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Effects of Some Cyanophyta Along with the Reduced Levels of Chemical Fertilizers on the Growth and Yield of Wheat

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Abstract

The present work was conducted in the fields of Al-Sewarah and Kurkok stations which belong to the State Board of Agricultural Researches, Ministry of Agriculture, Iraq during the growing season of 2018. The goal of the study was to test the effects of the application of cyanobacteria (*Anabaena circinalis* and *Nostoc commune*) alone or in combination with reducing the dose of chemical fertilizers (CFs), which consisted of diammonium phosphate (DAP) and urea (46% nitrogen), on growth, yield and yield components of wheat cv. IPA99. Application of 50% and 100% of CFs without cyanobacteria as well as control (without cyanobacteria and CFs) were also included in this study for comparison.

The results indicated that the use of wheat grains coated with compost amended with cyanobacteria, grains coated with compost, and foliar spray with cyanobacteria did not change yield, yield components and most of growth parameters tested in both stations. However, application of 50% CFs along with the treatments that included either the coating of grains with compost amended with cyanobacteria or the foliar spray with cyanobacteria extract resulted in grains yield, yield components, biological yield, harvest index, and test growth parameters similar to those achieved by the recommended dose of CFs. This study suggests that this approach can be applied to reduce the input of chemical fertilizers into the field and thereby reducing the cost and pollution of agroecosystem.

Keywords: wheat, cyanobacteria, biofertilizers, foliar, compost.

تأثير الطحالب الخضراء المزرقة مع جرعه مختزلة من سمادي الداب واليوريا في نمو وحاصل الحنطة

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الخلاصة

اجريت هذه الدراسة في حقول محطتي بحوث الصويرة وكركوك التابعة للهيئة العامة للبحوث الزراعية التابعة لوزارة الزراعة، العراق خلال الموسم الزراعي 2018. والهدف منها هو اختبار تأثير الطحالب الخضراء المزرقة (*Anabaena circinalis* and *Nostoc commune*) بصوره مفردة او مع جرعه مخفضة من سماد الداب في نمو وحاصل الحنطة صنف اباء 99. كما تضمنت اجراء معاملة بدون اضافة السماد والطحالب ومعاملي اضافة 50 و100% من سمادي الداب واليوريا (46% نيتروجين) لأغراض المقارنة.

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اذ تم اولا عزل الطحالب المذكورين من مناطق مختلفة من العراق ثم تنقيتهما وخطهما معا بعد ذلك ثم اكنار الخليط في مفاعلات بيولوجية تحت ظروف المختبر .
 أظهرت النتائج ان معاملة تغليف البذور بالسماذ العضوي المحمل بالطحالب الخضراء المزرقه او الرش بمستخلص الطحالب الخضراء المزرقه لم يكن لهما زياده في الحاصل ومكوناته وفي اغلب الصفات الزراعية الاخرى المدروسة. غير ان استخدام 50% من السماذ الكيمايين مع معاملة تغليف البذور بالسماذ العضوي المحمل بالطحالب الخضراء المزرقه او معاملة الرش بمستخلص الطحالب الخضراء المزرقه ادى الى زياده حاصل الحبوب ومكوناته و الحاصل البيولوجي و دليل الحصاد والصفات الزراعية المدروسة بنسبة لم تختلف احصائيا عن معاملة التوصية السماذية. بينت هذه الدراسة امكانية اختزال سماذ اليوريا و الداب المضامين للحقل الى النصف عند اضافة الطحالب الخضراء المزرقه دون المساس بحاصل الحنطة مما يساعد ذلك على اختزال التكاليف والحد من تلوث النظام البيئي الزراعي .

Introduction

Agricultural fertilizers are essential to enhance proper growth and yield of crops. Most of the agriculture sectors are heavily dependent on inorganic chemical fertilizers. The overdependence and irrational use of chemical fertilizers has led to many associated problems. The growing public awareness in recent past about quality of life has led to concentrate the efforts on searching for alternative agricultural approaches to reduce the input of chemical fertilizers in agroecosystems [1]. The utilization of beneficial microbes as biofertilizers has become a major interest in industrial agriculture for their potential role in food safety and sustainable crop production [2]. Cyanobacteria as biofertilizers is significantly capable of fixing atmospheric nitrogen [3], improving soil fertility and crop productivity, decreasing the pollution of the agricultural environment and enhancing the quality of the produced food [4]. Additional roles of cyanobacteria were reported to include the excretion of a number of substances that influence plant growth and development such as auxin [5], gibberellins [6], cytokinins [7], vitamins, polypeptides, and amino acids [8]. The cyanobacteria can be applied to the field by soil drenching [9], spraying as a foliar extract [10] and by compost amended with cyanobacteria culture [11].

