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EFFECT OF ENRICHED COMPOST TEA AND RHIZOBACTERIA ON NODULATION, GROWTH AND YIELD OF CHICKPEA IN SANDY SOIL

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ABSTRACT: *Two field experiments were conducted in sandy soil at Ismaillia Agricultural Research Station during two successive winter-growing seasons of 2004/2005 and 2005/2006 to evaluate the effect of enriched compost tea and some rhizbacteria, namely, Serratia sp., Bacillus megaterium and Pseudomonas fluorescens on nodulation, growth, yield and some yield components of chickpea plants (Cicer arietinm) inoculated with Rhizobium spp. under drip irrigation system. Also, some chemical and biological properties of the sandy soil after crop harvesting were determined.*

The obtained results showed that co-inoculation of chickpea with Rhizobium and any of the tested bacterial strains led to a significant increase for the all plant growth parameters in both growing seasons as compared with the uninoculated treatment or inoculated with Rhizobium alone. Also, all growth parameters significantly responded to foliar application of the enriched compost tea. The highest values of nodular tissues, shoot dry weight, as well as shoot nitrogen and phosphorus contents in both two seasons were obtained by foliar application of the enriched compost tea in combination with co-inoculation with the mixtures of tested bacterial strains and Rhizobium. In addition, results of chickpea yields (seed and straw) and some yield components (100-seed weight and crude protein percentage of seeds) showed a similar trend for the vegetative growth. Moreover, changes occurring in some chemical and biological properties of the sandy soil after harvesting of chickpea confirmed again the superiority of using the enriched compost tea along with such mixed bacterial strains to achieve higher values of organic-C, total-N, available N,P and K with more flourishing in the activity of dehydrogenase in the sandy soil.

Currently, it could be concluded that the conjunctive use of enriched compost tea along with such mixed bacterial strains resulted not only in highest and sustainable chickpea crop yield but also enhanced the efficiency of added bacterial strains, as well as fertility status of the sandy soil.

Key words: *Diazotrophy, Leguminous plants, Organic wastes, Bacillus megaterium, Serratia sp., Pseudomonas fluorescens and Rhizobium sp.*

INTRODUCTION

Chickpea (*Cicer arietinm*) is one of the most important legume crops for human nutrition grown in arid and semi-arid regions. The area cultivated of chickpea in Egypt is about 20,000 feddan annually. This area has been started to increase specially in newly reclaimed desert areas.

The newly reclaimed sandy soils are ones of those low productive soils and also, ones of the main items of agricultural expanding policy in Egypt. These soils are characterized by a rapid turnover of organic materials and low nitrogen content. Hence for sustainable improvement of the nutrient and moisture supplying capacity of the soil, continuous application of organic materials will be the only solution. (Abdel-Wahab *et al* ., 2002 and Badawi, 2003). Moreover, the exploitation of biologically nitrogen fixation would sustain high yield and save large amounts of N-fertilizers (Tilak *et al*., 2005).

Inoculation of legumes with specific rhizobia is also widely used in agriculture for a valuable improvement. Numerous publications are indicating to necessitate of such sandy soil to be inoculated with efficient rhizobial strains (Abdel-Wahab *et al*., 2005 and Hassanein *et al*., 2006).

The concept of PGPBR, created by Luz *et al.* (1998), is intended to encompass both PBPR (Plant Bioprotect Promoting Rhizobacteria) which are rhizbacteria that promote the protection against major plant pathogens and PGPR (Plant Growth Promoting Rhizobacteria) which are rhizobacteria that promote beneficial effects on plant growth. Generally, plant growth promoting rhizobacteria may stimulate growth directly via fixation of atmospheric nitrogen, solubilization of minerals such as phosphorus, production of siderophores or production of plant growth regulators (Kloepper, 2003). In addition, certain rhizobacteria affect the development and function of roots by improving mineral and water uptake (Tilak *et al.,* 2005).

