

# **Impact of Soil Conditioners and Cyanobacteria Under Varied Irrigation Levels on Growth and Productivity of Wheat (*Triticum Aestivum* L.) in Sandy Soil**

## **Abstract**

During the winter seasons 2021/2022 and 2022/2023, two field experiments were conducted at the Ismailia Experiment Research Station in Ismailia Governorate, Egypt, to assess the effect of soil conditioners and cyanobacteria at different irrigation levels on the growth and productivity of wheat plants grown in sandy soil. The experimental treatments were arranged in the split-split plot design shown below: Two bio fertilizer treatments were represented by subplot A<sub>0</sub>: no application and A<sub>1</sub>: cyanobacteria (*Anabaena circinalis*) inoculation. Four natural soil conditioner treatments at a rate of 2.4 mg ha<sup>-1</sup> were arranged in sub-sub plot (control): no application, (Z) zeolite, (B) bentonite, and (F) feldspar. The results revealed that cyanobacteria inoculation combined with natural soil conditioners resulted in positive and statistically significant increases in all parameters studied. The highest mean values were obtained in the majority of cases when cyanobacteria and feldspar were combined in a 70% irrigation level, with no significant difference when cyanobacteria and feldspar were combined in full irrigation level. All growth parameters were increased per plant. The investigated factors had a significant impact on NPK uptake by grains and straw, total amino acid percentages in wheat grains, and available NPK in soil. Furthermore, the presence of cyanobacteria associated with soil conditioners led to an increase in soil dehydrogenase, indole acetic acid levels. Therefore, the objectives of this study were to use cyanobacteria and soil conditioners as natural resources to minimize water use while boosting the production and growth characteristics of wheat plants. Finally, the findings of this study suggested that inoculating wheat plants with cyanobacteria in combination with soil conditioners can reduce up to 30% of the total amount of water required by wheat plants, and that using natural resources and bio fertilizer can be recommended to improve soil fertility while minimizing the environmental impact of chemical fertilizer.

**Keywords:** soil conditioners, cyanobacteria (*Anabaena circinalis*) inoculation, irrigation levels.

## **Introduction**

Wheat is the most important cereal crop in the Egyptian public's main food stable. Egypt's national goal is to increase wheat productivity in order to close the gap between wheat consumption and production. By using high-yield crops, luxurious irrigation, and massive amounts of fertilizer, herbicides, and pesticides, intensive agricultural practises have increased not only wheat production but also land degradation and environmental problems since the 1970s. The main environmental issues that may threaten the future viability of agricultural systems are land degradation, limited water availability, biodiversity loss, declining agricultural genetic diversity, and climate change [1], [2].

*Anabaena circinalis* is a cyanobacterium that has been identified as a promising producer of metabolites that represent various crops and yields, such as tannic acid, carotenoids, total chlorophyll-a, phenol, and flavonoid content [3][4]. Cyanobacteria have been shown to increase aggregate stability by enriching soil with organic matter, increasing biological activity, and secreting exocellular polysaccharides (EPS) [5]. Fertilizers are typically used in agriculture to improve soil qualities, crop yield, and nutrient quality by making up for low levels of nitrogen, phosphorous, and potassium. Utilizing microorganism-based farming techniques that are economical and environmentally benign is currently a strategy for sustainable green agriculture [6]. The advantages of using biofertilizers, which are organic chemicals made by living microorganisms [7] instead of chemical fertilizers include minimizing ecological disruption and being more affordable [8].

Zeolites and bentonite are naturally occurring phyllosilicate minerals with high cation exchange and ion adsorption capacities. Zeolites, in particular, are hydrated aluminosilicates of alkaline and alkaline-earth minerals [9]. Bentonite, a clay mineral, can be utilized as a safe, natural soil supplement that releases water and nutrients for plant uptake during dry spells while retaining a significant quantity of water and nutrients during rainfall events. Other types of clay conditioners added to sandy soil have been shown in prior studies to increase soil waterholding capacity, reduce water **evapotranspiration** and increase water use efficiency. This is most likely because improved soil aggregates and decreased soil bulk density are to blame for these effects. Bentonite is a natural soil amendment that can reduce soil water loss and increase crop yield, but few studies have been conducted to determine how bentonite affects soil biochemical properties. Their structure is composed of a framework of  $[\text{SiO}_4]_4$  and  $[\text{AlO}_4]_5$  tetrahedrons linked

to each other's corners by oxygen atoms shared. In tetrahedral sites, the substitution of  $\text{Si}_4^+$  by  $\text{Al}_3^+$  results in more negative charges and high cation exchange capacity [10].