Wheat (*Triticum aestivum* L.) is one of the oldest cereals widely consumed by human being. It is an important crop in Iraq which cultivates in the rain fed regions in the north and the salt affected areas of the southern and central regions of Iraq. The role of cyanobacteria biofertilizers in cereal crops is reported to be beneficial, as they not only reduce the use of chemical fertilizers but also improve the overall health and nutritional status of soil [12]. No published reports exist on using cyanobacteria as biofertilizers for wheat crop in Iraq under the abovementioned diverse environments. Therefore, the present study was conducted to isolate and purify the local isolates of cyanobacteria (*Nostoc* and *Anabaena*) determine the best approach to apply them to the wheat field, and comparing the outcomes of applying them alone or in combination with the reduced dose of chemical fertilizer. The experiments were conducted in the fields of two regions of different environmental conditions in Iraq.

Materials and methods

Isolation and purification of cyanobacteria

Local cyanobacteria species, *Anabaena* and *Nostoc*, were isolated according to Rippka *et al.* [13] from paddy fields of different sites in Baghdad, Al-Nagaf Al-Ashraf and Al-Diwaniyah during summer of 2018. The isolates were grown in conical flasks containing sterilized blue green algae (BG11) free of nitrogen medium with pH 7.2 or 8.2 and incubated under 16 h photoperiod (3000 lux) at 28 ± 2 °C [14]. The unialgal cultures were purified to obtain axenic culture as described by Pringsheim [15].

Identification of cyanobacteria isolates

Microscopic examinations were made to identify each of cyanobacteria cultures under low (10x) and high power (40x) objective lens of compound light microscope based on morphological observations, namely thickness of the sheath, and presence or absence of heterocyst, akintes. and gas vacuoles [16] .

Mass cultivation

Photobioreactor (PBR) is a fermentation bubble column consisting of a circular glass flask of 10 liters volume filled with sterilized liquid BG-11 medium. Cyanobacteria cultures (*Anabaena circinalis* and *Nostoc commune*) were cultivated in a combination of equal portions of fresh weight from each

algal culture suspension at the stationary phase [9]. The suspensions were mixed together and incubated under 16 h photoperiod (3000 lux) at 28 ± 2 °C with initial pH values of 7.2 or 8.2 [17]. The cultures were incubated for 2-3 weeks, while being air bubbled by a commercial aquarium pump and maintained until the logarithmic phase achieved [11]. Biomasses of *N. commune* and *A. circinalis* were collected from several experimental bioreactors. The fresh weights were washed several times with distilled water to remove impurities, crushed, and the resulting salt crystals were used in subsequent experiments [18]. The growth of cyanobacteria was determined by measuring the biomass concentrations in the cultures through the cell dry weight, according to an initial rate of 0.1 to a maximum rate of 1 g/L, as described by Vonshak *et al.* [19].

Preparation of cyanobacteria extract

Cyanobacteria mixtures were harvested by centrifugation at $2,000 \times g$ for 10 min. Purified cell pellet was extracted by distilled water using electrical blender at a rate of 5g / 500 ml (1%) [20]. The obtained natural extract of cyanobacteria was used as a foliar extract [10].

Incubation of cyanobacteria with compost

Compost (palm fronds) with typical chemical and physical properties was used as an incubation medium. Ten ml of mixed culture (*A. circinalis* and *N. commune*) was added to 100 mg of compost and moisturized with 50 ml distilled water. The culture was then incubated for 30 days and the activity of cyanobacteria was then examined [11, 21].

