Evaluating the plant growth promoting efficiency of freshwater cyanobacteria using maize (*Zea mays* L.) as an experimental crop

Krishna Moorthy Sivalingam

Associate Professor, B-062, Department of Biology, College of Natural and Computational Sciences, Wolaita Sodo University, Wolaita Sodo, Post Box No.: 138, Ethiopia. skrish.microbiologist@gmail.com

Abstract: ***The present study was mainly focussed on evaluating the plant growth promoting activity of eleven cyanobacterial cultures (ten non-heterocystous and one heterocystous) obtained from the germ plasm collections of the Department of Biology, Wolaita Sodo University, Ethiopia, using Zea mays L. as an experimental crop under pot culture experiment. All the pots were treated with 2.5g of both non-heterocystous and heterocystous cyanobacteria as individual as well as in combined form. The pots treated with 2.5gm of chemical fertilizer Di Ammonium Phosphate was used for comparative purpose. Pots without inoculation was served as a control. All pots inoculated by cyanobacterial cultures and chemical fertilizer showed significant enhancement in all the morphological and biochemical parameters over uninoculated control. The pots treated with non-heterocystous cyanobacterial isolates Geitlerinema sp. WSU3 and heterocystous cyanobacterial isolates Calothrix sp. WSU11 showed significantly the highest results when compared to control, chemical fertilizer treatment, individual and combined treatment of all other cyanobacterial cultures. Based on the current study results, we recommend the cyanobacterial isolates Geitlerinema sp. WSU3 and Calothrix sp. WSU11 can be used as biofertilizers for the cultivation of Z. mays L. as well as can also be used as alternatives for the chemical fertilizers.***

Keywords: Cyanobacteria; Plant growth promotion; Heterocystous; Non-heterocystous; Chemical fertilizer; Maize.

1. Introduction

Ethiopia is one of the largest populated African countries with a population of 102.4 million people [1]. The country shares boundaries with Eritrea to the north, Kenya to the south, Somalia to the east and Sudan to the west. The majority (83.8%) of Ethiopians reside in the rural areas and performing agriculture for their regular income. Agriculture sector is the mainstay of the Ethiopian economy and therefore this sector regulates the growth of all the other sectors and, subsequently, the whole national economy of Ethiopia [2 and 3].

This agriculture sector constitutes above 50% of the gross domestic product (GDP), accounts for over 85% of the labour force and earns above 90% of the foreign exchange [4]. On average, crop production makes up 60% of the sector's outputs whereas livestock accounts for 27% and other areas contribute 13% of the total agricultural value added. The sector is dominated by small-scale farmers who practice rain-fed mixed farming by employing traditional technology, adopting a low input and low output production system. This low input and low output concept were followed by farmers usually due to the high cost of chemical fertilizers, low availability and side effects of chemical fertilizers in the soil as well as to the crops. So, the requirement of biofertilizers as an alternative to chemical fertilizers is very urgent to improve the productivity of crops in agriculture sector. Biofertilizers are microorganisms applied as live form to enhance the crop productivity and improve the soil health. Different kinds of microorganisms belonging to several taxa of the bacteria, fungi, algae and possibly, protozoa kingdoms, colonizing the rhizosphere or the plant tissues and promoting plant growth microorganisms (PGPM), can be utilized for the production of biofertilizers [5, 6 and 7]. Among these various kinds of microorganisms, cyanobacteria placed in a first place.

Cyanobacteria are oxygenic, photosynthetic, free living and nitrogen fixing microorganisms commonly found in marine water, fresh water systems and soil. Cyanobacteria can be used as biofertilizer for plants, as food for human consumption and for the extraction for various products such as vitamins, drug compound and human growth factors [8]. Most of the present research related cyanobacteria aims to use N_2-fixing cyanobacteria as well as growth promoting cyanobacteria to decrease the dependence on chemical fertilizers for crop production. Many free-living blue-green algae (cyanobacteria) fix atmospheric nitrogen and since they are photosynthetic, they do not compete with crop plants and heterotrophic soil micro flora for carbon and energy. An additional benefit of using cyanobacteria as biofertilizer is the ability to secrete bioactive substances such as auxin, gibberellins, cytokinins, vitamins, polypeptide, amino acid, which promote plant growth and development [9 and 10]. They also improve the physico-chemical properties of the soil by enriching them with carbon, nitrogen, available phosphorus, etc.