Crops need a lot of potassium to survive, yet resource-constrained farmers in underdeveloped nations frequently don't feed their crops with K due to high fertilizer costs, which results in K deficits. In intensive agricultural production systems, where insufficient fertilizer-K application has resulted in the depletion of the soil's K stores, it has become a limiting factor.

K fertilizers are applied at a significantly lower rate than N and P fertilizer applications, and typically, less than 50% of the K lost by crops is replaced each year [11]. The most important K minerals in the soils are K-feldspar ( $\text{KAlSi}_3\text{O}_8$ ), feldspar is highly resistant to weathering in natural condition, increased secretion of exudates from plant roots mobilized K from metasediments [12]. Similarly, amino acids found in wheat and sugar beet root exudates desorbed K from a K-fixing soil [13].

The objective of this study is to determine how cyanobacteria (*Anabaena circinalis*) as a biofertilizer in the presence of bentonite, zeolite, and feldspar as essential mineral sources might reduce water usage and improve wheat crop characteristics.

## Materials and Methods

Two field experiments were conducted at the Ismailia Agricultural Research Station, ARC, Egypt (Lat. 30° 35' - 41° 9' N, Long. 32° 10' - 45° 83' E) during the growing winter seasons of 2021/2022 and 2022/2023. Main soil properties described in table (1) were determined by Jackson [14] and Klute [15]. The experimental treatments were set up in a split-split plot design with 16 treatments and three replicates. The experiment had three components, which were as follows:

- (1) The main plots were assigned two irrigation levels: 70% ( $I_1$ ) and 100% ( $I_2$ ) of wheat evapotranspiration level (ETc)
- (2) Two bio fertiliser treatments were represented by subplots A0: no application and A1: inoculation with cyanobacteria (blue-green cyanobacteria).
- (3) Four natural soil conditioner treatments were applied at a rate of  $2.4 \text{ mg ha}^{-1}$  in sub-sub plots (control): no application, (Z): zeolite, (B): bentonite, and (F): feldspar.

Table (2) shows the main characteristics of soil conditioners. Wheat (*Triticum aestivum* L. Masr2) grain was mechanically sown in hills that were 5 cm apart under sprinkler irrigation in the third week of November 2021 and 2022. The experimental unit area was  $10.5 \text{ m}^2$  with  $3 \times 3.5 \text{ m}$  dimensions, and each plot had four ridges (3.5 m in length and 30 cm in width). Two weeks

before cultivation, the four soil conditioners (zeolite, bentonite, and feldspar) were thoroughly incorporated into the surface soil layer (30 cm). Before cultivation, the wheat grain was inoculated with cyanobacterial, which was provided by the Agric. Micro. Dept. in Solis, Waters, Environ. Insit. Agric. Rese. Center in Egypt. Nitrogen fertilizer (0.34 kg N kg<sup>-1</sup>) was applied at a rate of 238 kg N ha<sup>-1</sup> in two equal levels before the first and second irrigations. Phosphorus was applied at a rate of 16.09 P ha<sup>-1</sup> in the form of super phosphate (0.068 kg P kg<sup>-1</sup>) during the final stage of land preparation for planting, and potassium was added at a rate of 95 kg K ha<sup>-1</sup> in two equal levels after sowing and flowering.

ET<sub>0</sub> values were calculated using data from metrological stations and the Month of equation CROPWAT model [16]. The crop evapotranspiration portion values were computed using the equation: ET<sub>c</sub> = ET<sub>0</sub> × KC

Where: ET<sub>c</sub> = crop evapo-transpileveln (mm/day)

T<sub>0</sub> = reference evapo-transpileveln (mm/day)

KC = crop coefficient value for peanut (FAO 56)

The amount of water used was calculated using the following equation by Vermirer and Jopling [17]:

$$AIW = \frac{ETC \times Kr}{Ea (1 - LR)} \times I$$

Where: AIW = head of applied irrigation water (mm/day)

ET<sub>c</sub> = crop evapo-transpileveln (mm/day).

Kr = evapo-transpileveln reduction coefficient that depends on grown cover (FAO 56).

I = irrigation interval (day).

Ea = irrigation efficiency of sprinkler system (an average 75% was used).

LR = leaching requirement (10% of the calculated irrigation water was applied per-irrigation during the growing season for leaching purpose).