Field study

Site selection

The proposed field study was conducted in two research stations, Al-Sewarah and Kurkok stations, which belong to the State Board of Agricultural Researches, Ministry of Agriculture, Iraq, during the growing season of 2018. Some of the physical and chemical properties of soil of the two stations are listed in Table-1. All tests were conducted in the Soil Testing Laboratory of the State Board of Agricultural Researches. Soil samples from both stations were air-dried and used to determine soil reaction (pH), according to the method of Van Reeuwijk [22], and electric conductivity (EC), following Rhoads and Polemic's method [23]. Soil texture was determined by the hydrometric method as described by Day [24] while the organic matter was determined as stated by Walkley [25]. Bicarbonate, magnesium and calcium concentrations were measured according to Jackson [26]. Carbonate level was determined as reported by Hess [27] while that of sodium was tested as described earlier [28]. Total nitrogen was analyzed using the Kjeldahl's method [29], while phosphorus determination was carried out using Olsen's method [30] and the estimation of potassium was performed according to the procedure reported by Black [31].

Table 1-Some physical and chemical properties of the surface soils from Al-Swearah and Kurkok stations prior to treatments

Parameters	Values*	
	Al-Sewarah station	Kurkok station
pH	8.0	7.5
E.C. dS m ⁻¹	2.6	3.2
Ca Meq/l	27.5	27.5
Mg Meq/l	10.0	7.5
Na Meq/l	5.5	16.3
Cl Meq/l	5.0	7.5
Co ₃ Meq/l	0.0	0.0
Hco ₃ Meq/l	2.0	1.0
So ₄ Meq/l	5.7	30.9
N ppm	28.0	21.0
P ppm	20.0	10.0
K ppm	198.0	157.0
O.M. %	0.87	0.57
% Sand	24.4	58.0
% Silt	37.2	36.8
% Clay	38.4	5.2
Texture	Clay loam soil	Sandy loam soil

* Each value is an average of three replicates.

Implementation of experiments

The fields of both stations were tilled in December 2018 using a disc plough and each field was divided into 12 plots, each measured $2 \times 3 \text{ m}^2$. Wheat grains of cv. (IPA 99) were inoculated with two applications of cyanobacteria mixture either by grains coating with compost amended with cyanobacteria mixture [11], or by foliar spraying [10], and sown in rows at 120 kg/ha^{-1} with a distance of 20 cm between rows. The experiments were conducted in randomized complete block design (RCBD) with three experimental replicates.

The experiments consisted of the following treatments:

- 1- Control (without cyanobacteria and fertilizers).
- 2- 50% CFs (half dose).
- 3- 100% CFs (full dose).
- 4- Grains coating with compost amended with *Anabaena circinalis* and *Nostoc commune* mixture (A and N).
- 5- Grains coating with compost amended with *Anabaena circinalis* and *Nostoc commune* mixture (A and N) and 50% CFs.
- 6- Grains coating with compost amended with *Anabaena circinalis* and *Nostoc commune* mixture (A and N) and 100% CFs.
- 7- Grains coating with compost.
- 8- Grains coating with compost and 50% CFs.
- 9- Grains coating with compost and 100% CFs.
- 10- Foliar spraying of cyanobacteria (*Anabaena circinalis* and *Nostoc commune*) extract (A and N).
- 11- Foliar spraying of cyanobacteria (*Anabaena circinalis* and *Nostoc commune*) extract (A and N) and 50% CFs.
- 12- Foliar spraying of cyanobacteria (*Anabaena circinalis* and *Nostoc commune*) extract (A and N) and 100% CFs.

Urea (46% Nitrogen) at 260 kg/ha^{-1} and diammonium phosphate (DAP) at 200 kg/ha^{-1} were applied to their respective plots as recommended by the Iraqi Ministry of Agriculture for wheat crop. Half of the nitrogen and all phosphorus were applied during planting, while the remaining nitrogen was applied into three equal portions at tillering, booting and flowering stages [32]. Wheat crop was irrigated as needed at Al-Sewarah station, while rains were the main source of irrigation at Kurkok station.

Grains of wheat cv. IPA 99 were coated with compost amended with or without cyanobacteria in the presence or absence of 50 and 100% of the recommended dose of CFs [11]. Foliar spraying of cyanobacteria extract at 1% (W/V) was made at the time of urea application by using a spray pump [33]. Tween-20 at 0.1% (V/V) solution was used to decrease the surface tension [34].

