

## Response of Two Lentil Varieties to Bio-Enriched Compost Tea

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**Abstract:** Two field experiments were conducted at Gemmeiza Agricultural Research Station, El-Gharbia Governorate (ARC) located at 30° 44' 53.279" N for Latitude and 31° 7' 50.843" E for Longitude, Egypt, during the two winter seasons of 2010/11 and 2011/12 to evaluate the response of two lentil varieties (Sinai1 and Giza9) to different application rates of bio-enriched compost tea (zero, 100, 200 and 300 L/fed). Lentil seeds were inoculated with gamma irradiated vermiculite-based inocula for two *Rhizobium* strains (mixture of TAL168 and ICARDA139), prior to sowing. Aerated bio-enriched compost tea levels were sprayed in three equal split doses after 30, 45 and 60 days from sowing. Spraying was made to coat the leaves surface and to drench the soil around plants. The obtained results revealed that: (1) Giza 9 variety significantly surpassed the new released early maturing variety (Sinai 1) in root nodulation, all vegetative growth characters and all yield components as well as lentil yield (seeds and straw) and seed crude protein. (2) Significant predictable improvement in lentil nodulation status, all growth characters, lentil yield and its components due to the stimulatory effect of bio-enriched compost tea treatments. However, results evident that the synergy of using higher doses of bio-enriched compost tea (200 or 300L/fed), relatively to the untreated plants or plants treated with 100 L/fed. (3) Data showed significant interaction between bio-enriched compost tea treatments and the varieties. Data exerted that addition of compost tea caused promotive impression in all studied characters, particularly in case of using 200 or 300 L/fed with Giza 9 variety, as was reflected by its highest values in comparison to other tested combinations or untreated ones. From these results, it could be concluded that the combination between Giza 9 variety and the stimulating dose of bio-enriched compost tea (200 L/fed) may be acting as a good practice for improving the most growth and yield characters and leading to healthier food, particularly under sustainable agricultural systems. However, these trials are in need to be repeated under different soil conditions to reach the level of recommendation and to clarify the best compost tea rate required for each crop.

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### 1. Introduction

Lentil (*Lens culinaris*, Medik.) is one of the most important leguminous crops grown in Egypt. It contributes significantly to food, feed and sustainable farming systems and contains high amount of digestible protein (22-31%), some nutrients particularly calcium, iron, zinc and vitamins and niacin, thus providing nutritional security to consumers. It has the lowest content of lectins and trypsin inhibitors among legumes. Lentil straw is a valuable animal feed as it has high digestibility protein, calcium and phosphorous compared to wheat straw (Zeidan, 2007). Its cultivation improves soil health by adding nitrogen and organic matter, thus provides sustainability to the cereal-based cropping systems. The ability of symbiotic fixation (through symbiotic association with rhizobia) may offer an opportunity to improve nitrogen status of the soil and crop productivity (Ahmed *et al.*, 2008).

The concept of PGPBR is intended to encompass both PBPR (Plant Bioprotect Promoting

Rhizobacteria), which are rhizobacteria that promote the protection against major plant pathogens and PGPR (Plant Growth Promoting Rhizobacteria), which are rhizobacteria that promote beneficial effects on plant growth. The direct growth promoting mechanisms are biological nitrogen fixation, increasing the availability of nutrients in the rhizosphere and inducing of phytohormones production (Vessey, 2003). The indirect mechanisms of plant growth promotion includes antibiotics production, depletion of iron from the rhizosphere, synthesis of antifungal metabolites, production of fungal cell wall lysing enzymes, competition for sites on roots and induced systemic resistance (Verma *et al.*, 2010). A divers array of bacteria has been shown to promote plant growth (Rasouli Sadaghiani *et al.*, 2008). *Serratia*, *Bacillus* and *Pseudomonas* are able to produce higher values of all plant growth promotion traits and *Serratia* has a unique ability to produce extracellular enzymes that have the ability to degrade chitin, a substance mainly comprises fungal cell walls and promotes plant growth

by production of antagonistic substances inducing resistance against plant pathogens (Malik and Sindhu, 2011). Many PGPR strains promote legume nodulation and N<sub>2</sub>-fixation in association with rhizobia (Verma et al., 2010).

There is an increasing in global interest in the use of liquid organic fertilizers and inoculums of beneficial microbes in support of biological farming and sustainable agriculture (Naidu et al., 2010). A primary reason for producing compost tea is to transfer microbial biomass, fine particulate organic matter and soluble chemical components of compost into an aqueous phase that can be applied to plant surfaces and soils in ways not possible or economically feasible with solid compost (Hargreaves et al., 2009). To promote plant growth with compost tea the extract must be derived from compost that also promotes plant growth (Shrestha et al., 2011a). Compost tea is produced by mixing compost with water and culturing for a defined period, either actively aerating (aerated compost tea, ACT) or not (non-aerated compost tea, NCT) and with or without additives that are intended to stimulate microbial population densities during the incubation period (Lanthier, 2007 and Naidu et al., 2010). The diverse microbial profile in compost tea help the plant's leaves absorb nutrients from the air, and as they find their way into the soil, they help the plant's root system extract nutrients from the soil (Pane et al., 2012).