**Table 1. Main characteristic of the studied soil.**

Coarse sand	Fine sand	Silt	Clay	Texture class	Calcium carbonate (gk g <sup>-1</sup> )	Organic matter (gk g <sup>-1</sup> )	pH	EC (dSm <sup>-1</sup> )	CEC (cmolc kg <sup>-1</sup> )	Available macronutrient (mg/kg soil)		
										N	P	K
49.01	44.25	5.29	1.45	Sandy	7.5	1.32	8.01	1.08	0.96	11.83	10.4	3.85

\*pH soil: water suspension at 1: 2.5, EC in soil saturation extract.

Table 2. Main characteristics of the used soil conditioners

Conditioner	EC (dSm)	SP (%)	Na (g kg <sup>-1</sup> )	K (g kg <sup>-1</sup> )	Ca (g kg <sup>-1</sup> )	Mg (g kg <sup>-1</sup> )	SO <sub>4</sub> (g kg <sup>-1</sup> )	Cl (g kg <sup>-1</sup> )	pH
Zeolite	1.18	36	4.7	0.35	4.5	2	2.05	8.5	8.1
Bentonite	8.8	195	33.4	1.75	28.5	23.5	16.2	67.5	7.2
Feldspar	1.52	56	6.1	0.75	4.5	3.5	3.35	10	7.8

EC: Solution 1: 5

Table 3. Monthly and seasonal of water consumptive use for the irrigation levels.

Irrigation levels	Monthly water consumptive use (m <sup>3</sup> )						Seasonal consumptive use (m <sup>3</sup> )
	November	December	January	February	March	April	
I <sub>1</sub>	315.08	1042.4	2720.3	2713.2	1012.8	350.1	8153.9
I <sub>2</sub>	220.6	729.68	1904.2	1899.2	708.96	245.1	5707.7

## Plant and Soil Analyses

Grain and straw yields were recorded as kg ha<sup>-1</sup> at harvest (150 days after planting). Plant samples from both seeds and straw were collected to determine some growth parameters (number of spikes per plant, weight of 100 grain, plant height, and macronutrient uptake (percentages of N, P, and K), and the mean of the two seasons was recorded. Plant harvesting samples, as well as grain and straw, were oven dried at 72°C for 48 hours and digested with sulfuric (H<sub>2</sub>SO<sub>4</sub>) and perchloric acid (HClO<sub>4</sub>) mixed (1:1) according to Page et al., 1982, and total amino acids were calculated using Llamas and Fontaine [18] method.

Soil samples were collected from the surface layer (0-30 cm) to determine some soil chemical and biological properties. Casida's technique for estimating dehydrogenase activity was used on soil samples [19]. Gordon and Weber's [20] technique of indole acetic acid (IAA) in soil.

## Statistical Analysis

The main and interaction effects of treatments (irrigation level, cyanobacteria, and soil conditioners) were statistically analysed using the (ANOVA) test and the Co-State software programme to calculate the LSD at a significantly level P =0.05 as described by Snedecor and Cochran [21].

## Results and Discussion

### Growth and Yield Parameters

Data in Tables (4 and 5) demonstrated how irrigation rates, cyanobacteria inoculation (bio-fertilizer), and various soil conditioner applications affected the growth and yield parameters of wheat plants, including grain and straw yield, harvest index, number of spikes per plant, weight 100 grains, and plant height. Concerning the influence of irrigation levels, it is clear that full irrigation level resulted in significant increases in all studied parameters when compared to 70% irrigation level, while cyanobacteria (*A. circinalis*) inoculation, and soil conditioners application on wheat plant growth and yield parameters, data revealed that this triple interaction resulted in positive and significant increases in all studied parameters. In most cases, the highest mean values were obtained with the combination treatment of *A. circinalis* and feldspar in irrigation full level treatment, with no significant difference with the treatment of *A. circinalis* with feldspar in 70% irrigation level. The relative increases for grain yield, straw yield, number of spikes per plant, weight of 100 grain, and plant height were 98.74, 99.0, 97.32, 99.18, and 98.9%, respectively. Furthermore, inoculation with cyanobacteria (*A. circinalis*) in combination with any of the natural soil conditioners (zeolite, bentonite, and feldspar) at rate of 5 mg ha<sup>-1</sup> had a positive effect on all parameters when compared to the treatment of untreated plots. Also, the obtained results show that the application of soil conditioners had a significant effect on all growth parameters of wheat plants when compared to the control treatment. This is due to the use of natural materials as soil conditioners in association with cyanobacteria, which increases water use efficiency and nutrient conveyance, resulting in increased wheat plant growth and yield [22] [23] [24]. Furthermore, the combined treatment of cyanobacteria with feldspar in 70% irrigation level resulted in a 30% reduction in irrigation requirements. These results agreed with those of Abbas et al. [24] Arafa et al. [25] and EL-Edfawy and Fanous [26]. This could be for the natural materials are broken down by soil microorganisms that are sensitive to environmental conditions [27] [28]. The increasing effect of irrigation on wheat plant growth and yield parameters may be due to the primary role of used water on cell division and elongation, as well as the physiological function of the cells, which affect plant growth. These findings are consistent with those reported by Hussaini et al. [29] and Ichiet al. [30].

