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Potential Use of Cyanobacterial Bio-fertilizer on Growth of Tomato Yield Components and Nutritional Quality on Grown Soils Contrasting pH

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Abstract
Soil fertlity loss is considered as the most important prblem in developing tropical countries.This is especially serious for the Ethiopia whose larger proportion of the land mass is highland and soil mining through continous cultivation is common. On the other hand, cost of inorganic fertilizer is expensive and used in small quantity thus contributing to less crop yield. Even when this is possible, continous use of the chemical fertilizers in agricultural production is seriuos enviromental concern. In this study, therefore, a series of two different experiments were conducted to assess growth of cyanobacterial strains under two different water sources and to comparatively evaluate the use of cyanobacterial biofertilizer on growth and biomass production, and on nutritional quality of tomato fruits grown under contrasting soil PH (soil from WCU farm and Balesa are 5.9 and 8 respectively). In experiment I, two N fixing cyanobateria (Anabaena spp.) strains (E-3 and E-6) were evaluated in tap and river water for their growth and N fixation capacity. The result showed that there were siginficant difference ($P<0.001$) between strains in growth performance in both water sources. Accordingly, E-3 was found higher in growth and performance best in both water sources. In experiment II, five treatments namely dry as well as liquid cyanobacteria biofertilizer, urea, compost and unfertilized (control) were employed on tomato plant and studied in a CRD. The total experimental unit of the this research was the combination of two factors(soil type and fertlizer type), thus altogether making 10 treatments. Also, the residual effect of the cyanobacterial biofertilizer on soil fertlity has been assessed. Analysis of results indicated that there were significant difference among N sources on plant height, fruit number,number of flower and primary branches, beta carotene, plant Nitrogen (N), Phosphrous (P), Zinc (Zn) and Iron (Fe) contents of the tomato plant. As compared to the control treatment, the dried cyanobacteria resulted in increased value in plant height, primary branches, fruit number, in fruit weight per plant, shoot dry weight and number of flowers. In the same manner after harvesting dried cyanobacteria treatment resulted in more soil available phosphrus (Av.P), soil total Nitrogen (TN), while there were reduction in soil pH and soil EC. And also, analysis of nutrient content of plant revealed that the dried cyanobacteria treatments resulted in an increased value of nutrient content of plant (TN, phosphrus Zinc, Iron and fruit β carotene) over the control treatments. In almost all parameters studied, the tomato plants performed better on soil from WCU farm than in soil from Balesa farm soil showing inherent difference in fertility of the soils at these sites. Generally, plants showed better growth with application of cyanobacyeria bio-fertilizers than with urea fertilizer and compost, thus indicating the potential of cyanobacteria biofertilizer as having a postive effect on soil fertility and yield and nutritional quality of cultivated vegetables such as tomato plant.
Keywords: Cyanobacteria, N fixation,tomato, Growth parametrs and Yield components

1. INTRODUCTION

Agriculture is the core driver for Ethiopia's growth and long-term food security. Also, the economy of Ethiopia is predominantly dependent on agriculture, and small scale farming is a dominant portion of the sector. However, small scale farming still practices rain fed farming by employing traditional technology, adopting a low input and low output production system.

Most regions of Ethiopia are suitable for the production of a wide range of tropical and sub-tropical fruits, vegetables and flowers adaptable to specific locations and altitudes (Bonegr *et al*., 2004). Vegetable crops are valuable sources of vitamins, minerals and proteins especially to Ethiopia, where rural people often experience malnutrition (Michel Golden, 2002). Also, they are important for food security in times of drought, famine and food shortage; they are grown in the country both under rainfed and irrigated conditions. They provide a source of income for the farmers/producers.