Like all agricultural tools, compost tea is not a silver bullet for solving widespread problems associated with depleted soils or unsustainable farming practices. However, produced with microbiological quality in mind, and integrated into holistically managed biological farming systems, compost tea can be used as a carrier to deliver plant nutrients and manage plant diseases (Scheuerell, 2004). Researchers are urged to collaborate with farmers to document effects of compost tea on plant health, fertility, and microbiological quality to assist farmers in making informed decisions about compost tea in their production system. The literatures suggest that certain liquid extraction of manures or composts can supply plants with at least four major benefits: a source of inorganic nutrients and beneficial organic compounds (Shrestha et al., 2011b and Pane et al., 2012); an ability to suppress certain plant disease (Shrestha et al., 2011a); as a way to build soil structure when applied as a drench and optimizes the soil pH (Ha et al., 2008).

In fact, there are a number of reports demonstrate the ability of PGPR-microorganisms, involving in compost tea, to suppress a wide range of both air-and soil-borne plant pathogens and induce the systemic resistance in the plants against different pathogens. The beneficial microorganisms hinder pathogens in several

ways-covering surfaces and thus preventing access by pathogens; competing for nutrients required by some pathogens; secreting secondary metabolites (antibiotics) on plant surfaces; and directly parasitizing pathogens (Scheuerell and Mahaffee, 2004). Shrestha et al. (2011b) and Pane et al. (2012) recoded that compost tea rich in soluble mineral nutrients and contains a high population of microbiota can be used to fertilize crops; inoculate crop residue to facilitate decomposition; improve nutrient cycling in soil through increased microorganism activity and manage certain plant pathogens, to some extent, through microbial competition; improved plant nutrition and build soil structure when applied as a drench.

The objective of this study is to determine the effect of different rates of bio-enriched compost tea on nodulation, growth, yield and some yield components of two lentil varieties (Saini1 and Giza 9).

## 2. Materials and Methods

### Microbial cultures:

Two foreign *Rhizobium* strains (TAL168 and ICARDA139) and two rhizobacterial strains, namely *Serratia marcescens* (WW4) and *Pseudomonas fluorescens* (IFO.2034) and *Bacillus polymyxa* (local isolate of rhizobacteria) were supplied by Microbiology Dept., Soils, Water and Environment Research Institute, Agricultural Research Center (ARC), Giza, Egypt. *Rhizobium* was cultured in a yeast extract mannitol (YEM) broth medium (Vincent, 1970). *Serratia*, *Bacillus* and *Pseudomonas* were grown in King's medium B (Atlas, 1995). Cultures were incubated at 28°C for three days on rotary shaker until early log phase had been developed to 10<sup>9</sup> viable cell ml<sup>-1</sup>.

### Preparation of *Rhizobium* inocula:

Vermiculite supplemented with 10% Irish peat was packed in polyethylene bags (400g). Bags were sealed and sterilized by Gamma irradiation (5.0 x 10<sup>6</sup> rads). *Rhizobium* cultures was injected into the sterilized carrier to satisfy 60% of the maximal water holding capacity and mixed thoroughly.

### Preparation of enriched compost tea:

Aerated compost tea was prepared from a matured compost made from rice straw, farmyard manure, bentonite, rockphosphate, feldspar, elemental sulphur and urea with action of *Trichoderma viridi* and *Trichoderma harzianum* inoculum, which had been composted in thermophilic and aerobic heap for three months (Abdel-Wahab, 2008). To prepare the bio-enriched compost tea, ten kg of mature compost blended with 1 kg molass, 50g (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, 50g MgSO<sub>4</sub>.7H<sub>2</sub>O and 10g NaCl in a 150 liter plastic barrel. These ingredients were drenched in 100 liter tap water (previously stored to avoid the harmful effect of Cl<sub>2</sub> on microbial load of compost). This mixture had been

allowed to stand in a shaded place for 7 days with a suitable daily stirring by an air compressor using a PVC pipe dipped in the barrel. Aeration was done at rate of 4 hr/day in intermittent periods (Ingham, 2005). After elapsing of incubation time, the liquid mixture was filtered on a 100 mesh screen, then inoculated with 1L liquid culture from *Serratia marcescens*, *Bacillus polymyxa* and *Pseudomonas fluorescens* (as a liquid carrier) and became ready to use. The main traits of compost and the produced compost tea are shown in Tables (1 and 2).

#### Lentil varieties:

Lentil seeds (vars., Sinai 1 and Giza 9) were provided by Food Legume Research Program, Field Crops Research Institute, Agricultural Research Center (ARC), Giza, Egypt.

#### Field experiments:

**Table (1): Some physical, chemical and microbiological characteristics of compost**

Property	Value
Color	Dark brown
Bulk density (kg/m <sup>3</sup> )	546.0
Water holding capacity (%)	203.4
pH (1:10 extract)	7.12
EC (dS/m)	3.67
Organic carbon (%)	26.10
Organic matter (%)	44.89
Total-N (%)	1.61
C/N ratio	16.21
Total-Phosphorus (%)	1.16
Total-Potassium (%)	1.73
Total soluble-N (mg kg <sup>-1</sup> )	689.5
Available-P (mg kg <sup>-1</sup> )	276.4
Available-K (mg kg <sup>-1</sup> )	761.9
DTPA <sup>*</sup> -extractable (mg kg <sup>-1</sup> ):	
Fe	199.8
Mn	44.2
Zn	55.1
Cu	6.5
CEC (c mol/kg)	123.6
E <sub>4</sub> /E <sub>6</sub> ratio	3.91
Total count of bacteria (cfu/g)	3.1 x 10 <sup>7</sup>
Total count of fungi (cfu/g)	1.2 x 10 <sup>5</sup>
Total count of actinomycetes (cfu/g)	1.3 x 10 <sup>6</sup>
Dehydrogenase activity (mgTPF <sup>**</sup> /100 g)	188.9
Germination test of cress seeds <sup>***</sup> (%)	89.0

\* Di-ethylene tri-amine penta acetic acid.