Irrigation levels	Cyano-bacteria	Soil conditioners (C)														
		Control	Z	B	F	Mean	Control	Z	B	F	Mean	Control	Z	B	F	Mean
		Grain yield(kg ha <sup>-1</sup> )					Straw yield (kg ha <sup>-1</sup> )					Harvest index (%)				
I <sub>1</sub>	A <sub>0</sub>	2607.43	3208.60	3510.63	5295.77	3655.61	3220.47	4160.97	4629.90	6226.73	4559.52	34.20	36.87	38.07	39.27	37.10
	A <sub>1</sub>	2609.87	3399.80	3771.60	6083.17	3966.11	3501.57	4279.87	4776.97	6631.67	4547.52	35.17	39.65	42.10	45.03	40.49
Mean		2608.65	3304.20	3641.12	5689.47	3810.86	3361.02	4220.42	4703.43	6429.20	4553.52	34.68	38.26	40.08	42.15	38.79
I <sub>2</sub>	A <sub>0</sub>	2985.70	4314.88	4474.53	4618.10	4098.30	3709.30	6158.40	5747.70	5299.67	5228.77	34.10	33.33	33.20	36.33	34.24
	A <sub>1</sub>	3000.00	4537.13	4997.17	6007.10	4635.35	3676.20	5925.87	6342.23	6692.10	5659.10	46.13	47.13	45.30	48.60	46.79
Mean		2992.85	4426.01	4735.85	5312.60	4366.83	3692.75	6042.13	6044.97	5995.88	5443.93	40.12	40.23	39.25	42.47	40.52
Grand mean		2800.75	3865.10	4188.48	5526.03	4095.09	3526.88	5131.28	5374.20	5962.54	4998.73	37.40	39.25	39.67	42.31	39.66
Means of Cyanobacteria																
A <sub>0</sub>		2796.57	3761.74	3992.58	5006.93	3889.46	3464.88	5159.68	5188.80	5763.20	4894.14	34.15	35.10	35.63	37.80	35.67
A <sub>1</sub>		2804.93	3968.47	4384.38	6045.13	4300.73	3588.88	5102.87	5559.60	6161.88	5103.31	40.65	43.39	43.70	46.82	43.64
LSD <sub>0.05</sub>		I=368.31 A= 98.19 C=113.95 IxA=ns IxC=80.58 AxC=161.16 IxAxC=90					I=444.92 A= ns C=396.86 IxA=ns IxC=561.52 AxC=ns IxAxC=54.73					I=ns A=ns C=2.07 IxA=ns IxC=ns AxC=ns IxAxC=ns				

Table 4. Effect of irrigation levels, bio-fertilizer and soil conditioners applications on yield parameters of wheat plant (average of two seasons)

I<sub>1</sub> and I<sub>2</sub>: irrigation at 70 and 100 % from water requirement, A<sub>0</sub> and A<sub>1</sub> without and with inoculation with cyanobacteria, C:soil conditioners, Control: without application, Z: zeolite, B: bentonite F: Feldspar application, ns: non-significant at the 5% levels of probability at L.S.D test.

Table 5. Effect of irrigation levels, bio-fertilizer and soil conditioners applications on growth and yield components of wheat plant (average of two seasons).

