Azotobacter under Supplemental Irrigation Conditions at the North Western Coast of Egypt. Alex. Sci. Exch. , 40, 672–682. [CrossRef]

Abdelraouf RE, El-Shawadfy MA, Ghoname AA, Ragab R. (2020a). Improving crop production and water productivity using a new field drip irrigation design. Plant Archives Vol. 20 Supplement 1, 2020 pp. 3553-3564

Abdelraouf, R.E.; El-Shawadfy, M.A.; Fadl, A.; Hashem,Bakr, B.M.M.,(2020 b). Effect of deficit irrigation strategies and organic mulching on yield, productivity of irrigation water and fruit quality of navel orange under arid regions conditions. Plant Archives Vol. 20 Supplement 1, pp. 3505- 3518.

Abdou S. M. M.; Abdelraouf ,R. E. ; Farrag ,F. R. M. ; Nesrin F. M. ; Amira A. K. (2023).Response of barley to different moisture depletion rates and n fertilization forms within the root zone. FJARD VOL. 37, NO. 2. PP. 335-347

Abdou, S.M.M.; Emam S.M. (2016). Response of wheat grown on old- cultivated soil to liquid ammonia fertilization and water management via different levels of soil moisture depletion. Menufia Journal of Soil Science, vol. 1 August: 77-91.

Ali, M. H., Hoque, M. R., Hassan, A. A. and Khair, A. (2007). Effects of deficit irrigation on yield, water productivity and economic returns of wheat. Agricultural water management, 92 (3): 151-161.

Allen, R. G.; Pereira, L. S.; Raes, D. and Smith, M. (1998). Crop evapotranspiration. Irrigation and Drainage paper, No. 56, FAO, ROME, Italy.

Alotaibi, M.M.; Aljuaid, A.; Alharbi, M.M.; Qumsani, A.T.; Alzuaibr, F.M.; Alsubeie, M.S.; Ismail, K.A.; Gharib, H.S.; Awad-Allah, M.M.A.(2024): The Effects of Bio-Fertilizer by Arbuscular Mycorrhizal Fungi and Phosphate Solubilizing Bacteria on the Growth and Productivity of Barley under Deficit of Water Irrigation Conditions. Agronomy , 14, 1973. https://doi.org/10.3390/ agronomy14091973.

Alsunuse, Bouzeriba & Al-Ani, Mehjin & Faituri, Mikaeel & Ashilenje, Dennis & Alawami, Ahmed & Stahl, Peter. (2021). Effects of arbuscular mycorrhizal fungi on growth and phosphorus uptake of maize (Zea mays L.) at different levels of soil phosphorus and soil moisture. Journal of Dryland Agriculture. 7(3). 22-33. 10.5897/JODA2020.0063.

Attia, M.I.; El-, A.; Tahoun, A.M.A.; Abdelghany, F.I.M.; El-Serafy, R. (2022). Productivity of Some Barley Cultivars as Affected by Supplemental Irrigation under Rainfed Conditions. Aust. J. Crop Sci. , 2022, 665–675. [CrossRef]

Awad-Allah, M.M.A.; Attia, K.A.; Omar, A.A.; Mohamed, A.H.; Habiba, R.; Alzuaibr, F.M.; Alshehri, M.A.; Alqurashi, M.; Aloufi, S.; Dessoky, E.S.(2022). Combining Ability and Gene Action Controlling Agronomic Traits for Cytoplasmic Male Sterile Line, Restorer Lines, and New Hybrids for Developing of New Drought-Tolerant Rice Hybrids. Genes , 13, 906. [CrossRef]

Begum, N., Ahanger, M. A., Su, Y., Lei, Y., Mustafa, N. S. A., Ahmad, P., & Zhang, L. (2019). Improved Drought Tolerance by AMF Inoculation in Maize (*Zea mays) Involves Physiological and Biochemical Implications. Plants (Basel, Switzerland), 8(12), 579. https://doi.org/10.3390/plants8120579*

Bernardo, L., Carletti, P., Badeck, F.W., Rizza, F., Moricia, C., Ghizzoni, R., Rouphael, Y., Colla, G., Terzi, V. and Lucini, L. (2019). Metabolomic responses triggered by arbuscular mycorrhiza enhance tolerance to water stress in wheat cultivars. Plant physiol. Biochem. 137, 203 212.https://doi.org/10.10161/j.plaphy.2019, 02.007.