The spray was made on plants, fertilized or not fertilized, with 50 or 100% CFs. At physiological maturity (159 days after cultivation for Al-Sewarah station and =146 days after cultivation for Kurkok station), ten plants were randomly selected from each plot and measured for grains and biological yields, harvest index, flag leaf area, chlorophyll, and spike length, using standard procedures [35].

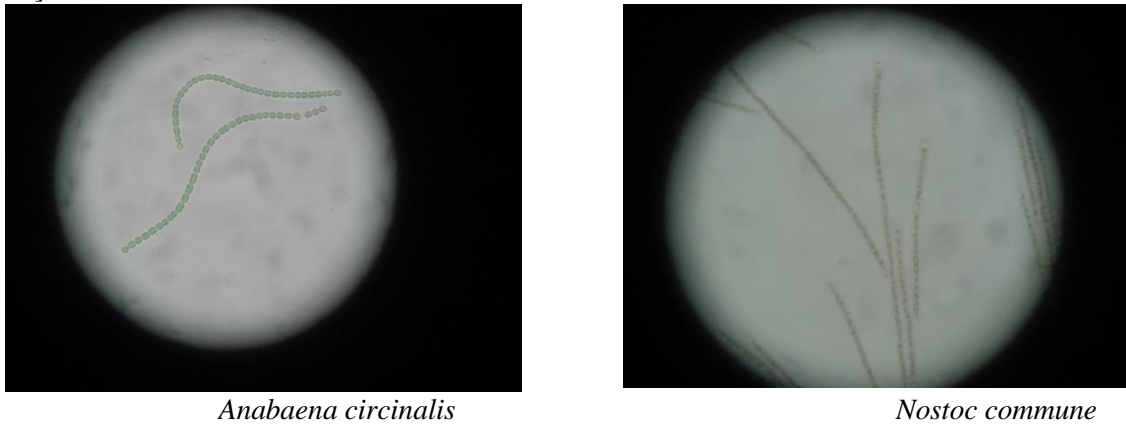
Statistical analysis

The data were subjected to statistical analysis using analysis of variance (ANOVA) by GENSTAT computer software package. Differences among treatment averages were compared using Least Significant Difference (LSD) at 0.05 probability level [36].

Results and Discussion

Our study results indicated that cyanobacteria isolates mixture (*Nostoc and Anabaena*) (Figure- 1), cultured in the experiment bioreactors, produced higher fresh biomass at values of 13.2 g/l to free sodium nitrate concentrations after 28 days of incubation. The combination of the two cyanobacteria species is believed to significantly increase the germination percentage, stimulate the growth parameters including photosynthetic pigment, and decrease the need for the usage of the mineral form of nitrogen fertilizer [9]. Moisturized compost amended with cyanobacteria significantly affected all test parameters, except salinity which was decreased by 24% over control, while N and P were increased by 38.6 and 14.2%, respectively, over control (Table-2). No attempt was carried out to explore the reasons of such differences; however, previous investigations indicated that the addition of cyanobacteria to compost enhanced the microbial activity and resulted in the excretion of many substances (growth promoting regulators, vitamins, amino acids, polypeptides, antibacterial agents,

and polymers, especially exopolysaccharides) which induced the growth of other microorganisms [11, 37].



Anabaena circinalis

Nostoc commune



Figure 1-Cultivation of cyanobacteria isolates in bioreactors

It is noteworthy to mention that although the concentrations of nitrogen and phosphorus were increased by the addition of cyanobacteria, the amount added to the medium was far below the concentration required by the plant. Thus the compost can be considered as an inert source of fertilizer.

Table 2 -Biochemical characteristics of compost used in the experiments.

Treatments	Parameters*			
	pH	EC dS m ⁻¹	N ppm	P ppm
Control (compost without addition)	6.5	6.7	232	121.0
Compost amended with cyanobacteria mixture	6.6	5.1	378	141.0
LSD ≤ 0.05	0.3	0.3	46.8	9.0

*Each value is an average of three replicates

1. Effects of cyanobacteria combined with reduced dose of CFs

All treatments significantly averted grains, yield and harvest index of wheat, with the exception of grains coated with compost amended with cyanobacteria, grains coated with compost, and foliar spraying with cyanobacteria at Al- Searah station (Table-3). However, the application of 50% CFs along with the treatments of grains coating with compost amended with cyanobacteria or foliar with cyanobacteria extract provided grains yield, biological yield and harvest index similar to those achieved by the recommended dose of CFs.