Tomato *(Lycopersicon esculentum*) is one of the fruit vegetables, and it is a member of the *Solanacea*e family (Peralta and Spooner, 2001). Tomato is cultivated mainly in the central Rift Valley part of the country under irrigation (Lemma, 2002). Growing tomato in home gardens is an excellent investment of gardening time and is an income source, in addition to having health benefits, including eye sight, good gut health and low hypertension, diabetes, skin problems and urinary tract infections (Khachik *et al*., 1995). It is probably the most widely cultivated vegetable by the home gardener because of its food value, relatively easy to culture and locally widely available. Tomato is a source of carotenoids such as beta carotene, a precursor to vitamin A (Bauernfeind,

1972). In Ethiopia, an estimated five million people suffer from vitamin A deficiency and lack of essential minerals, of which 80% are children (Haile-Giorgis *et al.* 1996). Therefore, daily consumption of tomato is recommended to boost health, apart from improving the flavor of food.

Tomato is an intensively cultivated vegetable which requires large quantities of major nutrients like Nitrogen, Phosphorus and Potassium, in addition to secondary nutrients such as Calcium and Sulfur for better growth and fruit production. Therefore, maintenance of soil fertility is most important for sustainable tomato production to feed the rapidly increasing population. However, Ethiopia continues to face a set of constraints in soil fertility that restricts further and accelerated agricultural productivity and economic growth. Nutrient mining from the soil without using sufficient organic manure or inorganic fertilizer is the greatest cause for loss of soil fertility in most agricultural soils in Ethiopia. Limited access to sufficient amounts of fertilizer is a serious challenge to agricultural productivity and economic growth. Soils in Ethiopia are among the most N deficient at the regional level (Stroovegel *et al*., 1990). Nitrogen being an essential nutrient used in relatively large amount by living things, it is critically important to plants because it is a fundamental part of the chlorophyll molecule and is essential in the formation of amino acids and protein, and thus considered as yield limiting nutrient (Walch-Liu *et al*., 2000). Even though the input of N fertilizer is an inevitable and basic requirement for high yield, increased cost of the fertilizer is becoming an economic constraint for the small scale farmers of developing countries like Ethiopia. In Ethiopia, almost all smallholder farmers are resource limited to buy inorganic fertilizer. Even, when this is possible, continuous use of chemical fertilizers in agricultural production is a serious environmental concern.

Application of biofertilizer is among the solutions which are suggested to address these problems. Bio-fertilizers may be Nitrogen fixing - *Rhizobium*, Phosphorus Solubilising - *Bacillus*, Phosphate mobilization - *Pseudomonas* and/or cyanobacteria biofertilizer. Biofertilizer is known to improve growth, yield as well as productivity of crops. They are low cost, renewable sources of plant nutrients and have the ability to use freely available solar energy, atmospheric Nitrogen and water (Amal *et al*., 2010). There are variations between different strains in performance, and it is possible to use selected strains in laboratory culture and produce them in large quantities. Use of biofertilizer has positive effects on soil fertility, environmental safety and in increasing crop yield. According to Choudhury and Kennedy (2005), biofertilizers are gaining momentum recently due to increasing emphasis on maintenance of soil health, to minimize environmental pollution and cut down on the use of chemicals in agriculture.

Cyanobacteria are one of the biofertilizers that are potentially environmentally friendly supplements to the use of chemical fertilizers for realizing the ultimate goal of increased productivity. Having the ability to fix atmospheric N_2 into plant available N forms (under special circumstances), cyanobacteria make an important biofertilizer. Cyanobateria are photosynthetic prokaryotes that are colonizing microorganisms found everywhere in the world. Cyanobacteria are remarkably well adapted to a wide range of environmental conditions like salinity, pH, electrical conductivity and temperature (Paerl *et al*., 2000). Thus, in view of mounting fertilizer costs, the limited resources with smallholder farmers and the growing interest for organically grown vegetables, it is imperative to test cyanobacterial bio-fertilizer as a supplementary source of Nitrogen and other nutrients for tomato production.