\*\*Tri-Phenyl-Formazan.

\*\*\*Cress seeds incubated for 48 hr.

**Table (2): The main chemical and microbiological traits of the bio-enriched compost tea**

Trait	Value
pH	6.90
E.C. (dS m <sup>-1</sup> at 25°C)	2.83
Organic-C (%)	5.92
Total- N (%)	0.028
NH <sub>4</sub> <sup>+</sup> -N (ppm)	81.6
NO <sub>3</sub> <sup>-</sup> -N (ppm)	14.0
Total soluble-N (ppm)	95.6
Available-P (ppm)	41.2
Available-K (ppm)	128.7
Extractable - Fe (ppm)	16.4
~ - Mn (ppm)	3.5
~ - Zn (ppm)	6.8
~ - Cu (ppm)	1.5
E <sub>4</sub> /E <sub>6</sub> ratio	3.91
Total count of bacteria (cfu ml <sup>-1</sup> )	8.1 x 10 <sup>7</sup>
Total count of fungi (cfu/ml)	7.3 x 10 <sup>5</sup>
Total count of actinomycetes (cfu ml <sup>-1</sup> )	1.3 x 10 <sup>6</sup>
Germination test of cress seeds (%)	91.0

Two field experiments were conducted at Gemmeiza Agricultural Research Station, El-Gharbia governorate (ARC) located at 30° 44' 53.279" N for Latitude and 31° 7' 50.843" E for Longitude, Egypt, during two successive winter growing seasons of 2010/11 and 2011/12 to study the effect of different rates of bio-enriched compost tea (zero, 100, 200 and 300 L/fed) on nodulation, growth, yield and some yield components of two lentil varieties. Some physical and chemical properties of the experimental soils are shown in Table (3). (**1 hectare = 2.38 Feddan**).

A split plot design with four replicates was used and the plot area was 10.5m<sup>2</sup> (1/400 fed). The main plots included lentil varieties, whereas compost tea treatments were assigned to sub-plots.

The following treatments were tested:

- 1- Zero bio-compost tea.
- 2- 100 L/fed bio-compost tea.
- 3- 200 L/fed bio-compost tea.
- 4- 300 L/fed bio-compost tea.

Lentil seeds were inoculated with gamma irradiated vermiculite-based inocula for two *Rhizobium* strains (mixture of TAL168 and ICARDA139) at a rate of 300g/30Kg seeds, prior to sowing using 16% Arabic gum solution as a sticking agent. All treatments received superphosphate fertilizer (15% P<sub>2</sub>O<sub>5</sub>) at a rate of 200 Kg/fed and potassium sulphate (48% K<sub>2</sub>O) at a rate of 50 Kg/fed. All plots received 15 kg N/fed in the form of ammonium sulphate (20.5% N) at sowing as an activator dose. Bio-enriched compost tea (100, 200 and 300 L/fed) was sprayed in three equal split doses after 30, 45 and 60 days from sowing using the back-portable equipment. Spraying was made to coat the leaves surface and to drench the soil around plants.

Plant samples were uprooted from each plot after 75 days from sowing and assayed for number and dry weight of nodules, as well as dry weight of shoots. Nitrogen, phosphorus and potassium content of shoots were also determined.

**Table (3): Physical and chemical properties of the experimental soil in both seasons of study**

Property	Season 2010/2011	Season 2011/2012
<b>Particle size distribution (%):</b>		
Sand	20.6	20.5
Silt	32.8	33.0
Clay	46.6	46.5
Texture grade	Clay loam	Clay loam
CaCO <sub>3</sub>	0.60	0.65
Saturation percent (SP %)	40.30	40.20
pH (soil paste)	7.72	7.70
E.C (dS m <sup>-1</sup> , at 25°C)	0.53	0.56
<b>Soluble cations (meq L<sup>-1</sup>):</b>		
Ca <sup>++</sup>	1.90	1.98
Mg <sup>++</sup>	1.10	1.05
Na <sup>+</sup>	2.10	2.22
K <sup>+</sup>	0.60	0.65
<b>Soluble anions (meq L<sup>-1</sup>):</b>		
CO <sub>3</sub> <sup>-</sup>	nd.*	nd.*
HCO <sub>3</sub> <sup>-</sup>	1.20	1.32
Cl <sup>-</sup>	2.10	2.20
SO <sub>4</sub> <sup>-</sup>	2.40	2.38
Organic matter (%)	0.75	0.80
Total-N (%)	0.054	0.051
Total soluble- N (mg kg <sup>-1</sup> )	77.90	80.50
Available- P (mg kg <sup>-1</sup> )	8.81	9.76
Available-K (mg kg <sup>-1</sup> )	341.42	358.12
<b>DTPA<sup>**</sup>-extractable (mg kg<sup>-1</sup>):</b>		
Fe	4.31	4.21
Mn	3.10	3.32
Zn	1.12	1.48
Cu	0.18	0.22

\* nd: not detected.

\*\* DTPA: Di-ethylene tri-amine penta acetic acid.

At harvest, ten guarded plants were randomly harvested from the second inner two rows of each plot to determine the following characters:

- 1- Plant height (cm)
- 2- Number of pods/plant.
- 3- Number of seeds/plant.
- 4- Seed yield/plant (g).