Maize (*Zea mays* L.) or corn is one of the important cereal crops cultivated in Ethiopia and act as a staple food crop [11]. White maize is one the major food crop in Ethiopia after tef (*Eragrostis tef*). Ethiopia ranked 5th major producer of corn in Africa and 94% of the crop cultivation is covered by smallholder farmers [12]. All the farmers are applying chemical based inorganic fertilizers for cultivation of maize.

Due to continuous and over dosage of inorganic fertilizers hardly affecting the soil health which leads to decline in the crop yield. So many studies outside Ethiopia have been studied related to plant growth promoting efficiency of cyanobacterial cultures using different crops but very rare in Ethiopia. Hence in the present study, an attempt has been made to evaluate the plant growth promoting efficiency of freshwater cyanobacteria using Maize (*Zea mays* L.) as an experimental crop under pot culture experiment.

2. Material and Methods

2.1. Sample source and sample collection

The fresh water non-heterocystous cyanobacterial cultures *Pseudanabaena* sp. WSU1, *Phormidium* sp. WSU2, *Geitlerinema* sp. WSU3, *Arthrospira* sp. WSU4, *Oscillatoria* sp. WSU5, *Phormidium* sp. WSU6, *Lyngbya* sp. WSU7, *Gloeocapsa* sp. WSU8, *Oscillatoria* sp. WSU9, *Spirulina* sp. WSU10 and a heterocystous cyanobacterial culture *Calothrix parietina* WSU11 was obtained from the germplasm collections of Department of Biology, College of Natural and computational Sciences, Wolaita Sodo University, Wolaita Sodo, Ethiopia.

2.2. Mass Cultivation of fresh water cyanobacteria under laboratory condition

The non-heterocystous cyanobacterial cultures *Pseudanabaena* sp. WSU1, *Phormidium* sp. WSU2, *Geitlerinema* sp. WSU3, *Arthrospira* sp. WSU4, *Oscillatoria* sp. WSU5, *Phormidium* sp. WSU6, *Lyngbya* sp. WSU7, *Gloeocapsa* sp. WSU8, *Oscillatoria* sp. WSU9, *Spirulina* sp. WSU10 and the heterocyst forming cyanobacterium *Calothrix parietina* WSU11 was inoculated individually to the conical flasks containing sterilized BG11 media aseptically. All the inoculated conical flasks were incubated under 1500lux (Philips cool-white light, 16hrs light 8hrs dark cycle) and at 25±2°C temperature in culture room [13]. The cyanobacterial cultures were harvested after 15-20days of incubation to evaluate the plant growth promoting efficacy under pot experiment [14].

2.3. Pot Experiments

All the 11 (both heterocystous and non-heterocystous) mass cultivated cyanobacterial cultures were harvested and dried under shadow, and further the dried cultures were then powdered by using mortar and pestle and used as inoculum. 4 numbers of healthy seeds of *Zea mays* L. were added to each 3 Liter capacity pots. All the pots were treated with both non-heterocystous and heterocystous cyanobacterial cultures individually as well as in combined form. 2.5g of each cyanobacterial isolate were inoculated to each pot and 2.5gm of chemical fertilizer Di-ammonium Phosphate (DAP) was added in other pot for comparative purpose at 15 days interval. Pot without any cyanobacterial inoculation and chemical fertilizer was served as a control [15].

2.3.1. Morphological analysis

The experimental plants (*Zea mays* L.) were harvested 30 days after planting and examined for a number of morphological parameters such as plant height, number of leaves, leaf length and leaf width, leaf fresh weight, leaf dry weight, number of roots, root length, root fresh weight and dry weight [16 and 17].

2.3.2. Biochemical analysis

The experimental plant leaves were harvested and photosynthetic pigments contents such as Chlorophyll *a* [18], Chlorophyll *b* [18], Total chlorophyll [18], and carotenoids [19] were quantitatively analyzed.