Therefore, this research was conducted with the following objectives:

Objectives

- To evaluate the growth rate and Nitrogen fixing capacity of different strains of cyanobacteria (E-3 and E-6) in two different water sources, river and tap water.
- To assess the effect of cyanobacteria biofertilizer on tomato (*Lycopersicon esculentum*) growth and biomass yield as compared to urea and (poultry) compost.
- To find out the residual effects of applying these different fertilizers on the chemical characteristics of the test soils after harvesting the tomato.
- To determine and compare the nutritional quality especially the beta (β) carotene (pro vitamin A) content in the ripe fresh fruit of tomato grown using cyanobacteria and urea and (poultry) compost fertilizer sources.

2. Materials and Methods

2.1 Description of the study site and soil sampling location

The research was conducted in the chemistry laboratory and in the lath house at the Wachemo University and microbiology laboratory at the Hawassa University in 2015/16.

Soil samples were collected from WCU farm and Balesa farm site.

2.2 Experiments

Two cyanobacteria (*Anabaena* spp.) strains (E-3, E-6) were evaluated for their growth and Nitrogen fixation under river and tap water were combined in factorial arrangement. In this study the Nitrogen fixing capacity, growth characteristics and heterocyst and vegetative cells were evaluated. Finally, the best strain was selected

based on the above criteria for mass production and use in the lath house experiment. Both dried and liquid cyanobacteria were used as Nitrogen fertilizer treatment in Experiment II. In addition to these cyanobacteria biofertilizers, urea fertilizer and poultry compost were used to grow tomato (*Lycoperiscum esculuntum*) in pots.

2.1.1 Strain selection in laboratory

Two cyanobacteria (*Anabaena* spp.) strains (E-3 and E-6) and tap and river water were used for the study. The E-3 and E-6 strains were isolated at Colorado State University from samples obtained from Ziway cabbage and pigeon pea fields and Chiko swamp, respectively. The cultures were grown in the Allen and Arnon (AA) medium which was prepared with **+pi** and **-pi** stock solutions (Allen and Arnon, 1955). And then, the two different cyanobacteria (*Anabaena* spp.) strains (E-3 and E-6) were grown in AA medium prepared using tap and river water sources in Erlenmeyer flasks. The laboratory experimental set up is depicted in Figure 1. The two strains of cyanobacteria (E-6, E-3 + the control) and the two water sources (Table 1), were arranged in a complete randomized design (CRD), with the factorial combination of two factors, water sources and the strains. Each strain was replicated three times in each water source.

Table: 1 Treatments for strain selection in laboratory

T1=E-3+tap water,	T4=E-3+river
T2=E-6+tap water,	T5=E-6+ river
T3= tap water only (control),	T6= river water only (control).

Each strain was inculcated into each of 180ml of growing media in a 1:9 culture dilution (Wood *et al*., 2005). Finally, the volume of the culture was maintained at 200ml. Cultures were grown in the light box set-up prepared in the lab. The strains were incubated in Erlenmeyer flasks at room temperature under 2500 lux light intensity with **12:12** hours light and dark cycle. The light was supplied with fluorescent lamps, and every day 6 hr aeration periods were given from Air Pump (AIR-8000) through plastic hose and distributed using gang valves. The pH was adjusted at 7.8 varying the amount of NaOH 0.1M and HCl 0.1M in the medium (Fogg and Thake, 1987). Prior to setting this experiment, each strain was assessed under the microscope for purity or to determine whether there were predators.

2.3 Data collected

Data were collected from experiment I, and variables were recorded from each strain as indicated below.

Optical density was measured by using spectrophotometer (GENWAY-6300, UK) and cuvette at 655 nm wave lengths for 21 days starting from the first day of inoculation, and the statistical analysis was done on the final OD measurement. Blank liquid Allen-Arnon medium was used as the standard for cell abundance.

Growth rate of strains was estimated as changes in OD over time from the log-linear portion using linear regression analysis (Tang *et al*., 1997).