Irrigation levels	Cyano-bacteria	Soil conditioners (C)														
		Control	Z	B	F	Mean	Control	Z	B	F	Mean	Control	Z	B	F	Mean
		No. of spike					Weight of 100 grain (g)					plant height (cm)				
I <sub>1</sub>	A <sub>0</sub>	6.37	6.83	6.78	6.99	6.74	4.69	5.51	5.50	5.90	5.40	76.50	86.67	89.70	90.73	85.90
	A <sub>1</sub>	6.71	7.25	7.06	7.64	7.17	4.81	5.89	5.97	6.16	5.71	80.70	89.80	93.07	100.27	90.96
Mean		6.54	7.04	6.92	7.32	6.96	4.75	5.70	5.73	6.03	5.55	78.60	88.23	91.38	95.50	88.43
I <sub>2</sub>	A <sub>0</sub>	6.20	7.13	7.38	6.93	6.91	4.66	5.53	5.74	6.13	5.52	81.20	86.60	91.73	92.97	88.13
	A <sub>1</sub>	7.01	7.04	7.44	7.85	7.34	5.53	5.85	5.90	6.11	5.85	77.13	88.77	92.17	101.37	89.86
Mean		6.61	7.09	7.41	7.39	7.12	5.10	5.69	5.82	6.12	5.68	79.17	87.68	91.95	97.17	88.99
Grand mean		6.57	7.06	7.17	7.36	7.04	4.92	5.70	5.78	6.07	5.62	78.88	87.96	91.67	96.33	88.71
Means of Cyanobacteria																
A <sub>0</sub>		6.29	6.98	7.08	6.96	6.83	4.68	5.52	5.62	6.01	5.46	78.85	86.63	90.72	91.85	87.01
A <sub>1</sub>		6.86	7.15	7.25	7.75	7.25	5.17	5.87	5.93	6.14	5.78	78.92	89.28	92.62	100.82	90.41
LSD <sub>0.05</sub>		I=ns A=0.36 C=0.39 IxA=ns IxC=0.15 AxC=0.06 IxAxC=0.16					I=0.11 A=0.25 C=0.24 IxA=ns IxC=ns AxC=0.04 IxAxC= 0.03					I=ns A=3.30 C= 2.49 IxA=ns IxC=ns AxC=3.69 IxAxC=0.84				

I1 and I2: irrigation at 70 and 100 % from water requirement, A0 and A1 without and with inoculation with cyanobacteria C: soil conditioners, Control: without application, Z: zeolite, B: bentonite F: Feldspar application, ns: non-significant at the 5% levels of probability at L.S.D test

## Nutrient Uptake

Regarding the impact of irrigation levels, cyanobacteria inoculation and soil conditioner applications on NPK uptake by wheat plants in grain and straw, were examined. Results in tables 6 and 7 showed that the irrigation levels had no statistically significant effect on N, P, and K by wheat plant grain and straw. Data reported Tables 5 and 6 demonstrate that the feldspar with cyanobacteria in full irrigation level treatment, in all nutrient uptake yielded the highest mean values of N, P and K by grain and straw of wheat plants, with no statistically significant difference between the treatments feldspar with cyanobacteria in 70% irrigation level. For N, P, and K uptake by grain, the relative increases between these two treatments were 97.8, 97.7, and 98.1%, respectively, while for N, P, and K uptake by straw, they were 98.1, 88.5, and 97.7%, respectively.

**Table 6. Effect of irrigation levels, bio-fertilizer and soil conditioners applications on NPK uptake by grain (kg ha<sup>-1</sup>) of wheat plant (average of two seasons).**

Irrigation levels	Cyanobacteria	Soil conditioners (C)														
		Control	Z	B	F	Mean	Control	Z	B	F	Mean	Control	Z	B	F	Mean
		N%					P%					K%				
I <sub>1</sub>	A <sub>0</sub>	20.62	26.66	29.99	30.68	26.99	8.17	10.23	9.85	10.95	9.80	15.97	20.90	23.83	26.17	21.72
	A <sub>1</sub>	23.93	31.87	32.37	42.80	32.87	9.10	11.03	10.23	13.30	10.92	18.17	25.99	28.00	38.30	27.62
Mean		22.28	29.27	29.99	36.74	29.57	8.63	10.63	10.04	12.13	10.36	17.07	23.45	25.92	32.23	24.67
I <sub>2</sub>	A <sub>0</sub>	21.20	26.07	30.70	34.53	28.13	8.12	9.58	10.33	10.46	9.63	18.65	23.84	29.14	31.58	25.80
	A <sub>1</sub>	33.63	24.70	38.27	44.77	35.34	10.95	11.74	11.65	14.60	12.24	29.78	31.13	30.54	40.05	32.88
Mean		27.42	25.39	34.49	39.65	31.73	9.54	10.66	10.99	12.53	10.93	24.22	27.49	29.84	35.81	29.34
Grand mean		24.85	27.33	32.99	38.20	30.83	9.09	10.65	10.52	12.33	10.64	20.64	25.47	27.88	34.02	27.00
<b>Mean of Cyanobacteria</b>																
A <sub>0</sub>		20.91	26.37	30.35	32.61	27.56	8.15	9.91	10.09	10.71	9.71	17.31	22.37	26.49	28.87	23.76
A <sub>1</sub>		28.78	28.29	38.27	43.79	34.10	10.03	11.38	10.94	13.95	11.58	23.98	28.56	29.27	39.18	30.25
LSD <sub>0.05</sub>		I=ns A=1.48 C=1.14 IxA=1.14 Ix C=1.61 AxC=1.56 IxAxC=2.28					I=ns A=0.44 C=0.71 IxA=0.71 Ix C=ns AxC=0.43 IxAxC=					I=ns A=0.44 C=0.71 IxA=1.12 Ix C= 1.98 AxC=1.00 IxAxC=1.32				