2.4. Statistical Analysis

The measurements of growth and biochemical parameters were subjected to one-way analysis of variance (ANOVA) technique (Origin pro software package 7.0) and mean separations were adjusted by the Multiple Comparison test. Means were compared by using Fisher's test at $p<0.05$ level of significance. All the data included in the figures were presented in mean and standard error (±) of mean of three replicates per treatment and repeated three times.

3. Result and Discussions

Pot experiment was conducted to examine the growth promoting efficiency of heterocystous and non-heterocystous cyanobacterial isolates and compared with chemical fertilizer and control. During this pot experiment periods, the morphological parameters such as Plant height, Number of leaves, Leaf length, Leaf width, Root length, Number of roots, Shoot fresh and dry weight, Root fresh and dry weight were observed, and the biochemical parameters such as Chlorophyll *a*, chlorophyll *b*, Total chlorophyll and carotenoids content was also quantified. The results from pot experiments were collected on 30th day and displayed in the forms tables and photographs. All the results collected from pot experiments are as follows.

3.1. Analysis of morphological parameters

In the present pot investigation, the applications cyanobacterial isolates showed significant effects on all morphological characteristics of *Zea mays* L. (Table 1, Table 2, Figure 1 and Figure 2). Table - 1 reveals the growth of the plant which was expressed in terms of plant height, number of leaves, leaf length and leaf width. The morphological parameters such as plant height, number of leaves, leaf length and leaf width of pots treated with chemical fertilizers (DAP), pots treated with both heterocystous and non-heterocystous cyanobacterial isolates (combined treatment), pots treated with all non-heterocystous and heterocystous cyanobacterial isolates as individual showed significantly higher results over control (Pots without any dosage).

The pots treated with combinations of heterocystous and non-heterocystous cyanobacterial isolates, pots treated with non heterocystous isolates such as WSU1 *(Pseudanabaena* sp. WSU1), WSU2 (*Phormidium* sp. WSU2), WSU3 (*Geitlerinema* sp. WSU3), WSU4 (*Arthrospira* sp. WSU4), WSU5 (*Oscillatoria* sp. WSU5), WSU6 (*Phormidium* sp. WSU6), WSU7 (*Lyngbya* sp. WSU7), WSU8 (*Gloeocapsa* sp. WSU8), WSU9 (*Oscillatoria* sp. WSU9, WSU10 (*Spirulina* sp. WSU10) and heterocystous cyanobacterial isolate WSU11 (*Calothrix* sp. WSU11) as individually showed significant changes in the morphological parameters such as plant height, number of leaves, leaf length and leaf width over control pots (Table 1). The maximum plant height (56.50 ± 0.404cm), number of leaves (8.67 ± 0.333), leaf length (47.10 ± 0.208cm) and leaf width (3.67 ± 0.033cm) were observed in the pots treated with non-heterocystous cyanobacterial isolates WSU3 (*Geitlerinema* sp. WSU3) which was significantly higher than control pots, chemical fertilizers treated pots, pots with combined treatment of heterocystous and non-heterocystous, and all other cyanobacterial isolates treated pots (Table 1).

Table 1: Effect cyanobacterial isolates on morphological parameters of *Zea mays* L. under pot experiment on 30 DAP (Days After Planting)