Cell count in the laboratory experiment, the number of heterocyst and vegetative cells per filament of the three cyanobacteria strains were counted using a light microscope 100 xs and oil immersion.

Tissue Nitrogen content was analyzed from 21 day old cultures or at the last day of the experiment using micro-Kjeldahl digestion methods (Nelson and Sommers, 1980). The blank Allen and Arnon medium was used as a standard.

pH measurements of pH of the culture were done every day throughout the cyanobacteria growth period by using pH meter.

2.4 Mass cultivation of E-3 strain for lath house experiment

Mass cultivation of the selected cyanobacterial strain (E-3) was carried out in a lath house, in transparent polyethylene plastics. After 21 days of culturing, supernatant was separated using mesh cloth and the sediments were dried. Thus, the dried cyanobacteria-mats were used as solid bio-fertilizer Nitrogen concentration was 0.36%/100g) while the liquid (Nitrogen concentration was 47ppm) was used as liquid biofertilizer to grow tomato in the lath house.

2.5 Pot experiment in lath house

The pot experiment was conducted in lath house at Wachemo University in 2015/16.The Tomato *(Lycopersicon esculentum)* plant seeds were sown in receiving the different treatments (Table 2). The experiment was laid out in a complete randomized design with the factorial combination of two factors, soil types and treatments. Each treatment was replicated three times in each soil type. This pot experiment consisted of 10 treatments.

Table 2: Treatment combinations of N-sources and soil type for lath house experiment

N sources (pot^{-1})	Soil types	
	Soil from WCU farm (S1)	**Soil from Balesa site (S2)**
N0 (control)	N0S1	N0S2
N1 (8.2g DCB)	N1S1	N1S2
N2 (4.2 liters LCB)	N2S1	N2S2
N3 (1.085g of urea)	N3S1	N3S2
N4 (11.5 g compost)	N4S1	N4S2

The bulk soil samples were collected from 15cm depth top soil of each site, air-dried, and then sieved through a 4mm diameter mesh. Pots were filled with 5kg of sieved soils. A dried cyanobacterial bio-fertilizer (8.2g) was incorporated into each of the soil types, before seven days of sowing; liquid cyanobacterial bio-fertilizer (4.2L) was applied in three split phases. Urea with recommended rate 100 kg N/ha (Maanavifard *et al*., 2010) was applied in spilt (0.72g of urea/5kg soil at sowing and 3.6g of urea after 3 weeks). Compost with recommended rate of 4600 kg/ha of which 11.5g of poultry compost was added to each pot and 0.5g of TSP per 5kg of soil or (100 kg/ha) TSP fertilizer was applied to all treatments equally.

Tomato (*Lycopersicon esculentum*) seeds were sown directly in different treatments in each pot at a depth of 0.2cm, and after germination the weak seedlings from each pot were removed leaving three plants per pot.

2.6 Growth, Yield and Nutritional quality parameter Data

Plant height, Number of branches per stem, Plant shoot and root dry weight, Number of flowers per plant, Number of fruits per plant and Fresh fruit weight per plant were collected to determine yield and yield components of the tomato.

Plant height length of the main stem measurement was made from the root collar to the tip of the plant, in centimeter (cm) at the last harvesting stage. **Number of branches per stem** number of primary branches per stem of each plant at final harvest was counted.

Plant shoot and root dry weight after harvest, the dry wt. content of (shoots and roots) of the tomato were measured (in g) after drying samples in an oven at 70ºC for 48hrs, until constant weight was achieved.

Number of flowers per plant the number of flowers plants at 100% (before fruit set) flowering stage from each plant was counted per plant.

Number of fruits per plant means number of ripened fruits of individual plants from each pot at each 3 successive harvesting harvest was recorded.

Fresh fruit weight per plant fruit weight of each tomato per plant was weighed at each 3 successive harvest and expressed in grams (g).