Table 3-Effects of *Anabaena circinalis* and *Nostoc commune* (A and N) in combination with CFs on grains, biological yields, and harvest index of wheat at Al- Sewarah station.

Treatments*	Grains Yield (t / ha)	Biological Yield (t / ha)	Harvest index (%)
Control	2.8	10.1	28
50% CFs	4.7	12.9	34
100% CFs	5.7	15.1	38
Grains coating with compost amended with (A and N)	3.0	11.0	26
Grains coating with compost amended with (A and N) and 50% CFs	6.1	15.4	39
Grains coating with compost amended with (A and N) and 100% CFs	5.8	15.0	39
Grains coating with compost	2.7	9.8	28
Grains coating with compost and 50% CFs	4.9	12.8	35
Grains coating with compost and 100% CFs	6.1	15.7	39
Foliar application of cyanobacteria (A and N) extract	3.0	10.4	29
Foliar application of cyanobacteria (A and N) extract + 50% CFs	6.2	16.0	40
Foliar application of cyanobacteria (A and N) extract + 100% CFs	6.0	16.0	38
LSD \leq 0.05	0.9	1.9	2.6

* Average of three replicates.

At Kurkok station, lower values of grains and biological yields of wheat were observed due to the differences in the amount of irrigation water, soil texture, and other factors. Yet, the trend of the effects of the tested treatments on growth and yield parameters remained almost the same (Table-4). Treatments that included grains coating with compost amended with cyanobacteria, grains coating with compost, and cyanobacteria extract applied as a foliar, did not have significant differences from control in all parameters of yield components. Also, combined application of 50% CFs and grains coating with compost amended with cyanobacteria or cyanobacteria extract as a foliar have resulted in grains, biological yields, and harvest index values similar to those achieved by sole application of the recommended rate of CFs.

Table 4-Effects of *Anabaena circinalis* and *Nostoc commune* (A and N) alone and in combination with CFs on grains and biological yields of wheat at Kurkok station.

Treatments*	Grains Yield (t / ha)	Biological Yield (t / ha)	Harvest index (%)
Control	2.13	9.44	23
50% CFs	3.67	12.81	29
100% CFs	4.77	14.44	33
Grains coating with compost amended with (A and N)	2.23	10.64	21
Grains coating with compost amended with (A and N) and 50% CFs	4.80	14.01	34
Grains coating with compost amended with (A and N) and 100% CFs	4.63	13.84	34
Grains coating with compost	2.10	9.24	23
Grains coating with compost and 50% CFs	3.77	12.43	30
Grains coating with compost and 100% CFs	4.53	13.33	34
Foliar application of cyanobacteria (A and N) extract	2.20	9.20	24
Foliar application of cyanobacteria (A and N) extract and 50% CFs	4.70	13.54	35
Foliar application of cyanobacteria (A and N) extract and 100% CFs	4.17	12.38	34
LSD \leq 0.05	0.38	1.66	2.5

* Average of three replicates

The results presented in Tables- 3 and 4 show that the application of cyanobacteria with compost or as a foliar in the absence of 50% CFs did not have any significant effects on grains, biological yields, and harvest index of wheat. However, once this amount of fertilizer was added, a remarkable increase in grains, biological yield and harvest index over control and over sole application of 50% CFs treatments was obtained. This suggests that this amount of fertilizer did not only improve the nutritional status of the plant but also provided growth conditions with nitrogen and phosphate which are essential for the growth and propagation of cyanobacteria [38].

The increased harvest index value suggests that the plant may be able to transfer and allocate more dry matter towards the grains, and thereby grains crop yield is enhanced [39].