The middle three rows of each plot with 3m<sup>2</sup> area were harvested to determine the following characters:

- 1- Seed yield (ardab/fed.).
- 2- Straw yield (ton/fed.).
- 3- 1000-seed weight (g).
- 4- Crude protein content of seeds (%).

#### Analysis:

#### Compost and enriched compost tea:

Physical properties of mature compost were determined according to **Iglesias-Jimenez and Perez-Garcia (1989)**. Determination of chemical and microbiological traits was executed according to **Page et al. (1982)**. Seed germination test was assayed using cress seeds (*Lepidium staivum* L., local variety) to evaluate compost maturity (**Pare et al., 1997**). Extinction coefficient (E<sub>4</sub>/E<sub>6</sub> ratio) was measured at 465 and 665 nm wavelengths in aqueous extract as described by **Page et al. (1982)**

#### Soil:

Mechanical and chemical analyses of the soil were carried out according to **Piper (1950)** and **Black et al. (1965)**.

#### Plant materials:

The oven dried plant materials were wet digested by using a mixture of pure HClO<sub>4</sub> and H<sub>2</sub>SO<sub>4</sub> at a ratio of 1:1 according to **Jackson (1973)**. Total nitrogen was determined using the micro Kjeldahel method, phosphorus was determined Spectrophotometrically using ammonium molybdate and stannus chloride reagents and potassium was determined using Flamephotometer (**Page et al., 1982**). Crude protein was determined by multiplying the nitrogen percentage by 6.25 (**A.O.A.C., 1990**).

#### Statistical analysis:

The obtained data were subjected to an analysis of variance (ANOVA) according to the procedure of **Snedecor and Cochran (1980)**.

### 3. Results and Discussion

Data recorded on nodulation, growth, yield and some yield components of two lentil varieties (Saini 1 and Giza 9) as affected by different application doses of bio-enriched compost tea will be presented and discussed as follows:

#### Lentil nodulation status:

Nodulation status of two lentil varieties as affected by bio-enriched compost tea in both growing seasons of 2010/11 and 2011/12 are given in Table (4). Considering lentil varieties, the obtained results showed that Giza 9 variety significantly surpassed the new released early maturing variety (Sinai 1) by 12.49 and 12.03% in number of nodules and in dry weight of nodules by 9.91 and 5.61% in both growing seasons, respectively. Many workers demonstrated that the new released early maturing variety (Sinai1) was superior only on early maturation character, while Giza 9, Giza 370 and Giza 4 varieties surpassed Sinai 1 in nodulation and most vegetative and yield characters (**Aloran, 2004 and Rizk et al., 2011**).

Regarding the main effect of the bio-enriched compost tea, data in Table (4) showed a significant predictable improvement in lentil nodulation status due to the stimulatory effect of bio-enriched compost tea treatments compared to the untreated plants. This trend

was true in both growing seasons. The highest values of lentil nodules number (33.83 and 34.00/plant) and nodules dry weight (135.83 and 138.50 mg/plant) in the first season and (42.50 and 43.17/plant) and (153.83 and 154.33 mg/plant) in the second one were obtained in plants treated with 200 and 300L/fed, respectively. The different between the two compost tea rates did not reach the level of significance. While, untreated plants recorded the lowest values of nodules number (22.00 and 17.67/plant) and nodules dry weight (75.50 and 70.67mg/plant) in both growing seasons, respectively. In this concern, **Ingham (2005)** reported that application rates range for foliar application varies from 20 to 50 litres/fed, whilst application rate for soil application ranges from 150 to 200 litres/fed. These

results imply that compost tea may provide the lentil leaves with maintained available micronutrients and growth factors, which improve the photosynthesis process leading to enhance nodulation performance. The promotive effects on nodulation might occur through the integration between the various mechanisms offered by nodulation promoting rhizobacteria (NPR), which act to enhance root proliferation and provide more infection sites to rhizobia. The most mechanisms that explain the improved rhizobia-legume association by other PGPR to enhance nodulation pattern and symbiotic performance has been reported by many investigators (**Badawi et al., 2011; Malik and Sindhu, 2011 and Rizk et al., 2011**).

**Table (4): Number and dry weight of root nodules developed on two lentil varieties as affected by different rates of bio-enriched compost tea after 75 days from sowing**

Treatments		Season 2010/11		Season 2011/12	
		Number/ plant	Dry weight (mg/plant)	Number/ plant	Dry weight (mg/plant)
<b>Overall means of varieties (V)</b>					
Sinai 1		26.67	103.42	30.42	113.08
Giza 9		30.00	113.67	34.08	119.42
LSD at 0.05		1.602	3.989	2.365	2.853
<b>Overall means of compost tea application rate (C)</b>					
Zero		22.00	75.50	17.67	70.67
100 L/fed.		23.50	84.33	25.67	86.17
200 L/fed.		33.83	135.83	42.50	153.83
300 L/fed.		34.00	138.50	43.17	154.33
LSD at 0.05		2.271	5.654	3.352	4.043
<b>Interaction Effect (V x C)</b>					
Sinai 1	Zero	21.00	70.33	14.67	67.33
	100 L/fed.	23.00	81.00	24.67	81.67
	200 L/fed.	31.67	129.67	41.00	151.00
	300 L/fed.	31.00	132.67	41.33	152.33
Giza 9	Zero	23.00	80.67	20.67	74.00
	100 L/fed.	24.00	87.67	26.67	90.67
	200 L/fed.	36.00	142.00	44.00	156.67
	300 L/fed.	37.00	144.33	45.00	156.33
LSD at 0.05		3.211	7.997	4.740	5.718