Beslemes, D.; Tigka, E.; Roussis, I.; Kakabouki, I.; Mavroeidis, A.; Vlachostergios, D.N.(2023). Effect of Arbuscular Mycorrhizal Fungi on Nitrogen and Phosphorus Uptake Efficiency and Crop Productivity of Two-Rowed Barley under Different Crop Production Systems. Plants , 12, 1908. [CrossRef]

Cheng, Y.; Narayanan, M.; Shi, X.; Chen, X.; Li, Z.; Ma, Y. (2023). Phosphate-Solubilizing Bacteria: Their Agroecological Function and Optimistic Application for Enhancing Agro-Productivity. Sci. Total Environ. , 901, 166468. [CrossRef]

Doorenbos, J. and Pruitt, W. O. (1975). Crop water requirements. Irrigation and Drainage paper, 24 FAO. Rome.

Downy, L. A. (1970). Water use by maize at three plant densities, Exper., Agric., 7 :161-169.

Duncan, D. B. (1955). Multiple range and Multiple F-test. Biometrics,11:1-42

EL-Hadidi, E. M.; Saied, M. M., Ghaly, F. M. and Khalifa, R. M. (2016). Assessing the effect of water discharge rates and cut-off irrigation on wheat production and some water Relations at North Nile Delta Region. J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol.7 (6) : 397-407.

EL-Mantawy, R. F. and Khalifa R. M. (2018). Response of Barley plants to potassium spraying under deficit conditions. J. Plant Production, Mansoura Univ.,9(4):359-367.

Elshafie, A. F., Ramadan, A. R., and Abdebaset, M. M. (2021). Impact the Grand Ethiopian Renaissance Dam on the Egyptian water resources and agricultural production. J. of water and climate change, 12 (3), 1009-1025.

Elshamy, M. E., Seidu, O., Ouarda, T. B. and Eltahir, E. A. (2020). Impact of climate change and the Grand Ethiopian Renaissance Dam on the Nile water availability in Egypt. Hydrology and Earth system Sciences, 24 (4),1957-1976.

Fatemi, F.; Kianersi, F.; Pour-Aboughadareh, A.; Poczai, P.; Jadidi, O.(2022) Overview of Identified Genomic Regions Associated with Various Agronomic and Physiological Traits in Barley under Abiotic Stresses. Appl. Sci. , 12, 5189. [CrossRef]

Fayed, M. H., Sheta, M. H., Mancy, A. G. (2021). Improving the growth and productivity of Faba bean under deficit irrigation conditions by spraying of potassium selenate and potassium silicate. Egypt. J. Soil Sci., 61 (1): 95-111.

Fiorilli, V.; Maghrebi, M.; Novero, M.; Votta, C.; Mazzarella, T.; Buffoni, B.; Astolfi, S.; Vigani, G.(2022) Arbuscular Mycorrhizal Symbiosis Differentially Affects the Nutritional Status of Two Durum Wheat Genotypes under Drought Conditions. Plants , 11, 804.

Food and Agriculture Organization of the United Nations (FAO). (2021). FAOSTAT. http:// www. fao. Org /fao stat/en/#data/QC.

Francis, B.; Aravindakumar, C.T.; Brewer, P.B.; Simon, S. (2023). Plant Nutrient Stress Adaptation: A Prospect for Fertilizer Limited Agriculture. Environ. Exp. Bot. , 213, 105431. [CrossRef]

Gholinezhad, Esmaeil & Darvishzadeh, Reza & Siavash Moghaddam, Sina & Popović-Djordjević, Jelena. (2020). Effect of mycorrhizal inoculation in reducing water stress in sesame (Sesamum indicum L.): The assessment of agrobiochemical traits and enzymatic antioxidant activity. Agricultural Water Management. 238. 106234. 10.1016/j.agwat.2020.106234.

Giriappa, S. (1983). Water use efficiency in agriculture, Oxford – IBH publishing Co., New Delhi, 6-9.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for Agricultural Research, 2nd (Ed.), Willyand Sone Inc. New Yourk.

Hansen, V. W.; Israelson, O. W. and Stringham, Q. E. (1979). "Irrigation Principles and Practices". 4th ed., John willey and Sons. New York.

James, L. G. (1988). Principles of Farm Irrigation System Design. John willey and Sons (ed.), New York, pp.543.

Jerbi, M., Labidi, S., Laruelle, F., Tisserant, B., Ben Jeddi, F. and Sahraoui, A. L. (2022). Myccorhizal biofertilization improves grain yield and quality of hulles Barley (*Hordeum Vulgare ssp. Nudum L.)* under water stress conditions. Journal of Cereal Science 104 (2022)103436.