I1 and I2: irrigation at 70 and 100 % from water requirement, A0 and A1 without and with inoculation with cyanobacteria, C: soil conditioners, Control: without application, Z: zeolite, B: bentonite F: Feldspar application, ns: non-significant at the 5% levels of probability at L.S.D test.

These results are in the same line with Aysun and Yalcan[31], Abbas et al. [24] and EL-Shabrawy et al.[32].When wheat plants were fertilized with natural soil conditioners (zeolite, bentonite, and feldspar) instead of uninoculated treatment, the same trend in N, P, and K uptake was observed (control). These findings are consistent with those of Zhang et al.[33]. Theinteraction between natural fertilizer application and irrigation levels had a significant effect on N, P, and K uptake by both grain and straw of wheat plants. This could be because natural conditioners play an important role in providing plants with the water and nutrients they require to recover and produce a high yield of high quality [24][33].

Results in Table (7) showed that irrigation at 100% of the water requirements for wheat plants had a significant effect on available N, P, and K in soil when compared to 70%.In addition, cyanobacteria *A. circinalis* inoculation produced the same trend in available N, P, and K in soil as untreated plots,the results show that applying soil conditioners with *A. circinalis* at any irrigation level recorded a positive and significant increase in available N, P, and K in soil.

**Table 7. Effect of irrigation levels, bio-fertilizer and soil conditioners applications on N,P,K uptake by straw (kg ha<sup>-1</sup>) of wheat plant (average of two seasons).**

Irrigation levels	Cyanobacteria	Soil conditioners (C)														
		Control	Z	B	F	Mean	Control	Z	B	F	Mean	Control	Z	B	F	Mean
		N					P					K				
I1	A0	10.25	12.18	13.50	14.36	12.57	2.22	2.67	3.10	3.53	2.88	7.83	7.30	17.65	16.10	12.22
	A1	11.31	16.28	16.62	19.02	16.81	3.51	4.54	4.88	6.44	4.84	15.51	18.23	22.40	26.77	20.73
Mean		10.78	14.23	15.06	16.69	14.69	2.87	3.61	3.99	4.99	3.86	11.67	12.77	20.03	21.44	16.47
I2	A0	10.94	14.47	15.21	18.03	15.75	3.20	3.36	4.22	4.16	3.74	9.32	18.72	24.20	24.35	19.15
	A1	19.15	19.14	20.32	20.27	15.22	5.20	5.42	5.55	7.28	5.86	16.34	15.39	17.24	19.18	17.04
Mean		15.04	16.81	17.77	19.15	15.48	4.20	4.39	4.89	5.72	4.80	12.83	17.06	20.72	21.77	18.09
Grand mean		12.91	15.52	16.41	18.92	15.09	3.53	4.00	4.44	5.35	4.33	12.25	14.91	20.37	21.60	17.28
Means of Cyanobacteria																
A0		10.59	13.32	14.36	16.20	14.16	2.71	3.02	3.66	3.85	3.31	8.58	13.01	20.93	20.23	15.68
A1		15.23	17.71	18.47	21.64	16.01	4.36	4.98	5.22	6.86	5.35	15.93	16.81	19.82	22.98	18.88
LSD <sub>0.05</sub>		I=ns A=0.89 C=0.64 IxA=ns IxC=0.91 AxC=1.36IxAxC=1.28					I=ns A=0.13 C=0.54 IxA=0.54 IxC=ns AxC=0.60IxAxC=ns					I=ns A=0.52 C=0.85 IxA=0.85 IxC=1.20 AxC=1.21 IxAxC= 1.70				

I1 and I2: irrigation at 70 and 100 % from water requirement, A0 and A1 without and with inoculation with cyanobacteria, C: soil conditioners, Control: without application, Z: zeolite, B: bentonite F: Feldspar application, ns: non-significant at the 5% levels of probability at L.S.D test.