Enhancement of legume nitrogen fixation by co-inoculation of rhizobia with some plant growth promoting bacteria (PGPB) is a way to improve nitrogen availability in sustainable agriculture production systems. Most of the PGPB strains tested by coinoculation with *Rhizobium* or *Bradyrhizobium* species are general rhizobacteria (Dileep kumar *et al.,* 2001 and Bullied *et al*., 2002). Numerous publications have reported that co-inoculation of PGPR with rhizobia improves legume nodulation, plant growth and yield (Srinivasan *et al*., 1996 ; Zhang *et al.* 1996 and El-Sawi *et al.* 2001). In this concern, Parmar and Dadarwal (1999) and Bai *et al.* (2002) reported that many plant growth promoting rhizobacteria (PGPR) have beneficial effects on legume growth, and at least some PGPR strains enhance legume nodulation and nitrogen fixation by production flavonoid-like compounds and/or stimulating the host legume to produce more flovonoid signal molecules, which affecting signal exchange between the plants and rhizobia.

Interest in organic teas for use in agriculture and horticulture has grown rapidly during the last decade. To make an effective compost tea, it must start with properly composted material in respect to preparation conditions (hot, aerobic compost pile is preferred) and maturation degree. There are two basic ways to prepare compost teas. One way is to soak the compost in water without aeration. Compost is either added directly to open containers of water and stirred or compost is added to burlap bags, cheesecloth or other permeable material and then dipped like tea bags into water. This method is sometimes called passive extraction (Weltzein, 1991). The second way is to make an active or aerobic extract, which can be made by aerating the extraction solution. Air can be bubbled through the solution, or the solution can be constantly recycled through an aeration nozzle (Quarles, 2001). In addition, Merrill and Mckeon (2001) indicated that some additives or adjuvant including sugars, molasses, rocks fertilizers, kelp and fish products and barley malt may be add to soaked compost to increase the microbial activity in organic teas. The literature 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 (Hadas and Rosenberg, 1992) ; an ability to suppress certain plant disease (Brinton *et al.*, 1996 and Zhang *et al.*, 1998) ; as a way to build soil structure when applied as a drench and optimizes the soil pH (Ingham, 2000 a&b). In this respect, Ingham (2001) and Quarles (2001) mentioned that compost tea is rich in nutrients and microorganisms and can stimulate growth, protect plants from diseases and help suppress soil borne pathogens.

The present work aimed at studying the effect of enriched compost tea and rhizobacteria (*Serratia* sp., *Bacillus megaterium* and *Pseudomonas fluorescens*) on nodulation, growth, yield and some yield components of chickpea inoculated with *Rhizobium* spp. in sandy soil. Also, some chemical and biological properties of sandy soil after chickpea harvesting were investigated.

MATERIALS AND METHODS

Bacteria strains and growth conditions:

Rhizobium spp. (ICARDA 1148), *Serratia* sp., *Bacillus megaterium* and *Pseudomonas flurescence* (NRRL 14) strains were supplied by Microbiology Department, Soils, Water and Environment Research Institute (SWERI), Agricultural Research Center (ARC), Giza, Egypt.

Rhizobium was grown on yeast extract mannitol 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 a rotary shaker until early log phase had been developed to 10^9 viable cells ml^{-1}, then the cultures were transferred to sterile carrier materials (90% vermiculite + 10% Irish peat).

Inocula preparation:

Vermiculite supplemented with 10% Irish peat was packed in polyethylene bags (400 g/bag). Bags were then sealed and sterilized by gamma irradiation (5×10^6 rads). Bacterial culture was injected into a sterilized carrier to satisfy 50% of water holding capacity.

Preparation of enriched compost tea:

Aerated compost tea was prepared from a matured compost made from rice straw, farmyard manure, bentonite, rockphosphate, elemental sulphur and urea which had been composted in an aerobic heap for three months. To prepare the enriched compost tea, ten kg of matured compost blended with 1 kg molass, 500 g $(NH_4)_2SO_4$, 50 g $MgSO_4.7H_2O$ and 10 g NaCl in a 150 litter plastic barrel. These ingredients were drenched in 100 litter tap water (previously stored to avoid the harmful effect of Cl_2 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. After elapsing of incubation time, the liquid mixture was filtered on a 100 mesh screen and became ready to use. The main traits of the produced compost tea are shown in Table (1).