Kah, M., Tufenkji, N., White, J. C. (2019). Nano-enabled strategies to enhance crop nutrition and protection. Nat. Nanotechnol., 14:523-540. {cross Ref.}

Kahlown, M. A., Ashraf, M. and ul-Hag, Z. (2005). Effect of shallow ground water table on crop water requirements and crop yields. Agric. Water management, 79:24-35

Kamali, S. and Mehraban, A. (2020). Effects of Nitroxin and arbuscular mycorrhizal fungi on the agro-physiological traits and grain yield of sorghum (*sorghum bicolor L.)* under drought stress conditions. Plos One 15 (12), e0243824. https:// doi.org/10.1371/journal.Pone.0243824.

Karimove, A. Kh.; Simunek, J.; Hanjra, M. A.; Mirzaalim, A. and Forkusta, I. (2014). Effects of the shallow water table on water use of winter wheat and ecosystem health. Implications for unlocking the potential of ground water in the Fergana Valley (center Asia). Agricultural water management, 131: 57- 69

Khalifa, R. M. (2016). Effect of On-farm irrigation water management practices on yield of wheat crop and water saving. Ph.D. Thesis, Fac. Of Agric. Mansoura Univ., Egypt.

Khalifa, R. M. (2019). Response of faba bean to alternate irrigation and cut-off irrigation combined with mineral phosphorus and biofertilizer at North Nile Delta soils. Egypt. J. Soil Sci. Vol.59(2):175-191.

Khalifa, R. M. (2020). Effect of different irrigation water levels and Bio-minerals fertilization on fruit yield, quality and water productivity of watermelon grown in sandy soil, Egypt. Egypt, J. Soil Sci., 60 (30):231-246.

Khalifa, R. M. (2022). Cucumber response to drip irrigation and bio-mineral fertilizers management under protected cultivation conditions. J. of soil sci., and Agric. Engi., Mansoura Univ., 13 (12):403-411.

Khalifa, R. M. (2024). Canola Response to alternate Furrow and cut-off irrigation combined with Bio-mineral fertilizer applications at North Delta Region. J. od soil Sci., and Agric. Engi, Mansoura Univ., 15 (3):67-80.

Khalifa, R. M. Saied, M. M. and Khalifa, M. R. (2018). Improvement and evaluation of slide irrigation design in the Northern Delta clay soils Egypt. J. Soil Sci., 58 (2):207-220.

Klute, A. (1986). Methods of Soil Analysis (part1). Amer. Soc. of Agron., Inc. Madison, Wisconsin, USA.3rd edition.

Kohistani, A.W.; Choudhary, A. K. (2019). Influence of Applied Nitrogen on Productivity, Profitability and Resources-use Efficiency in Winter Barley (Hordeum Vulgare) under Semi-Arid Conditions of Afghanstan. Indian J. A gric. Sci.,89, 741-744.

Kumar, T.; Arunkumar, J. S. and Dawson, J. (2013). Effect of different levels of Nitrogen and Biofertilizers on growth and yield of barley (Hordeum Vulgare L.). Advance Research Journal of crop improvement, 4 (1): 59-61.

Masrahi, A.S.; Alasmari, A.; Shahin, M.G.; Qumsani, A.T.; Oraby, H.F.; Awad-Allah, M.M.A.(2023). Role of Arbuscular Mycorrhizal Fungi and Phosphate Solubilizing Bacteria in Improving Yield, Yield Components, and Nutrients Uptake of Barley under Salinity Soil. Agriculture, 13, 537. [CrossRef]

Mishra, R.K.(2023). Fresh Water Availability and Its Global Challenge. Br. J. Multidiscip. Adv. Stud. , 4, 1–78. [CrossRef]

Moursi, E. A., Khalifa, R. M., Meleha, A. M. and Aiad, M. A. (2019). Effect of irrigation Scheduling at different management allowable Deficit using Pan Evaporation on wheat yield and water efficiencies at North Delta. J. Sus. Agric. Sci., 45 (1):11-25.

Moursi, E. A.; Aziz, M. A. and EL- Mansoury, M. A. M. (2014). Effect of length of irrigation run and nitrogen rates on productivity of some wheat cultivars, some water relations and nitrogen content in heavy clay soils. J. Agric. Kafr. EL-Sheikh Univ., 40 (3): 630-658.

Moursi, E. A.; Soultan, I. M. and Abo Marzoka, E. A. (2015) .Effect of irrigation and bio-fertilizers on flax productivity ,quality and some water relations in the north middle Nile Delta region . J. Agric. Res. Kafr EL-Sheikh Univ.,41(4):1165-1191.