Data regarding nodulation status showed significant interaction between bio-enriched compost tea treatments and the varieties (Table 4). It is worthy to mention that number and dry weight of nodules varied depending on lentil variety and compost tea level used. However, the higher nodulation status were obtained due to application of 200 or 300 L/fed bio-enriched compost tea with relatively higher values in case of Giza 9 variety compared with the other tested combinations in both seasons. In the first season, plants treated with any level of bio-enriched compost tea

recorded significant increases in number of nodules for Sinai 1 variety ranged from 9.52 to 50.81% and nodules dry weight from 15.17 to 88.64% over the untreated treatment. The increases in Giza 9 variety ranged from 4.35 to 60.87% and from 8.68 to 78.91% for number and dry weight of nodules, respectively. Similar trend was exhibited by variety Sinai 1 in the second season, which recorded 68.17 to 181.73% for nodules number and 21.30 to 126.24% for nodules dry weight over the untreated treatment, respectively. The increases in Giza 9 variety ranged from 29.03 to

117.71% and from 22.53 to 111.72% for number and dry weight of nodules, respectively. So for nodulation was further strengthened by the application of bio-enriched compost tea. These may be attributed to the better environment condition in plant rhizosphere besides its role in increasing the level of supply in available form of nutritional elements required at trace levels both by the plant and by the nodule system. Many investigators confirmed the stimulating effect of rhizobacteria and organic materials in creating a favorable habitat for legume growth and biological nitrogen fixation (**Abdel-Wahab and Said, 2004, Verma et al., 2010, Malik and Sindhu, 2011 and Rizk et al., 2011**).

#### Shoot dry weight and its NPK contents:

Shoot dry weight and NPK contents of two lentil varieties as affected by bio-enriched compost tea in both growing seasons of 2010/11 and 2011/12 are given in Tables (5 and 6). The obtained data showed that all growth parameters were significantly affected by different treatments under study.

Regarding the influence of lentil varieties, results behaved in similar manner as in root nodulation status

and confirmed that Giza 9 variety surpassed the new released early maturing variety (Sinai1) concerning to these traits. The recorded increases were 4.82 and 8.18% in shoot dry matter, 14.41 and 14.77% in shoot N-content, 17.48 and 20.19% in shoot P-content and 10.51 and 11.84% in shoot K-content over the Sinai1 variety in both growing seasons, respectively. These results confirmed that Giza 9 variety surpassed Sinai1 in most vegetative growth characters (**Aloran, 2004 and Rizk et al., 2011**).

Response of lentil shoot dry weight and its NPK contents to different rates of bio-enriched compost tea are shown in Tables (5 and 6). Data exerted that plants treated with any level of bio-enriched compost tea (100, 200 or 300 L/fed) exhibited gradual increases in shoot dry weights as compared with untreated plants. Response of shoot N, P and K contents behaved similarly to the effect of bio-enriched compost tea on shoot dry weight. However, results clearly evident that the synergy of using 200 or 300 L/fed compost tea, relatively to the untreated plants or plants treated with 100 L/fed. The difference between the two higher doses could not reach the level of significance.

**Table (5): Dry weight and shoot nitrogen content of two lentil varieties as affected by different rates of bio-enriched compost tea after 75 days from sowing**

Treatments		Season 2010/11		Season 2011/12	
		Dry weight of shoot (g/plant)	Shoot N-content (mg/plant)	Dry weight of shoot (g/plant)	Shoot N-content (mg/plant)
<b>Overall means of varieties (V)</b>					
Sinai 1		2.49	67.99	2.69	78.15
Giza 9		2.61	77.79	2.91	89.69
LSD at 0.05		0.078	5.935	0.047	2.164
<b>Overall means of compost tea application rate (C)</b>					
Zero		2.11	44.29	2.44	59.73
100 L/fed.		2.34	65.02	2.57	70.54
200 L/fed.		2.87	89.86	3.15	103.52
300 L/fed.		2.89	92.39	3.05	101.92
LSD at 0.05		0.111	8.413	0.067	3.068
<b>Interaction Effect (V x C)</b>					
Sinai 1	Zero	2.08	43.04	2.15	50.65
	100 L/fed.	2.26	56.99	2.49	65.45
	200 L/fed.	2.84	84.88	3.10	98.90
	300 L/fed.	2.82	87.06	3.01	97.61
Giza 9	Zero	2.15	45.53	2.55	55.80
	100 L/fed.	2.42	73.05	2.80	75.62
	200 L/fed.	2.90	94.83	3.19	108.14
	300 L/fed.	2.95	97.73	3.08	106.23
LSD at 0.05		0.157	11.900	0.096	4.339

**Table (6): Phosphorus and potassium shoot contents of two lentil varieties as affected by different rates of bio-enriched compost tea after 75 days from sowing**