S. No.	Treatments	Morphological parameters			
		Plant height (cm)	No. of leaves (nos.)	Leaf length (cm)	Leaf width (cm)
1	Control	23.33 ± 1.76	5.67 ± 0.33	20.37 ± 0.85	2.1 ± 0.10
2	Chemical fertilizer	38.00 ± 1.73*	6.33 ± 0.33*	31.80 ± 0.76*	3.03 ± 0.03*
3	Combined Treatment	46.83 ± 1.36*a	7.67 ± 0.33*a	35.4 ± 0.87*a	3.2 ± 0.10*
Non - Heterocystous Isolates					
4	WSU - 1	44.43 ± 0.81*a	7.33 ± 0.33*a	34.96 ± 0.84*a	3.43 ± 0.03*a
5	WSU - 2	51.00 ± 0.90*ab	8.33 ± 0.3*ab	40.60 ± 0.55*ab	3.56 ± 0.03*ab
6	WSU - 3	56.50 ± 0.40*ab	8.67 ± 0.3*ab	47.10 ± 0.21*ab	3.67 ± 0.03*ab
7	WSU - 4	46.67± 0.705*a	7.66 ± 0.33*a	34.20± 0.643*a	3.23 ± 0.089*
8	WSU - 5	39.27 ± 1.131*	6.67 ± 0.33*	30.63 ± 0.39*	2.63 ± 0.09*
9	WSU - 6	41.53 ± 0.53*a	7.67 ± 0.33*a	33.30 ± 0.47*	3.07 ± 0.07*
10	WSU - 7	34.36± 0.554*a	6.66±0 .333*	26.67± 0.696*a	2.80 ± 0.208*
11	WSU - 8	46.87± 0.69*a	7.67 ± 0.33*a	36.53± 0.721*a	3.30 ± 0.290*
12	WSU - 9	40.9±0. 862*	6.33±0 .333*	33.57± 0.726*	2.93 ± 0.091*
13	WSU - 10	45.60± 1.40*a	6.67 ± 0.333*	34.50± 0.569*a	3.36 ± 0.145*a
Heterocystous Isolate					
14	WSU - 11	49.30 ± 0.65*ab	8.33 ± 0.3*ab	37.6 ± 0.65*ab	3.57 ± 0.09*ab

Values are the mean of three replicates ± SEM.
* - Indicates significance results over control ($p<0.05$)
a – Significance results over chemical ($p<0.05$)
b – Significance results over combined treatment ($p<0.05$)

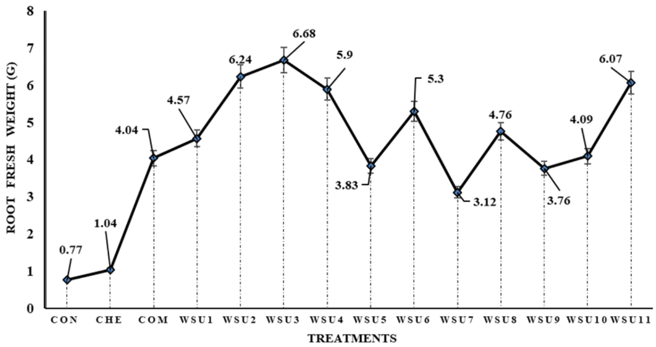
The treatments of chemical fertilizers (DAP), treatment of combinations of heterocystous and non heterocystous cyanobacterial isolates, individual treatments of all the cyanobacterial isolates showed significant improvement in the morphological parameters such as root length, number of roots, shoot fresh and dry weight; root fresh weight and dry weight when compared to control (Table 2, Figure 1 and Figure 2). The maximum improvement in the root and shoot parameters of *Z. mays* L. was observed in the pots treated with non-heterocystous cyanobacterial isolate WSU3 (*Geitlerinema* sp. WSU3) when compared to the treatment of control, chemical fertilizers and combination of heterocystous and non heterocystous cyanobacterial isolates. The pots treated with non heterocystous cyanobacterial isolates WSU3 (*Geitlerinema* sp. WSU3) showed significantly highest results in overall analysis of morphological parameters of *Z. mays* L. followed by heterocystous cyanobacterial isolates WSU11 (*Calothrix* sp. WSU11).

Table 2: Effect cyanobacterial isolates on morphological parameters of *Zea mays* L. under pot experiment on 30 DAP (Days After Planting)