Beta (β) carotene content in fruits fresh, fully-ripe tomato fruits collected and quantified beta carotene using spectrophotomer.

2.7 Soil sampling and analysis

Determination of some soil physic-chemical properties, before planting and after harvest was conducted on air dried and sieved through a 4mm diameter mesh soil samples.

Soil texture was determined by hydrometric method in the laboratory (Day, 1965). The percentage of sand, silt and clay in the inorganic fraction of soil was measured by these methods.

Soil pH was determined by using a pH meter with combined glass electrode in water (H_2O) at 1:2.5 soils: water ratio as described by Van Reeuwijk (1992).

Electrical conductivity (EC) was measured according to Rhoades (1996) using portable EC meter.

Organic Carbon was determined using the wet oxidation method (Walkley and Black, 1934) where, the carbon was oxidized under standard conditions with potassium dichromate in sulfuric acid solution.

Available phosphorous determination was carried out by the Olsen method using $NaHCO_3$ as extracting solution (Olsen and Sommer, 1982).

Total Nitrogen was analyzed using the Kjeldahl method by oxidizing the OM with sulfuric acid and converting the N into NH_4^+ as ammonium sulfate as described by (Bremner, 1965).

CEC was measured after leaching NH_4OAc extracted soil samples with 10% NaCl solution. The amount of ammonium ion in the percolate was determined by the usual Kjeldahl procedure and reported as CEC.

Micronutrients (Fe and Zn) were determined with di-ethylene tri-amine penta-acetic acid (DTPA) method as described by Lindsay and Norvell (1978).

Plant sampling for N, P, and Fe and Zn analysis

Post harvest shoots were collected and oven dried in an oven at 70ºC for 48hrs, until constant weight was achieved.

Total plant N and P the nutrient contents of total Nitrogen (N) and Phosphorous (P) of leaves were analyzed

using Kjeldahl digestion method (Nelson and Sommers, 1980) and colorimetric method (Olsen and Sommer, 1982), respectively.

Fe and Zn contents digested plant tissue was analyzed using atomic absorption technique (Isaac and Kerber, 1971).

2.8 Statistical analyses

The cyanobacteria biomass, growth rate, number of heterocyst and vegetative cells, soil physico chemical properties and agronomic data, yield components and beta (β) carotene content were subject to analysis of variance (ANOVA) using the general linear model procedure (SAS Institute, 2001). The least significance difference (LSD) test was used to separate significantly differing treatment means after treatment effects were found to be significant at $P \leq 0.05$ probability level. Correlation analysis was made using Pearson's simple correlation coefficient between all examined parameters.

3. Results and Discussions

3.1 Growth characteristics of cyanobacterial strains

The analysis of variance indicated that there was a significant difference among strains and water sources on the tissue Nitrogen, optical density, growth rate, number of heterocysts and vegetative cells. The results are presented below.

Table 3: Mean comparison of tissue Nitrogen (mg/l), optical density, growth rate (mg/l), number of heterocyst and vegetative cells of cyanobacteria as affected by strain and water sources

Treatments	OD at 655 nm	Veg. cells per filament	G. Rate (OD day^{-1})	Het. Per Filament	Tissue Nitrogen (mg/l)
Strain					
E-3	1.843^{a}	55.83^{a}	0.27^{a}	4.17^{a}	47.2^{a}
E-6	1.46^{b}	36.83^{b}	0.16^{b}	2.33^{b}	39.30^{b}
LSD 0.05	0.033	0.968	0.0125	0.624	0.78
Water sources					
Tap	1.65^{a}	47.20^{a}	0.23^{a}	3.3300^{a}	46.80^{a}
River	1.13^{b}	46.90^{b}	0.20^{b}	3.00^{b}	44.00^{b}
LSD 0.05	0.094	2.13	0.005	0.165	0.045
CV (%)	1.53	4.72	4.35	9.25	7.42

Means followed by the same letters within a column are not significantly different at $p \leq 0.05$

3.2 Pot experiment

3.2.1 Physico chemical properties of the soils before planting

Some physical and chemical properties of the experimental soils were analyzed before initiation of pot experiment. Based on the results that are depicted in Table 4.