Seeds:

Chickpea seeds (*Cicer arietinm* cv. Giza 195) were supplied from Crops Research Institute, ARC, Giza, Egypt.

Field experiments:

Two field experiments were conducted on a sandy soil at Ismaillia Experimental Research Station, during two successive winter-growing seasons of 2004/2005 and 2005/2006 to study the effect of enriched compost tea and rhizbacteria (*Serratia* sp., *Bacillus megaterium* and *Pseudomonas fluorescens*) on nodulation, growth, yield and some yield components of chickpea plants inoculated with *Rhizobium* spp.

Representative soil samples were collected, air dried, ground and sieved through 2 mm screen. Some physical and chemical properties of the used soil are presented in Table (2).

Table (1): The main chemical and microbiological traits of the enriched compost tea used.

Trait	Value
pH	6.93
E.C. ($dS\ m^{-1}$ at 25°C)	3.92
Total- N (%)	0.014
Total- P (%)	0.13
NH^{+}_{4}-N (ppm)	86.9
NO^{-}_{3}-N (ppm)	11.5
Total soluble-N (ppm)	98.4
Available-P (ppm)	22.4
Extractable- Fe (ppm)	18.6
~ - Zn (ppm)	7.5
~ - Mn (ppm)	3.2
~ - Cu (ppm)	1.8
E_4/E_6 (Extinction coefficient)	3.84
*Seed germination test (%)	91.0
Total count of bacteria (cfu/ml)	8.2×10^{7}
Total count of fungi (cfu/ml)	7.4×10^{5}
Total count of actinomycetes (cfu/ml)	1.2×10^{6}

*Cress seeds incubated for 48 hr.

Table (2): Physical and chemical properties of the experimental soil in both seasons of study.

Property	Season 2004/2005	Season 2005/2006
Particle size distribution (%):		
Sand	90.0	90.1
Silt	3.8	3.7
Clay	6.2	6.2
Texture grade	Sandy	Sandy
$CaCO_3$	1.64	1.62
Saturation percent (S.P %)	20.12	21.00
pH (soil paste)	7.45	7.38
E.C (dS m^{-1}, at 25°C)	0.32	0.30
Soluble cations (meq/L) :		
Ca^{++}	0.54	0.56
Mg^{++}	0.33	0.30
Na^{+}	1.62	1.53
K^{+}	0.65	0.60
Soluble anions (meq/L) :		
$CO^{=}_3$	0.00	0.00
HCO^{-}_3	0.88	0.84
Cl^{-}	0.59	0.60
$SO^{=}_4$	1.67	1.55
Organic matter (%)	0.24	0.26
Organic-C (%)	0.14	0.15
Total-N (%)	0.020	0.022
C/N ratio	7.00	6.82
Total soluble- N (ppm)	17.30	16.63
Available- P (ppm)	6.81	6.76
Available-K (ppm)	41.42	48.12
DTPA-extractable (ppm):		
Fe	1.31	1.21
Mn	0.30	0.32
Zn	0.46	0.48
Cu	0.26	0.22

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

The following treatments were introduced:

1- Uninoculated.
2- *Rhizobium*. (*R.*)
3- *Rhizobium* + *Serratia* sp. (*R.+S.*)
4- *Rhizobium* + *Bacillus megaterium*. (*R.+B.m*)
5- *Rhizobium* + *Pseudomonas fluorescens*. (*R.+Ps.*)
6- *Rhizobium+Serratia+Bacillus megaterium+Pseudomonas fluorescens*. (*R.+S.+B.m+Ps.*)

These treatments were conducted in absence or presence of enriched compost tea.