S. No.	Treatments	Morphological parameters			
		Root Length (cm)	No. of Roots (Nos.)	Shoot Fresh Weight (g)	Shoot Dry Weight (g)
1	Control	12.40± 0.74	6.0 ± 0.58	3.1 ± 0.21	0.283 ± 0.04
2	Chemical fertilizer	22.87 ± 0.744*	8.66 ± 0.333*	7.37 ± 0.143*	1.00 ± 0.057*
3	Combined Treatment	40.9 ± 1.01*a	13.6 ± 0.81*	8.46 ± 0.14*a	1.77 ± 0.07*a
Non - Heterocystous Isolates					
4	WSU - 1	52.3 ± 0.6*ab	16.7 ± 0.9*ab	8.96 ± 0.15*a	2.08 ± 0.08*ab
5	WSU - 2	71.6 ± 1.1*ab	18.7 ± 0.8*ab	10.76± 0.26*ab	2.23 ± 0.05*ab
6	WSU - 3	77.46 ± 1.29*ab	22.33± 0.8*ab	13.52± 0.59*ab	2.62 ± 0.13*ab
7	WSU - 4	43.56 ± 1.26*a	18.7 ± 0.7*ab	9.10 ± 0.35*a	1.36 ± 0.03*a
8	WSU - 5	78.36± 0.89*ab	11.33± 0.67*a	6.72 ± 0.25*	0.72 ± 0.03*
9	WSU - 6	47.90 ± 1.05*ab	16.7 ± 0.9*ab	8.77 ± 0.35*a	1.06 ± 0.05*
10	WSU - 7	49.56 ± 0.41*ab	10.33± 0.33*	4.57 ± 0.32*	0.57 ± 0.03*
11	WSU - 8	45.46 ± 0.55*ab	16.0 ± 0.6*ab	9.22 ± 0.51*a	1.73 ± 0.06*a
12	WSU - 9	46.90 ± 0.70*ab	13.3 ± 1.12*a	7.06 ± 0.29*	1.19 ± 0.09*a
13	WSU - 10	66.90 ± 1.61*ab	16.7 ± 0.9*ab	8.73 ± 0.32*a	1.13 ± 0.07*
Heterocystous Isolate					
14	WSU - 11	60.3 ± 1.6*ab	21.1 ± 0.9*ab	11.5 ± 0.4*ab	2.21 ± 0.06*ab

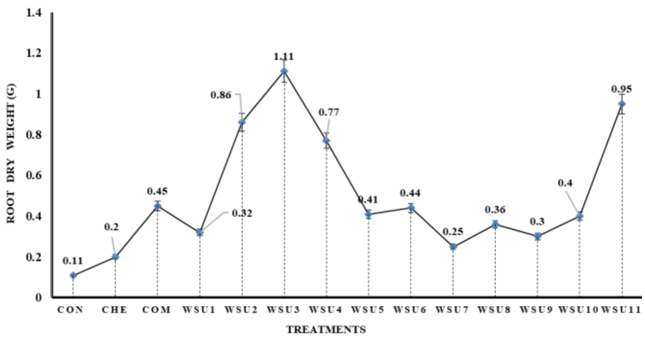
Values are the mean of three replicates ± SEM.
* - Indicates significance results over control ($p<0.05$)
a – Significance results over chemical ($p<0.05$)
b – Significance results over combined treatment ($p<0.05$)

The reasons for these significantly higher results are may be due to ability of phytohormones production like Auxins and cytokinin which helps plants to reach higher results. Another one reason is *Calothrix* sp. WSU11 a heterocystous cyanobacteria which can fix atmospheric nitrogen and can stimulates the plant growth. An important feature of cyanobacteria is their ability to fix atmospheric nitrogen under both free living and symbiotic conditions and promote the plant growth [20]. The biological production of various growth promoting active substances including phytohormones, such as auxin [21], gibberellins [22] and cytokinin [23]. The indirect promotion of plant growth occurs with fixing atmospheric nitrogen by cyanobacteria [20].



CON- CONTROL; CHE- CHEMICAL FERTILIZER; COM- COMBINED TREATMENT (Heterocystous + Non- Heterocystous); WSU1- *Pseudanabaena* sp.; WSU2- *Phormidium* sp.; WSU3- *Geitlerinema* sp.; WSU4- *Arthrospira* sp.; WSU5- *Oscillatoria* sp.; WSU6- *Phormidium* sp.; WSU7- Lyngbya sp.; WSU8- Gloeocapsa sp.; WSU9- Oscillatoria sp.; WSU10- Spirulina sp.; WSU11- *Calothrix* sp.; WSU- Wolaita Sodo University;

Figure 1. Effect cyanobacterial isolates on root fresh weight of *Zea mays* L. under pot experiment on 30 DAP (Days After Planting)



CON- CONTROL; CHE- CHEMICAL FERTILIZER; COM- COMBINED TREATMENT (Heterocystous + Non- Heterocystous); WSU1- *Pseudanabaena* sp.; WSU2- *Phormidium* sp.; WSU3- *Geitlerinema* sp.; WSU4- *Arthrospira* sp.; WSU5- *Oscillatoria* sp.; WSU6- *Phormidium* sp.; WSU7- Lyngbya sp.; WSU8- Gloeocapsa sp.; WSU9- Oscillatoria sp.; WSU10- Spirulina sp.; WSU11- *Calothrix* sp.; WSU- Wolaita Sodo University;