2. Effects of cyanobacteria combined with reduced CFs

The treatments that included grains coating with compost amended with cyanobacteria grains coating with compost, and cyanobacteria extract applied as a foliar did not show significant differences in comparison to the control in all yield component parameters tested. An exception was the number of spikes/plot which was recorded to be higher in foliar application of cyanobacteria extract than in control in Al-Sewarah station (Table- 5). However, a highly significant increase in the tested growth parameters was achieved following the application of 50% of CFs combined with compost amended with cyanobacteria or with cyanobacteria extract. Remarkably, the increase in yield components in the aforementioned treatments was statistically similar to that of the label rate of CFs.

Table 5-Effects of *Anabaena circinalis* and *Nostoc commune* (A and N) alone and in combination with reduced CFs on yield components of wheat at Al-Sewarah station.

Treatments*	Number of spikes /plot*	Number of grains /spike**	Weight of 1000 grains* (g)
Control	204	40	29.1
50% CFs	345	48	31.4
100% CFs	439	56	33.3
Grains coating with compost amended with (A and N)	203	41	31.8
Grains coating with compost amended with (A and N) and 50% CFs	425	57	34.7
Grains coating with compost amended with (A and N) and 100% CFs	420	53	33.6
Grains coating with compost	234	39	28.8
Grains coating with compost and 50% CFs	353	47	31.4
Grains coating with compost and 100% CFs	425	54	33.0
Foliar application of cyanobacteria (A and N) extract	271	43	31.1
Foliar application of cyanobacteria (A and N) extract and 50% CFs	455	54	33.5
Foliar application of cyanobacteria (A and N) extract and 100% CFs	433	52	32.1
LSD \leq 0.05	58	6.0	1.4

* Average of three replicates. ** Average of ten replicates

At Kurkok station, yield component values were lower than those of Al-Sewarah station, yet, the trend of the effects of the test treatments remained almost consistence across the stations (Table-6). Treatments that included grains coating with compost amended with cyanobacteria, grains coating with compost, and cyanobacteria extract applied as a foliar did not show significant differences than the control in all yield component parameters tested (Table-6). On the other hand, application of 50% CFs along with compost amended with cyanobacteria or with foliar cyanobacteria extract resulted in similar yield components as those noticed at 100% CFs.

Table 6-Effects of *Anabaena circinalis* and *Nostoc commune* (A and N) alone and in combination with CFs on yield components of wheat at Kurkok station.

Treatments*	Number of spikes /plot*	Number of grains / spike**	Weight of 1000 grains (g)*
Control	198	39	24.60
50% CFS	303	42	27.14
100% CFS	377	49	31.20
Grains coating with compost amended with (A and N)	211	40	25.58
Grains coating with compost amended with (A and N) and 50% CFs	377	49	31.10
Grains coating with compost amended with (A and N) and 100% CFs	350	48	30.15
Grains coating with compost	196	41	25.41
Grains coating with compost and 50% CFs	315	43	27.64
Grains coating with compost and 100% CFs	370	49	30.11
Foliar application with (A and N) extract	227	41	25.88
Foliar application with (A and N) extract and 50% CFs	397	50	31.90
Foliar application with (A and N) extract and 100 CFs	355	48	31.07
LSD \leq 0.05	51	2.6	1.73

* Average of three replicates. ** Average of ten replicates

The results in Tables- 5 and 6 revealed that the increase in grains yield was found to be due to the increase in all yield components in both stations. The increased number of spikes, number of grains per spike, and weight of 1000 grains when cyanobacteria was applied with 50% CFs may be attributed to the prolonged nutrients availability by cyanobacteria through the whole life cycle of wheat, through thus decreasing the leaching of nutrients [40].

3. Effects of cyanobacteria combined with reduced dose of CFs

Treatments of grains coating with compost amended with cyanobacteria, grains coating with compost, and cyanobacteria extract applied as a foliar did not show significant differences from the control treatment in all agronomic traits tested. An exception was noticed in chlorophyll content and plant height which were increased by treatments by cyanobacteria extract and grains coating with compost amended with cyanobacteria, respectively (Table-7). However, a highly significant increase in the tested growth parameters was achieved following the application of 50% of CFs combined with compost amended with cyanobacteria or with cyanobacteria extract. Remarkably, the increase in agronomic traits in the aforementioned treatments was statistically similar to that of the label rate of chemical fertilizers (100% CFs).