The combination treatment of *A. circinalis* with feldspar in full irrigation level produced the highest mean values, with no significant difference from the cyanobacteria with feldspar in f

70% irrigation level treatment. The relative increases for N, P, and K were 98.56, 95.4, and 94.5%, respectively, between these two treatments, this interaction is critical for improving drought resistance. The interaction effect of irrigation levels and natural soil conditioners produced a significant increase in soil available N, P, and K. Using of soil conditioner zeolite, bentonite, and feldspar can improve soil structure and nutrient soil content by reducing leaching [26][34]. These results are in the same line with Abo El-Khair et al. [22] Abbas et al. [24] El-Edfawy and Fanous [28].

### Total Amino acids percentages in wheat grains

Total amino acid analysis determines which amino acids are bound to proteins and which amino acids may be present as separate unbound units. Table (8) data showed the percentage of total amino acids in wheat grains in relation to cyanobacteria *A. circinalis* presence and absence, as well as natural soil conditioners feldspar, bentonite, and zeolite under various irrigation levels. Due to the presence of cyanobacteria *A. circinalis* with feldspar, bentonite and zeolite treatments, respectively, recorded the highest amino acids percentages of 7.80, 7.40 and 7.30 % in full irrigation level. While in 70% irrigation level, the greatest percentages were 7.20 and 7.16 % recorded by cyanobacteria *A. circinalis* with feldspar, bentonite treatments. Moreover, mixture treatments recorded the maximum means in terms of the presence of cyanobacteria with soil conditioners (feldspar, bentonite and zeolite) was means of cyanobacteria with feldspar treatment in 100% irrigation level, with a slight decrease in means of cyanobacteria with feldspar in 70% irrigation level, however, percentage of total amino acids were reduced in all treatments in the absence of cyanobacteria, in both irrigation levels.

Irrigation levels	cyanobacteria	Total Amino Acids in Grains (%)				
		Control	Z	B	F	Mean
I <sub>1</sub>	A <sub>0</sub>	6.32	5.41	5.39	6.23	5.84
	A <sub>1</sub>	6.78	6.88	7.16	7.20	7.00
Mean		6.55	6.15	6.28	6.72	6.42
I <sub>2</sub>	A <sub>0</sub>	6.60	6.40	6.50	6.8	6.58
	A <sub>1</sub>	7.03	7.30	7.40	7.80	7.38
Mean		6.73	6.62	6.73	7.11	6.79
Grand mean		6.64	6.38	6.5	6.91	6.61
Means of Cyanobacteria						
A <sub>0</sub>		6.46	5.91	5.95	6.52	6.21

A <sub>1</sub>	6.91	7.09	7.28	7.50	7.19
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**Table 8. Effect of irrigation levels, bio-fertilizer and soil conditioners applications on total amino acids (average of two seasons).**

I1 and I2: irrigation at 70 and 100 % from water requirement, A0 and A1 without and with inoculation with cyanobacteria, C: soil conditioners, Control: without application, Z: zeolite, B: bentonite F: Feldspar application, ns: non-significant at the 5% levels of probability at L.S.D test.

Wheat grain protein content supported the results of photosynthetic pigments and revealed a significant positive relationship between protein content and N- uptake [35]. In the rice-wheat cropping sequence, cyanobacterial inoculation is known to improve growth, nitrogen fixation, and yields [36]. For high efficiency surface irrigation methods, modern techniques such as bentonite and feldspar conditioners can be used. Because soil is the flow medium of water in surface irrigation methods, the type of soil has a direct impact on water distribution efficiency. The primary property of soil infiltration that affects the effectiveness of surface irrigation [37] [38].

### **Dehydrogenase activity(DHA) and Indole Acetic acid (IAA) in soil**

Table (9) data revealed that the presence of cyanobacteria *A. circinalis* increased soil biological activity as measured by the amount of DHA and indole acetic acid (IAA). In most cases, the highest mean values were obtained with the combination treatment of cyanobacteria with feldspar at the full irrigation level, with nearly by the mean of the cyanobacteria with feldspar treatment at the 70% irrigation level. The combinations produced the highest mean values. The highest DHA activity was 44.12 and 42.32 mg TPF g dry rhizosphere  $\text{soil}^{-1} \text{day}^{-1}$  (DHA) recorded by cyanobacteria with feldspar and cyanobacteria with bentonite, respectively, in 100% irrigation, followed by 42.47 and 40.54 mg TPF dry rhizosphere  $\text{soil}^{-1} \text{day}^{-1}$  (DHA) recorded by cyanobacteria with feldspar and cyanobacteria with bentonite, then, cyanobacteria recorded 42.27 and 41.37 mg TPF g dry rhizosphere  $\text{soil}^{-1} \text{day}^{-1}$  (DHA) in full irrigation level with zeolite treatment and control, respectively. In the same pattern, indole acetic acid (IAA) in soil increased in the presence of cyanobacteria with soil conditioners, specially feldspar, in full irrigation level treatments, with a slight decrease in means of cyanobacteria with feldspar in 70% irrigation level, increasing the IAA content in soil leads to increased wheat plant production and growth features. The highest IAA in soil was 15.56 mg  $\text{g}^{-1}$  soil which recorded by cyanobacteria with feldspar in full irrigation level. However, control and cyanobacteria with feldspar treatments