Figure 2. Effect cyanobacterial isolates on root dry weight of *Zea mays* L. under pot experiment on 30 DAP (Days After Planting)

The present study results are supported by the reports given by Eshetu Gebre [24] in which the liquid forms of cyanobacterial inoculants showed significantly higher results in the morphological parameters such as plant height, shoot fresh weight, number of leaves, leaf area and shoot dry weight than dried form of cyanobacterial inoculum, urea (chemical fertilizer), organic manure and control. Similarly the present study coincides with the study of Francis and Berhanu [16] who reported that the plants showed better in growth parameters (fresh shoot and root weight, dry shoot, root weight, leaf area, and number of branches) with application of cyanobacteria bio-fertilizers than with urea fertilizer and compost, thus indicating the potential of cyanobacteria biofertilizer as having a positive effect on soil fertility and yield and nutritional quality of cultivated vegetables such as tomato plant. Similarly, Mayur *et al.* [25] reported that the cyanobacterial isolates *Rivularia* spp., *Nostoc* spp., *Oscillatoria* spp., *Closterium* spp., *Gloeothece* spp., *Anabaena* spp., *Aphanocapsa* spp. and *Gloeocapsa* spp. showed positive effects on the root length and fresh weight of seedlings for mung and wheat when compared to control.

3.2. Analysis of biochemical parameters:

The experimental crop *Z. mays* L. plant was treated with different cyanobacterial isolates as individual as well as in combinations and examined for the changes occurred in the photosynthetic pigment contents and compared with control and chemicals fertilizers treatment. The results in the Table 3 shows that the changes in the chlorophyll *a*, chlorophyll *b*, total chlorophyll and carotenoid content of experimental crop *Z. mays* L. after 30 days of plantation. Based on the results showed in the Table 3, the pots treated with chemical fertilizers, combined treatment (Heterocystous and Non-heterocystous), individual treatments of all isolates significantly increased the photosynthetic pigment content of the experimental crop *Z. mays* L. over control. The pots treated with non-heterocystous cyanobacterial isolates WSU3 (*Geitlerinema* sp. WSU3) showed significantly best results followed by heterocystous cyanobacterial isolates WSU11 (*Calothrix* sp. WSU11) when compared to control Chemical fertilizers, combined treatment and all other individual treatments. The cyanobacterial treatment enhanced the *Z. mays* plant growth because cyanobacteria can release growth promoting substances (Auxin and cytokinin), increased soil organic content, improve soil structure and water holding capacity. They can also release micro and macro nutrients to the soils which supports the plant growth. This result was highly supported by Mohamed *et al.* [26] who reported that the application cyanobacterial culture *N. entophytum* and *O. angustissima* suspension inoculated at 1% and 0.5% significantly increased the photosynthetic pigments content of Pea plant. Cyanobacterial suspension contains a special set of biologically active compounds including plant growth regulators, which can decrease senescence and transpiration and increase the content of leaf chlorophyll.

The coir pith based cyanobacterial biofertilizers applied cow pea plants showed increase in biochemical parameters such as chlorophyll, carotenoid, protein and phenol content [26]. Abraham *et al.* [28] reported that the coir pith based cyanobacterial biofertilizers applied *Basella rubra* L. plants showed increase in biochemical parameters such as sugar (32.5 %), phenol (30.9 %), nitrate (13.1 %), protein (201.9 %), chlorophyll *a* (43.0 %) and carotenoid (14.2 %) in test plants over control. Similarly, the biochemical parameters of

Aloe barbadensis such as chlorophyll *a*, chlorophyll *b* and total chlorophyll, carotenoids, sugars and free amino acids contents were increased in the treatments of 0.1 %, 0.2 %, 0.3 % and 0.4 % of cyanospray but subsequent concentrations such as 0.5 % and 0.6 % of cyanospray treated plant pigments content was significantly decreased when compared to control [15].