Chickpea seeds were inoculated with gamma irradiated vermiculite-based inocula for each bacterium used at a rate of 400 g/40 kg seeds using 16% arabic gum solution as a sticking agent. Randomized complete block design with four replicates was used and the plot area was 10.5 m^2. All treatments received ammonium sulphate (20.5% N) at a rate of 36 kg N ha^{-1} at planting as an activation dose. Superphosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O) were incorporated into soil before planting at rates of 480 and 120 kg ha^{-1}, respectively. Enriched compost tea was sprayed before and after 15 days of flowering stage at a rate of 400 L/fed for each period, using the back-portable equipment. Spraying was made to coat the leaves surface and to drench the soil around plants. Drip irrigation was followed in the experiments.

Five chickpea plants were uprooted from each plot after 75 days of planting and assayed for number and dry weight of nodules, as well as dry weight of shoots. Nitrogen and phosphorus contents of shoots were also determined.

At harvest, the middle three rows of each plot were harvested to determine seed and straw yield (ton ha^{-1}), 100-seed weight and the crude protein percentage of seeds.

After harvesting, soil were sampled from each plot and analyzed for some chemical and biological properties.

Analyses:

Enriched compost tea: Determination of chemical and microbiological traits of the enriched compost tea was executed according to Page *et al.* (1982). Seed germination test was conducted using cress seeds to evaluate the compost maturity (Pare *et al.*, 1997).

Soil: Mechanical and chemical analyses of the soil were carried out according to Black *et al.* (1965). While, biological properties of the soil were determined according to Page *et al.* (1982).

Plant materials: The oven dried plant materials were wet digested by using a mixture of pure $HClO_4$ and H_2SO_4 at a ratio of 1:1 according to Jackson

(1973). Total nitrogen and phosphorus contents were assayed according to the methods of Page *et al.* (1982).

Statistical analysis:

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

RESULTS AND DISCUSSION

Nodulation status:

Results of chickpea nodulation as affected by the enriched compost tea, rhizobacteria and their combinations in both growing season of 2004/2005 and 2005/2006 are given in Table (3).

Regarding the main effect of the enriched compost tea, data, in general, showed that the response of nodulation (number and dry weight of root nodules) was significant. Plants treated with the enriched compost tea caused significant increases in number of nodules by (27.35 and 20.27%) and in dry weight of nodules by (15.13 and 15.49%) over the untreated plants in both growing seasons, respectively. These results imply that compost tea may provide the chickpea leaves with maintained available micronutrients and growth factors such as vitamins and hormones like substances. These substances improve the photosynthesis process leading to enhance nodulation performance (Ingham, 2003). Moreover, compost tea contains rhizobacteria in an active state via their existence in a suitable niche that improves chickpea plant growth and provide a protection against air borne diseases. In this respect, Ingham (2001) and Quarles (2001) reported that compost tea can supply plants with nutrients, beneficial microorganisms, stimulate growth and can protect plants from diseases.

Data of response of chickpea root nodulation to inoculation with some rhizobacteria (*Rhizobium, R.+Serratia, R.+Bacillus megaterium, R.+Pseudomonas* or *R.+Serratia+ Bacillus+Pseudomonas*) are shown in Table (3). Obtained results Illustrated that inoculation of chickpea with *Rhizobium* exerted a valuable improvement in nodulation status, which was reflected by significant increases in number and dry weight of nodules in the inoculated treatments in comparison to the uninoculated ones that failed to form any nodules. These results point out to the necessity of such sandy soil for inoculation with efficient rhizobial strains (Abdel-Wahab *et al.,* 2005 and Hassanein *et al.,* 2006). Moreover, chickpea plants inoculated with *Rhizobium* either alone or in combination with any of the tested bacterial strains showed an improved production of root nodules in both seasons. However, response of the nodulation status to co-inoculation (PGPR) surpassed that of *Rhizobium* only. Addition of mixed PGPR to the *Rhizobium* inoculant increased nodule number by 48.15% and nodule weight by 100.98% in the first season, and nodule number by 57.11% and nodule weight by 100.44% in

Table (3): Effect of the enriched compost tea, rhizobateria and their combination on nodulation of chickpea in the sandy soil used.