Table 4: Physico chemical characteristics of the surface soils from WCU farm and soil from Balesa prior to treatments application

Soil characters	**Soil from WCU farm**	**Soil from Balesa**
pH in water (1:2.5)	6.2	8.0
EC (mmhos/cm)	0.11	0.27
Organic carbon (%)	1.62	2.67
Total N (%)	0.15	0.19
CEC (C mol/kg)	20.08	43.52
Av. P(mg/kg)	11.4	15.4
Fe (mg/kg)	18.0	4.0
Zn (mg/kg)	6.42	1.91
C:N	10.8	14

TN=Total Nitrogen, Av. P=Available Phosphorus, EC= Electrical Conductivity.CEC=Cations Exchange Capacity, Fe=Iron and Zn=Zinc.

Table 5: Chemical composition of poultry compost used for the experiment

Poultry	**Value**
pH	6.7
Organic C (%)	14.5
Nitrogen (%)	2.2
C:N	6.7

Table 6: Mean plant growth parameters (plant height, number of primary branches per plant, shoot and dry wt., fruit number, fruit wt., and number of flowers) of tomato (*Lycoperisicum esculuntum*) as affected by soil type and fertilizers

Treatments	Parameters						
	Plant height (cm)	Shoot dry wt.(g/plant)	Root dry wt.(g/plant)	No. of branches. per /pant	Number of flower per plant	Number of fruit per/plant	Fruit wt.(g/plant)
Soil from WCU farm	42.60^{a}	15.80^{a}	9.51^{a}	10.80^{a}	11.66^{a}	4.66^{a}	385.07^{a}
Soil from Balesa	39.20^{b}	13.80^{b}	9.13^{a}	10.20^{a}	11.6^{7a}	3.80^{b}	374.67^{a}
LSD 0.05	**2.51**	**0.84**	**NS**	**NS**	**NS**	**0.43**	**NS**
Control	27.0^{d}	7.5^{d}	6.46^{d}	7.0^{d}	8.16^{d}	2.8^{c}	191.33^{d}
Dry cyan.bac	48.8^{a}	19.8^{a}	13.43^{a}	13.16^{a}	14.08^{a}	5.5^{a}	537.52^{a}
Liq. cya.bac	48.5^{a}	17.0^{b}	9.73^{b}	11.66^{ab}	13.58^{a}	5.3^{a}	433.67^{b}
Urea	43.8^{b}	15.6^{c}	9.02^{bc}	11.01^{bc}	11.83^{b}	4.0^{b}	395.17^{b}
Compost	36.3^{c}	14.5^{c}	8.04^{c}	9.66^{c}	10.66^{c}	3.5^{bc}	341.67^{c}
LSD 0.05	**3.96**	**1.32**	**1.24**	**1.60**	**0.89**	**0.688**	**39.16**
CV (%)	**7.98**	**7.37**	**11.09**	**12.6**	**6.32**	**13.4**	**8.49**

*, **, ***, NS = significantly different at p<0.05, p<0.01, 0.001 probability levels, non significant, respectively.

3.2.2 Beta (β)-carotene content

Beta carotene concentration in ripe fresh tomato fruit showed a highly significant difference (p<0.001) between fertilizer treatments as well as between soil types, and there was a significant interaction effect due to the two factors concerning beta carotene (Table 7)

Table 7: Effect of cyanobacterial and other fertilizers on beta (β) carotene content of ripe fresh fruit tomato (*Lycopersicon esculentum*) in µg/g