had the highest IAA content in soil at 13.53 and 13.48mg g<sup>-1</sup>soil, respectively, in a 70% irrigation. In all treatments, IAA content in the soil decreased when cyanobacteria were absent.

In contrast to the control treatment, which received no inoculation, the findings of this study are consistent with Aref and EL- Kassas [39] who discovered that cyanobacterial inoculation to maize fields dramatically increased dehydrogenase activity. They also indicated that increasing organic matter and microbial activity in the soil through biofertilization with cyanobacteria increased the microorganism community and, consequently, soil biological activity, presence of cyanobacteria [40]. Chittora *et al.* [41] stated that cyanobacteria play a chief role in the maintenance and build-up of soil fertility, consequently yield as a natural biofertilizer..

**Table 9. Effect of irrigation levels, bio-fertilizer and soil conditioners applications on dehydrogenase activity and indole acetic acid in soil (average of two seasons).**

Irrigation levels	Cyanobacteria	DHA in soil (mg TPF g <sup>-1</sup> dry rhizosphere soil <sup>-1</sup> day <sup>-1</sup> )					IAA in soil ( mg g <sup>-1</sup> soil)				
		Control	Z	B	F	Mean	Control	Z	B	F	Mean
I <sub>1</sub>	A <sub>0</sub>	34.94	38.12	33.47	35.27	35.45	7.13	8.13	9.19	9.44	8.43
	A <sub>1</sub>	38.28	39.52	40.54	42.47	40.70	13.53	10.42	11.74	13.46	12.29
Mean		37.61	38.82	37.005	38.87	38.08	10.33	9.275	10.47	11.45	10.38
I <sub>2</sub>	A <sub>0</sub>	38.18	39.59	37.82	38.12	38.43	12.06	10.85	12.45	13.48	12.21
	A <sub>1</sub>	41.37	42.27	42.32	44.12	42.52	14.91	14.36	15.35	15.56	15.05
Mean		39.775	40.93	40.07	41.12	40.47	13.485	12.61	13.9	14.52	13.63
Grand mean		38.70	39.88	38.54	40.00	39.28	11.91	10.94	12.18	12.99	12
<b>Means of Cyanobacteria</b>											
A <sub>0</sub>		36.56	38.86	35.65	36.70	39.28	9.60	9.49	10.82	11.46	10.34
A <sub>1</sub>		40.83	40.90	41.43	43.30	41.61	14.22	12.39	13.55	14.51	13.67

I<sub>1</sub> and I<sub>2</sub>: irrigation at 70 and 100 % from water requirement, A<sub>0</sub> and A<sub>1</sub> without and with inoculation with cyanobacteria, C: soil conditioners, Control: without application, Z: zeolite, B: bentonite F: Feldspar application, ns: non-significant at the 5% levels of probability at L.S.D test.

The release of various biologically active substances such as gibberellin, auxin, cytokinins [42], vitamins, amino acids, polypeptides, antibacterial and antifungal substances, and polymers, particularly exopolysaccharides [43] had a positive effect on crop yield. Indole acetic acid content increased as soil microbial count increased [44]. The major actions of blue-green cyanobacteria include; make porous soil and produce adhesive substances [45] excretion of

phytohormones(auxin, gibberellins, etc.), vitamins, amino acids , improve the water holding capacity of soil through their characteristic jelly structure, increase in biomass of soil after their death and decomposition , decrease in soil salinity, Controls weeds growth [46], availability of soil phosphate by excretion of organic acids [47].

## Conclusion

According to the previous discussion, the combined application of natural soil conditioners such as feldspar, zeolite and bentonite at a rate of 2.4 mg ha<sup>-1</sup> and inoculation with cyanobacteria *A. circinalis* can help to reduce up to 30% of the amount of water irrigation while improving the growth, yield parameters, and chemical composition of wheat plants.

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