Table 7- Effects of *Anabaena circinalis* and *Nostoc commune* (A and N) alone and in combination with CFs on some agronomic traits of wheat at Al- Sewarah station .

Treatments*	Plant height cm	Flag leaf area cm ²	Chlorophyll 1 (SPAD units)	Spike length cm
Control	68.0	34.8	38.9	9.9
50% CFs	74.2	43.3	47.3	11.9
100% CFs	83.0	56.4	51.8	12.9
Grains coating with compost amended with (A and N)	74.8	35.7	39.0	11.1
Grains coating with compost amended with (A and N) and 50% CFs	85.2	54.6	52.2	13.6
Grains coating with compost amended with (A and N) and 100% CFs	86.6	50.6	50.7	13.0
Grains coating with compost	71.2	36.1	39.5	10.9
Grains coating with compost and 50% CFs	75.2	45.4	44.7	12.2
Grains coating with compost and 100% CFs	81.4	53.9	49.7	12.1

Foliar application with (A and N) extract	72.2	34.8	43.6	11.6
Foliar application with (A and N) extract and 50% CFs	82.6	54.8	51.8	13.5
Foliar application with (A and N) extract and 100% CFs	81.2	53.1	53.0	13.3
LSD \leq 0.05	6.0	6.2	3.7	0.9

*Average of ten replicates

At Kurkok station, agronomic traits values were less than those of Al-Sewarah station, yet, the trend of the effects of the tested treatments remained almost consistence across the stations (Table- 8). Treatments of grains coating with compost amended with cyanobacteria, grains coating with compost, and cyanobacteria extract applied as a foliar did not record significant differences in all of the parameters tested in comparison to the control treatment. Exceptions were observed as related to plant height and spike length which increased over control by treatments of grains coating with compost amended with cyanobacteria and foliar application of cyanobacteria extract.

On the other hand, application of 50% CFs along with compost amended with cyanobacteria or with foliar cyanobacteria extract resulted in similar yield components as that noticed with 100% CFs.

Table 8-Effects of *Anabaena circcinalis* and *Nostoc commune* (A and N) alone and in combination with CFs on some agronomic traits of wheat at Kurkok station

Treatment*	Plant height cm	Flag leaf area cm ²	Chlorophyll (SPAD units)	Spike length cm
Control	60.8	29.2	30.3	8.8
50% CFs	68.2	36.3	38.9	10.8
100% CFs	79.4	43.3	43.7	12.4
Grains coating with compost amended with (A and N)	70.8	30.8	34.4	11.1
Grains coating with compost amended with (A and N) and 50% CFS	83.6	43.1	43.9	12.5
Grains coating with compost amended with (A and N) and 100% CFs	78.8	43.4	46.1	12.2
Grains coating with compost	64.6	30.6	33.4	9.5
Grains coating with compost and 50% CFs	74.6	38.3	43.1	11.1
Grains coating with compost and 100% CFs	80.2	42.8	43.3	11.6
Foliar application with (A and N) extract	72.0	33.1	35.5	11.8
Foliar application with (A and N) extract and 50% CFs	84.0	44.5	46.0	13.3
Foliar application with (A and N) extract and 100% CFs	79.0	41.5	45.4	12.5
LSD \leq 0.05	6	4.2	4.4	1.2

* Average of ten replicates

The increase of the tested growth parameters appeared to be due to complementary effects of cyanobacteria and reduced rate of fertilizers, since the application of 50% CFs alone resulted in an increase in the tested growth parameters which was less than the increase noticed following the combination of cyanobacteria and 50% CFs. Cyanobacteria is reported to increase the fertility, productivity and water holding capacity of soil and provide some growth regulators such as auxin, abscisic acid, gibberellins, and vitamin B12. In addition, it has a contribution in increasing the viability of minerals, particularly nitrogen and phosphors that are essentially required for plant growth and development [41].

Conclusions

Based on the obtained results, it can be concluded that wheat grains coating with compost amended with cyanobacteria or foliar spraying of cyanobacteria in the presence of 50% chemical fertilizers provide wheat growth and yield similar to that achieved by the label rate of chemical fertilizers. This implicates the importance of such approach in reducing the input of chemical fertilizers into agricultural ecosystems and promoting sustainability.

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