Najafi, A.; Ardakani, M.R.; Rejali, F.; Sajedi, N. (2012). Response of winter barley to co-inoculation with Azotobacter and Mycorrhiza fungi influenced by plant growth promoting rhizobacteria. Ann. Biol. Res. , 3, 4002–4006.

Novica, V. (1979). Irrigation of agriculture crops. Fac. Agric. Press, Novi sad Yugoslavia

Page, A. L., Miller, R. H. and Keeney, D. R. (1982). Methods of Soil Analysis. Part 2, 2nd ed. ASA and SSSA, Madison, Wisconsin, USA.

Pardo, J.J.; Sánchez-Virosta, A.; Léllis, B.C.; Domínguez, A.; Martínez-Romero,(2022) A. Physiological Basis to Assess Barley Response to Optimized Regulated Deficit Irrigation for Limited Volumes of Water (ORDIL). Agric. Water Manag. , 274, 107917. [CrossRef]

Paredes, P., Rodrigues, G. C.; Cameira, M. R., Torres, M. O. and Pereira, L.S. (2017). Assessing yield, water productivity and farm economic returns of malt barley as influenced by the sowing dates and supplemental irrigation. Agric. Water Manag., 179: 132-143.

Raklami, A.; Bechtaoui, N.; Tahiri, A.; Anli, M.; Meddich, A.; Oufdou, K. (2019). Use of Rhizobacteria and Mycorrhizae Consortium in the Open Field as a Strategy for Improving Crop Nutrition, Productivity and Soil Fertility. Front. Microbiol. , 10, 1106. [CrossRef]

Shakori, Sh. And Sharifi, P. (2016). Effect of phosphate Biofertilizer and chemical phosphorus on growth and yield of vicia faba L. Electronic Journal of Biology, Vol.51:47-52.

Sharma, B.; Tiwari, S.; Kumawat, K.C.; Cardinale, M. (2022). Nano-Biofertilizers as Bio-Emerging Strategies for Sustainable Agriculture Development: Potentiality and Their Limitations. Sci. Total Environ. , 860, 160476. [CrossRef] [PubMed]

Shi, J.; Wang, X.; Wang, E.(2023) Mycorrhizal Symbiosis in Plant Growth and Stress Adaptation: From Genes to Ecosystems. Annu. Rev. Plant Biol. , 74, 569–607. [CrossRef]

Singh, V.B.; Stevanovi´c, M.; Jha, C.K.; Beier, F.; Ghosh, R.; Campen, H.L.; Popp, A. (2023). Assessing Policy Options for Sustainable Water Use in India's Cereal Production System. Environ. Res. Lett. , 18, 094073. [CrossRef]

Soltan, I. M., EL-Mantawy, R. F. and Abosen, Th. M. (2018). Response of some soybean to different systems of phosphorus fertilizers in North Delta Region. J. Plant Production, Mansoura Univ., Vol. 9(4):339-344.

Suna, T.; Kumari, A.; Paramaguru, P.; Kushwaha, N.L. (2023). Enhancing Agricultural Water Productivity Using Deficit Irrigation Practices in Water-Scarce Regions. In Enhancing Resilience of Dryland Agriculture Under Changing Climate; Springer: Berlin/Heidelberg, Germany, ; pp. 177–206. [CrossRef]

Thalooth, T.A.; Bahr, A.; Tawfik, M.M.(2012). Productivity of some barley cultivars as affected by inoculation under water stress conditions. Elixir Appl. Bot. , 51, 10743–10749.

Thirkell, T. J., Charters, M. D., Elliott, A. J., Sait, S. M. and Field, K. J. (2017). Are mycorrhizal fungi our sustainable saviours ? Considerations for achieving food security. J. Ecol. 105(4), 921-929. https://doi.org/10.1111/1365-2745.12788

Tiwari, N.; Tiwari, U.S.; Shrivastava, D.K.; Tiwari, A. (2023). Sewage Water Reuse in Quality Vegetation: A Review on Potential, Current Challenges and Future Strategies. Proc. Natl. Acad. Sci. India Sect. B Biol. Sci. , 94, 471–481. [CrossRef]

Wahab, A.; Muhammad, M.; Munir, A.; Abdi, G.; Zaman,W.; Ayaz, A.; Khizar, C.; Reddy, S.P.P. (2023). Role of Arbuscular Mycorrhizal Fungi in Regulating Growth, Enhancing Productivity, and Potentially Influencing Ecosystems under Abiotic and Biotic Stresses. Plants , 12, 3102. [CrossRef]