Treatments		Season 2004/2005		Season 2005/2006	
		Number of nodules/ plant	Dry weight of nodules (mg/plant)	Number of nodules/ plant	Dry weight of nodules (mg/plant)
		Main effect of enriched compost tea (C)			
Without compost tea		24.39	126.67	28.22	137.67
With compost tea		31.06	145.83	33.94	159.00
L.S.D. 0.05		0.869	3.860	0.940	4.273
		Main effect of rhizobacteria (R)			
Control		-	-	-	-
Rhizobium (*R.*)		27.00	100.67	29.17	113.00
R. + *Serratia* (*S.*)		36.00	184.17	39.83	196.50
R.+ *Bacillus megaterium* (*B.M*)		30.33	158.33	34.00	172.00
R. + *Pseudomonas* (*Ps.*)		33.00	172.00	37.67	182.00
R. + *S.* + *B.M* + *Ps.*		40.00	202.33	45.83	226.50
L.S.D. 0.05		1.506	6.687	1.628	7.402
		Interaction effect (C x R)			
Without compost tea	Control	-	-	-	-
	Rhizobium (*R.*)	23.00	86.33	25.33	96.00
	R. + *Serratia* (*S.*)	31.00	169.67	35.00	186.67
	R.+*B. megaterium* (*B.M*)	28.00	151.00	30.67	164.67
	R. + *Pseudomonas* (*Ps.*)	29.33	166.67	35.33	177.00
	R. + *S.* + *B.M* + *Ps.*	35.00	186.33	43.00	201.67
With compost tea	Control	-	-	-	-
	Rhizobium (*R.*)	31.00	115.00	33.00	130.00
	R. + *Serratia* (*S.*)	41.00	198.67	44.67	206.33
	R.+*B. megaterium* (*B.M*)	32.67	165.67	37.33	179.33
	R. + *Pseudomonas* (*Ps.*)	36.67	177.33	40.00	187.00
	R. + *S.* + *B.M* + *Ps.*	45.00	218.33	48.67	251.33
L.S.D. 0.05		2.129	9.456	2.303	10.467

the second one, over the plants inoculated with *Rhizobium* only. Superiority of nodulation as a result of coinoculation of rhizobial inoculated chickpea with PGPRs mixture may be attributed to magnifying the diverse promoting mechanisms that trigger on onset and development of nodulation of legumes grown in such newly reclaimed soils. The promotive effects on nodulation might occur through the integration between the various mechanisms offered by mixing more than efficient rhizobacteria, which act to enhance root proliferation and provide more infection sites to rhizobia (Srinivasan *et al.*, 1997). Generally, coinoculation of legumes with rhizobia and nodulation promoting rhizobacteria (NPR) is becoming practical approach in development of sustainable agriculture (Bai *et al.*, 2002). The enhancement of nodulation pattern and symbiotic performance has been reported by many investigators (Zhang *et al.*, 1996; Parmar and Dadarwal, 1999 ; Bai *et al.*, 2002; Abdel-Wahab and Said, 2004 and Nassef *et al.*, 2005).

Concerning the combined effect of the enriched compost tea and rhizobacteria, results in Table (3) indicated that plants inoculated with any of the bacterial strains tested gave higher values of number and dry weight of nodules as compared with the untreated ones. These results behaved the same trend in the two seasons under investigation. However, the highest values of nodular tissues of chickpea roots were attained due to joint application of mixed bacterial strains and compost tea. Such increases in the first season were 45.16% and 89.85% in number and dry weight of nodules, respectively, over the plants treated with compost tea and inoculated with *Rhizobium* only. The increases in the second season were 47.48% and 93.33% in the same order. These results may indicate the great role of compost tea, which was reflected by synergistic effects on root growth and nodules formation. Many investigators confirmed the stimulating effect of rhizobacteria and organic materials (either as a soil application or its extracts) in creating a favorable habitat for legume growth and biological nitrogen fixation (Li and Alexander, 1999; Abdel-Wahab and Said, 2004; Abdel-Wahab *et al.*, 2006 and El-Tahlawy, 2006). Also, these results exhibited that compost tea had a dual pivotal role, as a source of natural rhizobacteria, which exists in phyllosphere and rhizosphere, beside providing the applied PGPRs with essential substances in rhizosphere. In this concern, Merrill and Mckeon (2001) revealed that organic tea can contain long chain carbon molecules, which provide carbon and oxygen for rhizosphere microbes. They added that compost tea coats plant surfaces (foliar application) or roots (liquid drench application) with living microorganisms and provides food for beneficial microorganisms.