Soil types	Dry cyano.bac	Liquid cyano.bac	Urea	Poultry compost	Control	**Mean**
Soil from WCU farm	2.13^{a}	1.34^{c}	0.46^{g}	0.81^{f}	0.10^{h}	**0.97**
Soil from Balesa	1.59^{b}	1.34^{c}	1.21^{d}	1.21^{d}	0.87^{e}	**1.24**
Mean	**1.86**	**1.34**	**0.83**	**1.01**	**0.47**	**1.10**
CV=3.4			LSD =0.07 (p<0.05)			

3.2.3 Shoot nutrient composition

To determine the comparative effect of cyanobacteria and other fertilizer sources on the shoot nutrient composition of tomato (*Lycopersicon esculentum*), the plant shoots were analyzed (after harvesting) for some essential elements (N, P, Zn and Fe), and compared with (control treatment). The results are depicted in Table 8.

Table 8: Mean comparison of plant N, P, Zn and Fe contents of tomato plant as affected by soil types and different fertilizers

Mean				
Treatments	Plant N (%)	Plant P (%)	Plant Zn (ppm)	Plant Fe (ppm)
Soils				
Soil from Balesa	1.086^{a}	0.390^{a}	32.79^{b}	63.7^{b}
Soil from WCU	0.905^{b}	0.401^{a}	39.11^{a}	64.2^{a}
LSD 0.05	**0.1123**	**NS**	**2.14**	**0.44**
Fertilizers				
Control (0 kg N)	0.702^{c}	0.235^{e}	27.7^{d}	48.5^{e}
Dried cyanobacteria	1.763^{a}	0.665^{a}	45.3^{a}	77.2^{a}
Liquid cyanobacteria	0.951^{b}	0.462^{b}	40.4^{b}	72.9^{b}
Urea	0.814^{b}	0.354^{c}	34.1^{c}	63.0^{c}
Compost	0.732^{c}	0.263^{d}	32.2^{c}	58.1^{d}
LSD 0.05	0.177	0.021	3.39	0.69
CV (%)	14.69	4.28	7.77	0.89

Means followed by the same letters with in a column are not significantly different at p≤0.05.

3.2.4 Chemical properties of soils after harvesting

Soil chemical analyses were carried out after harvesting the tomato plant to evaluate the residual effects of the treatments on the fertility of the soil. The ANOVA showed that there were highly significant differences (P<0.001) due to cyanobacteria application in soil parameters (Table 9). In general, application of the different cyanobacteria bio-fertilizer to the soil caused a significant enhancement of chemical properties of the soil after harvest, hence indicating the positive contribution of bio-fertilizer application for enhancing soil fertility and crop yields.

Table 9: Mean comparison of soil total N, available P, EC and pH after harvest

Mean				
Treatments	pH (1:2.5)	EC(ds/m)	Av.P (ppm)	TN (ppm)
Soils from				
Balesa farm	7.90^{a}	0.22^{a}	21.57^{a}	24^{b}
WCU farm	6.7^{b}	0.01^{b}	17.83^{b}	25^{a}
LSD 0.05	**0.13**	**0.017**	**2.62**	**0.12**
Fertilizers				
Control (0 Kg N)	7.07^{a}	0.23^{a}	13.8^{c}	12.3^{d}
Dried cyanobacteria	6.58^{b}	0.12^{e}	32.45^{a}	36.0^{a}
Liquid cyanobacteria	6.79^{c}	0.13^{d}	19.83^{b}	27.6^{b}
Urea	6.92^{ab}	0.19^{b}	16.81^{b}	0.224^{c}
Poultry compost	6.82^{bc}	0.16^{c}	15.50^{c}	0.22^{c}
LSD 0.05	0.18	0.025	4.25	0.0038
CV (%)	2.14	12.03	17.38	13.013

Means followed by the same letters within a column are not significantly different at p≤0.05. TN=Total Nitrogen, Av. P=Available Phosphorus, EC= Electrical Conductivity.