Treatments	Season 2010/11		Season 2011/12		
	Shoot P-content (mg/plant)	Shoot K-content (mg/plant)	Shoot P-content (mg/plant)	Shoot K-content (mg/plant)	
<b>Overall means of varieties (V)</b>					
Sinai 1	16.99	64.31	19.46	73.59	
Giza 9	19.96	71.07	23.39	82.30	
LSD at 0.05	2.214	5.508	1.651	3.669	
<b>Overall means of compost tea application rate (C)</b>					
Zero	12.49	46.09	15.31	55.88	
100 L/fed.	13.92	59.69	16.34	65.32	
200 L/fed.	23.82	80.91	27.57	95.71	
300 L/fed.	23.69	84.07	26.49	94.88	
LSD at 0.05	3.139	7.808	2.341	5.201	
<b>Interaction Effect (V x C)</b>					
Sinai 1	Zero	11.63	45.14	13.36	47.38
	100 L/fed.	12.57	56.38	15.20	62.47
	200 L/fed.	22.12	75.71	25.45	92.52
	300 L/fed.	21.67	80.01	23.81	92.01
Giza 9	Zero	13.36	47.04	15.25	54.39
	100 L/fed.	15.27	63.01	17.48	68.16
	200 L/fed.	25.52	86.10	29.69	98.90
	300 L/fed.	25.70	88.12	29.16	97.75
LSD at 0.05	4.439	11.040	3.310	7.355	

In this concern, **Hargreaves *et al.* (2009)** and **Shaban *et al.* (2012)** recommended that application rates range for compost tea as sprinkler on plants and soil varies from 200 to 500L/fed. In both seasons, increases of shoot dry weights were ranged from 10.90 to 36.97% and from 5.33 to 29.10% and those of shoots N-content were 46.81 to 108.60% and from 18.10 to 73.31%, respectively above the untreated plants. Increases in shoot P-content ranged from 11.45 to 90.71% and from 6.73 to 80.08%, while shoot K-content were ranged from 29.51 to 82.40% and from 16.89 to 71.28%, respectively. These result confirmed the prominent role of organic teas, which develop the root system of plants, and thereby improved water nutrient uptake, plus increasing food storage and soil respiration. Also, compost tea contains rhizobacteria in an active state via their existence in a suitable niche that stimulates root growth and provides it with more branching and larger surface area and provides a protection against phytopathogens. In this respect, **Abdel-Wahab and Said (2004)**, **Tartoura *et al.* (2005)**, **Abdel-Wahab *et al.* (2008)** and **Pant *et al.* (2009)** reported that compost tea is rich in nutrients and microorganisms; also, it is important for optimum nutrition, stimulation of growth and a good tool to suppress the incidence and/or severity of foliar and root diseases.

Data regarding shoot dry weight and its NPK contents showed significant interaction between bio-enriched compost tea levels and the varieties (Tables 5 and 6). Data evident that increasing application rate of compost tea from 100 to 300 L/fed, with the two tested lentil varieties, tended to a significant increase of the shoot dry matter and caused a more accumulation in nutrient uptake compared to the untreated plants. It may be argued that addition of the compost tea showed a significant augmentation in all studied characters, particularly in case of using 200 or 300 L/fed with Giza 9 variety, as was reflected by its highest values in comparison to other tested treatments or untreated ones. Generally, using the compost tea in combination with Sinai 1 variety gave an increases in shoot dry weight ranged from 8.65 to 36.54% and from 15.81 to 44.19% and those of shoot N-content were ranged from 32.41 to 102.28% and from 29.22 to 95.26% in both tested seasons, respectively above the untreated plants. Percentage increases in shoot P-content ranged from 8.08% to 90.20% and from 13.77 to 90.49%, while shoot K-content were ranged from 24.90% to 77.25% and from 31.85 to 95.27%, respectively. On the other hand, the increases in Giza 9 variety ranged from 12.56 to 37.21% and from 9.80 to 25.10% for shoot dry weight and ranged from 60.44 to 114.65% and 35.52 to 93.80% for shoot N-content, respectively. Increases in shoot P-content ranged from 14.30 to 92.37% and from

14.62 to 94.69%, while shoot K-content were ranged from 33.95 to 87.33% and from 25.32 to 81.83%, respectively. These findings may be attributed to the ability of bio-enriched compost tea to improve the plant growth, the absorption and translocation of NPK by leaves tissues, beside their contents from a considerable amount of soluble mineral nutrients that are readily available for plant uptake. Various studies confirm the beneficial effect of compost tea on plant due to its direct nutrients supplying and/or its microbial functions (Tartoura *et al.*, 2005, Pant *et al.*, 2009 and Hendawy *et al.*, 2010).

#### Lentil yield and its components:

Plant height, number of pods/plant, number of seeds/plant, seed yield/plant and 1000-seed weight as well as seed and straw yields and seed crude protein of two lentil varieties along the two consecutive seasons, as affected by application of bio-enriched compost tea are given in Tables (7, 8 and 9). Results elicited that the response of all yield and its attributes of two lentil varieties in both seasons parallel to vegetative growth stage.

Regarding the main effect of lentil varieties, data revealed that the higher values of all yield components as well as lentil yield (seeds and straw) and seed crude protein were obtained by Giza 9 variety. Plants of Giza 9 variety excelled Sinai 1 variety by 4.88 and 10.26% in plant height, by 6.17 and 7.79% in number of pods/plant, by 5.20 and 6.54% in number of seeds/plant, by 12.17 and 14.89% in seed yield/plant and by 3.56 and 4.83% in 1000-seed weight in both growing seasons, respectively. Also, Giza 9 variety was superior to Sinai 1 variety by 8.70 and 9.14% in seed yield, by 23.42 and 17.31% in straw yield and by 2.52 and 1.94% in seed crude protein in both seasons, respectively. Such increases in seed yield/fed of Giza 9 variety might be attributed to the increase in seeds weight/plant resulting from number of branches/plant and number of pods/plant. Aloran (2004) and Rizk *et al.* (2011) confirmed that Sinai 1 variety was superior only on early maturation character, while Giza 9, Giza 370 and Giza 4 varieties surpassed Sinai 1 in most vegetative and yield characters.