Shoot dry weight and N and P contents:

Table (4) showed the effect of the enriched compost tea, rhizobacteria and their combinations on shoot dry weight and N and P contents of chickpea plants in both growing seasons. The obtained data showed that all growth parameters significantly were affected by the different treatments under study.

Response of shoot dry weight to foliar application of the enriched compost tea was clear and gave increases of 31.95% and 30.68% in the first and second season, respectively over the control. Response of shoot N and P contents behaved similarly to the affect of foliar application of the enriched compost tea on shoot dry weight (Table 4). Increases in shoot N-content were 54.55% and 54.42% in the first and second seasons, respectively, while shoot P-content recorded 55.83% and 54.23%, 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. Similar trend was obtained by Zhang *et al.* (1998) and Quarles (2001) who 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.

Concerning the rhizobacteria inoculation, data in Table (4) revealed that all treatments are better than the control (uninoculated). In general, co-inoculation with any of the tested rhizobacteria led to significant increases of the shoot dry weight and shoot N and P contents, relatively to the untreated one or inoculated with *Rhizobium* only in both seasons. Nevertheless, inoculation with *Rhizobium* and other strains of PGPR, when applied together, confirmed again their synergistic interaction to stimulate plant growth, nitrogen and P accumulation in legume tissues. The corresponding values were 5.75 g plant^{-1}, 203.26 mg N plant^{-1} and 60.25 mg P plant^{-1} in the first season and 6.04 g plant^{-1}, 221.26 mg N plant^{-1} and 59.21 mg P plant^{-1} in the second season, respectively. While, values of shoot dry weight and N and P contents as a result of inoculation with *Rhizobium* only were 4.21 g plant^{-1}, 121.75 mg N plant^{-1} and 32.47 mg P plant^{-1} in the first season and 4.49g plant^{-1}, 146.87 mg N plant^{-1} and 33.84 mg P plant^{-1} in the second season. In general, these increases could be due to the biological role of such rhizobacteria in enhancing plant growth, N_2-fixation and phosphorus solubilization. The promotion effect of rhizobacteria on plant vigour has been reported by many investigators (Bai *et al.,* 2003; Zhinong *et al.,* 2003; Mekhemar *et al.,* 2005; Nassef *et al.,* 2005 and El-Tahlawy, 2006).

With respect to the combined effect of the enriched compost tea and rhizobacteria, data in Table (4) reveled that co-inoculation with the different rhizobacterial strains tended to a significant increase of the shoot dry matter and its N and P contents compared to other tested treatments under foliar application of the compost tea or not. Addition of the compost tea showed a significant augmentation in all studied characters particularly in case of co-

Table (4): Effect of the enriched compost tea, rhizobateria and their combination on shoot dry weight, shoot N and P contents of chickpea in the sandy soil used.