3.3 Discussions

The highest optical density, growth rate, number of hetrocyts, number of vegetative and nitrogen fixing capacity were resulted from strain E-3 as compare to others this could be attributed to its genetic efficiency and high Nitrogen fixation capacity. This result is in agreement with the work of Moisander *et al*. (2002) who observed the difference in growth of the strains could be attributed to the difference in their inherent physiological efficiency.

Comparing among the different fertilizer sources, the highest value of vegetative growth, crop yield and beta carotene were observed from dried form of Cyanos. The increase in vegetative growth and crop yield with dried cyanobacteria could mainly be due to the release of plant nutrients like N, P, K and excretion of plant growth promoting substances such as hormones (auxin, gibberellins), vitamins and amino acids (Rodriguez *et al*., 2006. This result is in agreement with the works of Kabil *et al*. (1997), who reported that application of cyanos significantly increased the vegetative growth, crop yield and nutritional quality of treated tomato plant. Similarly this result is in agreement with that of Maynard *et al*. (1999) who worked on the Fe and Zn contents of tomato plants receiving dried cyanobacteria biofertilizer and was in the high category indicating the potential contribution of the bio-fertilizer treatment for improving the nutritional quality of the plant

Soil chemicals after post harvesting of the tomato plant were showed that highly significant differences (P<0.001) due to cyanobacteria application in soil parameters. In general, application of the different cyanobacteria bio-fertilizer to the soil caused a significant enhancement of chemical properties of the soil after harvest, hence indicating the positive contribution of bio-fertilizer application for enhancing soil fertility and crop yields. The result is in agreement with the work of Kaushik and Murtii (1981) who found that application of cyanobacteria to alkali soils resulted in significant improvements in the aggregation status of these soils and decreased pH. Also, according to Singh (1961), alkaline soils could be reclaimed by using cyanobacteria that neutralize the pH of these soils.

The plant shoots were analyzed (after harvesting) for some essential elements (N, P, Zn and Fe), and compared with (control treatment). Accordingly, the highest content of N, P, Zn and Fe in the plant shoots were recorded from the dried cyanobacteria biofertilizer. The increased plant Nitrogen concentration under dried cyanobacterial biofertilizer treatment might be due to senescence like N, P, and K to promote the plant growth during the growth stage (Rodgers *et al*., 1979). The result is in agreement with Alla *et al*. (1993**)** who reported a significant increase (p<0.01) in plant Nitrogen under liquid and/or dead inocula (dried) of cyanobacteria bio-fertilizer could be attributed to nitrogenase activity (N- fixation) in the soil.

4 Conclusion.

From the present research, it can be concluded that application of cyanobacteria biofertilizer improved growth parameters, yield and nutritional quality of tomato plants. Since cyanobacteria are free living, photosynthetic and N-fixing microorganisms, which can inhabit a wide range of diverse environments characterized by extremes of temperature, desiccation, pH, salinity, light intensity and nutrients, they can be used as bio-fertilizers to induce an increase in mineral contents of the soil and thus improve soil fertility in an environment-friendly way, thereby improving the availability of nutrients to plants. Dried form of cyanobacteria biofertilizer showed superior fresh shoot and root weight, dry shoot, root weight, leaf area, and number of branches, which was on par with the treatment with liquid cyanobacteria biofertilizer inoculation. The inoculation of cyanobacteria in soil on tomato plants positively affected, root weight, dry shoot, root weight, leaf area, and number of branches with respect to the control.

The widely used chemical fertilizers are expensive for smallholder farmers and also have some adverse effects on the environment. In contrast, cyanobacteria may be a cheaper source of N, which does not cause pollution. Moreover, they improve the organic matter status and water holding capacity of the soil. Therefore, cyanobateria can serve as an important source of nutrients to tomato plants. As a result they can be considered as a potential supplement, if not alternative/substitute, to the costly and environmentally unfriendly inorganic fertilizers. However, the application of present findings under field conditions should be confirmed by further studies.

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