**Table (7): Plant height, number of pods/plant and number of seeds/plant of two lentil varieties as affected by different rates of bio-enriched compost tea**

Treatments		Season 2010/11			Season 2011/12		
		Plant height (cm)	No. of pods/plant	No. of seeds/plant	Plant height (cm)	No. of pods/plant	No. of seeds/plant
<b>Overall means of varieties (V)</b>							
Sinai 1		39.52	66.17	73.67	41.41	71.67	79.08
Giza 9		41.45	70.25	77.50	45.66	77.25	84.25
LSD at 0.05		0.929	2.152	2.695	0.934	2.069	1.859
<b>Overall means of compost tea application rate (C)</b>							
Zero		33.57	59.50	65.67	36.88	64.33	70.83
100 L/fed.		39.87	65.00	72.50	42.32	71.17	79.17
200 L/fed.		44.22	74.67	82.33	47.40	81.67	88.50
300 L/fed.		44.28	73.67	81.83	47.53	80.67	88.17
LSD at 0.05		1.317	3.050	3.820	1.324	2.934	2.636
<b>Interaction Effect (V x C)</b>							
Sinai 1	Zero	33.43	57.00	62.67	35.90	62.00	69.00
	100 L/fed.	37.93	63.00	71.00	39.37	68.33	76.33
	200 L/fed.	43.40	72.67	80.67	45.40	78.33	85.33
	300 L/fed.	43.30	72.00	80.33	44.97	78.00	85.67
Giza 9	Zero	33.70	62.00	68.67	37.87	66.67	72.67
	100 L/fed.	41.80	67.00	74.00	45.27	74.00	82.00
	200 L/fed.	45.03	76.67	84.00	49.40	85.00	91.67
	300 L/fed.	45.27	75.33	83.33	50.10	83.33	90.67
LSD at 0.05		1.862	4.313	5.403	1.872	4.149	3.727



**Table (8): Seed yield/plant and 1000-seed weight (g) of two lentil varieties as affected by different rates of bio-enriched compost tea**

Treatments		Season 2010/11		Season 2011/12	
		Seed yield/ plant (g)	1000-seed weight (g)	Seed yield/ plant (g)	1000-seed weight (g)
<b>Overall means of varieties (V)</b>					
Sinai 1		2.63	26.69	2.82	27.13
Giza 9		2.95	27.64	3.24	28.44
LSD at 0.05		0.048	0.664	0.117	0.827
<b>Overall means of compost tea application rate (C)</b>					
Zero		2.35	24.97	2.59	25.06
100 L/fed.		2.68	26.86	2.85	26.52
200 L/fed.		2.86	28.28	3.34	29.74
300 L/fed.		2.84	28.55	3.33	29.82
LSD at 0.05		0.068	0.941	0.166	1.172
<b>Interaction Effect ( V x C)</b>					
Sinai 1	Zero	2.31	24.51	2.42	24.64
	100 L/fed.	2.64	26.77	2.73	26.22
	200 L/fed.	2.78	27.76	3.06	28.92
	300 L/fed.	2.77	27.70	3.07	28.73
Giza 9	Zero	2.41	25.43	2.66	25.48
	100 L/fed.	2.72	26.95	2.98	26.82
	200 L/fed.	2.93	28.79	3.62	30.56
	300 L/fed.	2.91	29.40	3.60	30.90
LSD at 0.05		0.096	1.331	0.235	1.658

**Table (9): Seed yield (ardab/fed), straw yield (ton/fed) and seed crude protein (%) of two lentil varieties as affected by different rates of bio-enriched compost tea**

Treatments		Season 2010/11			Season 2011/12		
		Seed yield (ardab*/fed)	Straw yield (ton/fed**)	Seed crude protein (%)	Seed yield (ardab/fed)	Straw yield (ton/fed)	Seed crude protein (%)
<b>Overall means of varieties (V)</b>							
Sinai 1		3.68	2.22	26.22	3.83	2.60	26.74
Giza 9		4.00	2.74	26.88	4.18	3.05	27.26
LSD at 0.05		0.100	0.083	0.141	0.197	0.073	0.283
<b>Overall means of compost tea application rate (C)</b>							
Zero		3.33	2.14	25.01	3.42	2.33	25.78
100 L/fed.		3.66	2.35	25.96	3.74	2.77	26.26
200 L/fed.		4.15	2.73	27.26	4.32	3.45	27.88
300 L/fed.		4.22	2.69	27.98	4.56	3.48	28.08
LSD at 0.05		0.171	0.118	0.199	0.279	0.104	0.401
<b>Interaction Effect ( V x C)</b>							
Sinai 1	Zero	3.27	2.30	24.96	3.30	2.27	25.62
	100 L/fed.	3.59	2.51	25.76	3.53	2.58	26.24
	200 L/fed.	4.17	3.39	26.40	4.14	3.32	27.29
	300 L/fed.	4.09	3.36	27.74	4.27	3.41	27.82
Giza 9	Zero	3.48	2.44	25.06	3.43	2.48	25.94
	100 L/fed.	3.72	2.78	26.15	3.96	2.87	26.58
	200 L/fed.	4.34	3.67	28.12	4.49	3.73	28.47
	300 L/fed.	4.51	3.75	28.21	4.75	3.69	28.33
LSD at 0.05		0.241	0.166	0.282	0.396	0.147	0.567

\*One ardab = 160 kilogram. \*\* 1 hectare = 2.38 Feddan).