Treatments		Season 2004/2005			Season 2005/2006		
		Shoot dry weight (g/plant)	Shoot content (mg/plant) N	P	Shoot dry weight (g/plant)	Shoot content (mg/plant) N	P
		Main effect of enriched compost tea (C)					
Without compost tea		4.10	117.19	32.22	4.40	133.60	32.88
With compost tea		5.41	181.12	50.21	5.75	206.30	50.71
L.S.D. $_{0.05}$		0.160	8.784	1.547	0.141	7.966	1.364
		Main effect of rhizobacteria (R)					
Control		2.84	68.60	16.46	3.09	83.87	17.35
Rhizobium (*R.*)		4.21	121.75	32.47	4.49	146.87	33.84
R. + *Serratia* (*S.*)		5.55	185.20	45.52	5.92	203.78	46.52
R.+*Bacillus megaterium* (*B.M*)		4.91	145.36	50.12	5.30	169.04	49.97
R. + *Pseudomonas* (*Ps.*)		5.28	170.78	42.48	5.61	194.85	43.88
R. + *S.* + *B.M* + *Ps.*		5.75	203.26	60.25	6.04	221.26	59.21
L.S.D. $_{0.05}$		0.278	15.214	2.679	0.245	13.798	2.362
		Interaction effect (C x R)					
Without compost tea	Control	2.55	56.95	14.34	2.43	66.09	14.16
	Rhizobium (*R.*)	3.52	100.79	26.08	3.85	112.18	27.35
	R. + *Serratia* (*S.*)	4.77	139.81	34.53	5.32	164.70	35.05
	R.+*B. megaterium* (*B.M*)	4.20	113.42	38.32	4.71	140.90	39.12
	R.+ *Pseudomonas* (*Ps.*)	4.66	132.86	33.71	4.93	146.42	35.82
	R. + *S.* + *B.M* + *Ps.*	4.91	159.32	46.36	5.15	171.30	45.80
With compost tea	Control	3.13	80.25	18.57	3.74	101.66	20.55
	Rhizobium (*R.*)	4.90	142.72	38.85	5.14	181.57	40.33
	R. + *Serratia* (*S.*)	6.33	230.60	56.51	6.52	242.86	57.98
	R.+*B. megaterium* (*B.M*)	5.63	177.29	61.91	5.89	197.18	60.82
	R.+ *Pseudomonas* (*Ps.*)	5.90	208.69	51.26	6.28	243.29	51.94
	R. + *S.* + *B.M* + *Ps.*	6.58	247.20	74.14	6.94	271.22	72.62
L.S.D. $_{0.05}$		0.394	21.515	3.789	0.346	19.513	3.341

inoculation of *Rhizobium* with mixtures of rhizobacteria, as was reflected by its highest values in comparison to treatments untreated with the compost tea. Generally, using the compost tea in combination with mixtures of rhizobacteria gave higher figures of shoot dry weight (6.58 and 6.94 g/plant), shoot N-content (247.20 and 271.22 mg N/plant) and shoot P-content (74.14 and 72.62 mg P/plant) in the first and second seasons, respectively. This result confirms previous findings that the organic materials had a great promotive role in enhancing the activity of PGPRs in rhizosphere, particularly in sandy soils for boosting the plant growth and nutrients uptake of chickpea tissues. Claims to the synergistic effect of such combination were reported by various workers, Abdel-Wahab *et al.* (2003), Abdel-Wahab and Said (2004), Abdel-Wahab *et al.* (2006) and El-Tahlawy (2006) who mentioned that promotive effects as a result of combination between organic materials and biofertilizers could trigger from the beneficial effects of rhizobacteria on the nutrient availability, vital enzymes, hormonal stimulants leading to enhance plant growth and hasten the photosynthetic activity.

Chickpea yield and some of its attributes:

The response of chickpea yield and its attributes to foliar application of the enriched compost tea, rhizobacteria and their combinations are given in Table (5). The seed and straw yields in both seasons parallel to vegetative growth stage.

With regard to effect of the compost tea on chickpea yield as manifested by seed and straw yields, data in Table (5) displayed that plants treated with the compost tea recorded higher values of chickpea yields compared to untreated plants. This trend was true in the two seasons. The percentages of increase in seed yield were 23.87 and 26.28 in the seasons of 2004/2005 and 2005/2006, respectively. The corresponding percentage increases in straw yield were 8.25 and 34.59, respectively, in the same order. Superiority of foliar application of the compost tea in promoting of chickpea yield productivity could be due to hastening the performance of nutrients availability in presence of organic metabolites, beside high biological benefits of the used compost tea (Ingham, 2000 a&b ; Ingham, 2001 & Merrill and Mckeon, 2001). In this respect, Mekail (1998), Abdel-Wahab *et al.* (2003) & Abdel-Wahab and Said (2004) found that application of organic materials (solid compost or compost extract) gave a positive response on the legume yields productivity and their components in newly reclaimed soils.