Table 3: Effect cyanobacterial isolates on biochemical parameters of *Zea mays* L. under pot experiment on 30 DAP (Days After Planting)

S. No.	Treatments	Biochemical parameters			
		Chlorophyll *a* (mg/g)	**Chlorophyll *b* (mg/g)**	**Total Chlorophyll (mg/g)**	**Carotenoids (mg/g)**
1	Control	0.22 ± 0.012	0.15 ± 0.008	0.32 ± 0.017	0.06 ± 0.009
2	Chemical fertilizer	0.29 ± 0.035*	0.21 ± 0.014*	0.44 ± 0.026*	0.12 ± 0.005*
3	Combined Treatment	0.36 ± 0.008*a	0.27 ± 0.012*a	0.53 ± 0.020*a	0.14± 0.006*
Non - Heterocystous Isolates					
4	WSU - 1	0.31 ± 0.012*	0.28 ± 0.009*a	0.45 ± 0.019*	0.13 ± 0.033*
5	WSU - 2	0.47 ± 0.01*ab	0.30 ± 0.01*ab	0.70 ± 0.02*ab	0.19 ± 0.02*ab
6	WSU - 3	0.54 ± 0.01*ab	0.39 ± 0.02*ab	0.83 ± 0.03*ab	0.22 ± 0.01*ab
7	WSU - 4	0.39 ± 0.013*a	0.25 ± 0.012*a	0.50 ± 0.015*a	0.16 ± 0.006*a
8	WSU - 5	0.37 ± 0.009*a	0.20 ± 0.009*	0.47 ± 0.015*	0.13 ± 0.015*a
9	WSU - 6	0.40 ± 0.035*a	0.26 ± 0.015*a	0.55 ± 0.017*a	0.16 ± 0.008*a
10	WSU - 7	0.39 ± 0.012*a	0.26 ± 0.014*a	0.54 ± 0.008*a	0.15 ± 0.005*a
11	WSU - 8	0.40 ± 0.011*a	0.29 ± 0.012*a	0.58 ± 0.018*a	0.15 ± 0.020*a
12	WSU - 9	0.31 ± 0.012*	0.17 ± 0.005	0.40 ± 0.020*	0.11 ± 0.017*
13	WSU - 10	0.40 ± 0.008*a	0.20 ± 0.006*	0.55 ± 0.020*a	0.15 ± 0.012*a
Heterocystous Isolate					
14	WSU - 11	0.51 ± 0.01*ab	0.36 ± 0.01*ab	0.74 ± 0.02*ab	0.20 ± 0.014*ab

Values are the mean of three replicates ± SEM.
* **-** Indicates significance results over control (p<0.05)
a – Significance results over chemical (p<0.05)
b – Significance results over combined treatment (p<0.05)

Similarly, Subramaniyan *et al.* [29] reported that the effect of cyanobacterial biofertilizer effects on the growth parameters of corn (*Zea mays* L.). Cyanobacterial biofertilizers dosage increased the chlorophyll *a,* Chlorophyll *b* and total chlorophyll content of corn plants when compared with control and other treatments**.** The photosynthetic pigments content was also significantly enhanced by different combinations of coir pith based cyanobacterial biofertilizers cyanopith and cyanospray. The *Aloe* leaf pigments (chlorophyll *a,* chlorophyll *b,* and carotenoids) and consequently total pigments content was significantly (p<0.05) increased by all treatments of cyanopith with cyanospray when compared to control. The maximum improvement in the photosynthetic pigments content was obtained from the plants of T22 followed by plants of T16 and T12 [30].

4. Conclusions

The non-heterocystous cyanobacterial isolates *Geitlerinema* sp. WSU3 and heterocystous cyanobacterial isolate *Calothrix* sp. WSU11 showed the best results when compared control treatments, chemical fertilizers (Di Ammonium Phosphate) treatment, combined treatment (Heterocystous with Non-heterocystous cyanobacterial isolates) and individual treatment of all other cyanobacterial isolates under pot experiments. Based on the results obtained from the pot experimental studies, we can conclude that the cyanobacterial isolates *Geitlerinema* sp. WSU3 and *Calothrix* sp. WSU11 can be used as biofertilizers as well as can also be used as alternatives to the chemical fertilizers for the cultivation of *Zea mays* L.

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