Wei, Z.; Chen, Z.; Yang, X.; Luying, S.; Huan, M.; Zhu, S. (2023). Metagenomics Reveal Arbuscular Mycorrhizal Fungi Altering Functional Gene Expression of Rhizosphere Microbial Community to Enhance Iris Tectorum's Resistance to Cr Stress. Sci. Total Environ. , 895, 164970. [CrossRef]

Zaib, S.; Zubair, A.; Abbas, S.; Hussain, J.; Ahmad, I.; Shakeel, S.N. (2023). Plant Growth-Promoting Rhizobacteria (PGPR) Reduce Adverse Effects of Salinity and Drought Stresses by Regulating Nutritional Profile of Barley. Appl. Environ. Soil Sci. ,7261784. [CrossRef]

Zare, L.; Ronaghi, A.; Ghasemi-Fasaei, R.; Zarei, M.; Sepehri, M. (2023). Arbuscular Mycorrhizal Fungi and Nitric Oxide Alleviate Cadmium Phytotoxicity by Improving Internal Detoxification Mechanisms of Corn Plants. Environ. Sci. Pollut. Res. , 30, 93602–93616. [CrossRef]

تقييم علاقات المياه وإنتاجية الشعير في التربة الطينية في شمال دلتا النيل وتأثرها بتقنية الري والتسميد الحيوي -الكيميائي

رامي محمد خليفة

قسم الأراضي والمياه - كلية الزراعة – جامعة دمياط

الملخص

أجريت دراسة لموسمين شتويين متتاليين في محطة البحوث الزراعية بسخا، محافظة كفر الشيخ، لتقييم تأثير استراتيجيات الري والتسميد على إنتاجية الشعير وعلاقاته المائية والعوائد الاقتصادية. شملت تجارب الري ثلاث معاملات: إيقاف الري عند ١٠٠٪ (S_1)، و٩٠٪ (S_2)، و٨٥٪ (S_3) من طول شريحة الري. فيما تضمنت معاملات التسميد: B_1 (١٠٠٪ أسمدة معدنية مُوصى بها R_{NP})، وB_2 (٧٥٪ R_{NP} + 50 %مزيج من البيوفيرتيل والريزوباكتيرين)، وB_3 (٥٠٪R_{NP}+ 100% من المزيج الحيوي). أظهرت النتائج أن معاملة الري الكامل (S1) استهلكت أكبر كمية مياه ري موسمية، بينما وفرت S_2 وS_3 نسبة توفير مائي بلغت ٧,٣١٪ و١٠,٨٨٪ على التوالي مقارنةً بـS_1. رغم تقليل الري، تفوقت S_3 على S_1 في زيادة إنتاج الحبوب بنسبة ٨,٤٨٪ و٧,٩٠٪ خلال الموسمين. أما معاملة التسميد B3 فسجلت أعلى إنتاجية للحبوب، متفوقةً على B_1 بنسبة ١٩,١٨٪ و٢٠,٥٧٪. حقق الجمع بين S_3 وB_3 أعلى كفاءة لإنتاجية المياه، مع تحسين كفاءة الري لإنتاج الحبوب والقش، وخفض الاستهلاك المائي، وزيادة الكفاءة التطبيقية، مما أدى إلى أعلى صافي دخل وعوائد اقتصادية لكل وحدة مياه مستخدمة. كما ساهم المزيج S_3B_3 في توفير جزء من مياه الري المضافة بالاعتماد على المياه الجوفية والأسمدة المعدنية بالاعتماد علي الأسمدة الحيوية. قللت المعاملات B_2 وB_3 الاعتماد على الأسمدة التخليقية عبر دمج الأسمدة الحيوية، مما يدعم الممارسات الزراعية المستدامة دون المساس بالإنتاجية. اقتصاديًا، أثبت S_3B_3 تفوقًا في الجدوى المالية لكل من الغلة البيولوجية وحبوب الشعير، ما يجعله خيارًا مثاليًا في المناطق محدودة الموارد. تؤكد الدراسة أن الجمع بين الري المتناقص (S_3) والتغذية المُعززة بالأسمدة الحيوية (B_3) يوازن بين توفير المياه وزيادة الإنتاجية والربحية. عبر تحسين معاملات إيقاف الري واستبدال الأسمدة المعدنية بالبدائل الحيوية، يمكن تحقيق إنتاج مستدام للشعير، مع مواجهة ندرة المياه والتحديات البيئية. تُقدم هذه الاستراتيجيات نموذجًا قابلاً للتطوير لتعزيز المرونة الزراعية في المناطق شبه الجافة المماثلة.