Considering lentil yield and its components as affected by different application rates of bio-enriched compost tea, data in Tables (7, 8 and 9) followed a similar pattern to that of nodulation and vegetative growth stage. Here too, results confirmed again the superiority of using bio-enriched compost tea in achieving the highest values of all lentil yield and yield components compared to the untreated plants. This trend was true in both seasons of the study. Meanwhile, results evident that the synergy of using higher doses of bio-enriched compost tea (200 or 300 L/fed), relatively to the untreated plants or plants treated with 100 L/fed. The difference between the two higher doses could not reach the level of significance. These results stand in accordance with those obtained by **Hargreaves et al. (2009)** and **Shaban et al. (2012)**. The increases in plant height were ranged from 18.77 to 31.90% and from 14.75 to 28.88% and those of number of pods/plant were ranged from 9.24 to 25.50% and from 10.63 to 26.95%, while number of seeds/plant ranged from 10.40 to 25.37% and from 11.77 to 24.95% as well as seed yield/plant ranged from 14.04 to 21.70% and from 10.04 to 28.96% and those of 1000-seed weight were ranged from 7.57 to 14.34% and from 5.83 to 18.99% over the untreated plants in both seasons, respectively. The increases in seed yield ranged from 9.91 to 26.73% and from 9.36 to 33.33% and those of straw yield were ranged from 9.81 to 27.57% and from 18.88 to 49.36%, while seed crude protein were ranged from 3.80 to 11.88 and from 1.86 to 8.92%, respectively. These positive results could be ascribed to the promotive effects of tea compost, which contains beneficial rhizobacteria, or their metabolites, acted as plant growth promoting and/or as microbial -control agents (**Brinton, 1995**). This synergistic effect may be elucidated by their ability to enhance the N<sub>2</sub>-fixation performance, plant growth, absorption of nutrients and their efficiency as well as the metabolism of photosynthates and improve the productivity and quality of many legumes. These results stand in accordance with those obtained by **Verma et al. (2010)**, **Shrestha et al. (2011b)** and **Pane et al. (2012)**.

The interaction computed among the two studied factors was significant in the two growing seasons. Results in Tables (7, 8 and 9) elicited that increasing compost tea dosage from 100 to 300 L/fed, with the two tested lentil varieties, caused promotive impression in all lentil yield and its components compared to the untreated plants. However, Giza 9 variety exerted high responses to the increasing application rate of bio-enriched compost tea (200 or 300 L/fed), which surpassed the other tested treatments or untreated ones. Using the compost tea in combination with Sinai variety attained increases in plant height ranged from 13.46 to 29.82% and from 9.67 to 26.46% and those of number of pods/plant were ranged from 10.53 to

27.49% and from 10.21 to 26.34%, while number of seeds/plant ranged from 13.29 to 28.72% and from 10.62 to 24.16% as well as seed yield/plant ranged from 14.29 to 20.35% and from 12.81 to 26.86% and those of 1000-seed weight were ranged from 9.22 to 13.26% and from 6.41 to 17.37% above the untreated plants during the two growth seasons, respectively. The increases in seed yield ranged from 9.79 to 27.52% and from 6.97 to 29.39% and those of straw yield were ranged from 9.13 to 47.39% and from 13.66 to 50.22%, while seed crude protein were ranged from 3.21 to 11.14% and from 2.42 to 8.59%, respectively. On the other hand, Giza 9 variety gave increases in plant height ranged from 24.04 to 34.33% and from 19.54 to 32.29% and those of number of pods/plant were ranged from 8.06 to 23.66% and from 10.99 to 27.49%, while number of seeds/plant ranged from 7.76 to 22.32% and from 12.84 to 26.15% as well as seed yield/plant ranged from 12.86 to 21.58% and from 12.03 to 36.09% and those of 1000-seed weight were ranged from 5.98 to 15.61% and from 5.26 to 21.27% above the untreated plants during the two growth seasons, respectively. The increases in seed yield ranged from 6.90 to 29.60% and from 15.45 to 38.48% and those of straw yield were ranged from 13.93 to 53.69% and from 15.72 to 50.40%, while seed crude protein were ranged from 4.35 to 12.57 and from 2.47 to 9.75%, respectively. These positive results could be ascribed to the promotive effects of compost tea enriched with PGPRs, which exerted their influence on early nodulation (increased number of nodules, higher N<sub>2</sub>-fixation rates) and a general improvement of root development and nutrient uptake as well as improve overall health of plant and consequently the productivity. The promotive effect of enriched compost tea on the crop productivity had been demonstrated by many investigators (**Pant et al., 2009**; **Hendawy et al., 2010** and **Shrestha et al., 2011b**).

From these results, there is considerable evidence that the various levels of compost tea improved significantly lentil growth and yield characters, particularly when this practice is supported with effective rhizobacteria. The differences among studied varieties may be due to the growth habit and response of each one to environmental conditions, which controlled by genetical factors. Moreover, the combination between the Giza 9 variety and the stimulating dose of bio-enriched compost tea (200 L/fed) may be acting as a good practice for improving the most growth and yield characters and leading to healthier food, particularly under sustainable agricultural systems. However, these trials are in need to be repeated under different soil conditions to reach the level of recommendation and to clarify the best compost tea rate required for each crop.

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