Owing to the effect of rhizobacteria on chickpea yield, results in Table (5) confirmed that co-inoculation of chickpea with *Rhizobium* and any of the tested bacterial strains led to a significant increase of the seed and straw yields compared to the control or sole rhizobial inoculation. However, plants inoculated with *R.*+mixture of PGPR followed by *R.+Serratia* exhibited higher

Table (5): Effect of enriched compost tea, rhizobacteria and their combination on chickpea yield and some its attributes in the sandy soil under consideration.

Treatments		Season 2004/2005		Season 2005/2006		Season 2004/2005		Season 2005/2006	
		Seed yield (ton/ha)	Straw yield (ton/ha)	Seed yield (ton/ha)	Straw yield (ton/ha)	100-seed weight (g)	Crude protein of seeds (%)	100-seed weight (g)	Crude protein of seeds (%)
		Main effect of enriched compost tea (C)							
Without compost tea		1.55	2.91	1.56	2.66	24.10	23.61	24.53	24.24
With compost tea		1.92	3.15	1.97	3.58	25.38	25.09	25.77	25.65
L.S.D. 0.05		0.082	0.183	0.079	0.202	1.036	1.225	N.S	0.867
		Main effect of rhizobacteria (R)							
Control		1.01	1.79	1.25	2.19	21.20	21.90	21.30	22.10
Rhizobium (*R.*)		1.60	2.90	1.61	2.87	24.00	24.05	24.55	24.96
R. + *Serratia* (*S.*)		1.97	3.41	1.92	3.46	26.05	25.19	26.58	25.61
R.+*Bacillus megaterium* (*B.M*)		1.76	3.08	1.73	3.03	24.70	24.22	25.40	24.50
R. + *Pseudomonas* (*Ps.*)		1.84	3.36	1.92	3.47	25.25	24.78	25.65	25.55
R. + *S.* + *B.M* + *Ps.*		2.23	3.65	2.15	3.69	27.15	25.94	27.42	26.95
L.S.D. 0.05		0.141	0.318	0.136	0.350	1.795	2.122	2.184	1.503
		Interaction effect (C x R)							
Without compost tea	Control	0.75	1.65	1.15	1.92	19.50	21.30	20.30	21.50
	Rhizobium (*R.*)	1.48	2.48	1.54	2.67	23.50	23.50	24.00	24.10
	R. + *Serratia* (*S.*)	1.78	3.48	1.57	2.69	25.60	24.59	25.90	24.92
	R.+ *B. megaterium* (*B.M*)	1.67	2.89	1.52	2.91	24.30	23.33	24.80	23.80
	R. + *Pseudomonas* (*Ps.*)	1.63	3.20	1.75	2.81	25.00	23.70	25.70	24.90
	R. + *S.* + *B.M* + *Ps.*	1.97	3.76	1.82	2.98	26.70	25.24	26.50	26.20
With compost tea	Control	1.27	1.92	1.36	2.47	22.90	22.50	22.30	22.70
	Rhizobium (*R.*)	1.72	3.33	1.67	3.06	24.70	24.60	25.10	25.81
	R. + *Serratia* (*S.*)	2.16	3.34	2.27	4.23	26.50	25.80	27.27	26.30
	R.+ *B. megaterium* (*B.M*)	1.85	3.27	1.93	3.14	25.10	25.11	26.00	25.20
	R. + *Pseudomonas* (*Ps.*)	2.05	3.51	2.09	4.14	25.50	25.86	25.60	26.20
	R. + *S.* + *B.M* + *Ps.*	2.49	3.53	2.48	4.40	27.60	26.64	28.33	27.70
L.S.D. 0.05		0.199	0.450	0.193	0.496	N.S	N.S	N.S	N.S

values of chickpea yield in both growing seasons. The percentages of increase in seed yield obtained in the season 2004/2005 were 120.79 and 95.05 and in the season 2005/2006 were 72.0 and 53.60 over the uninoculated treatment. The corresponding increase percentages of straw yield attained in the season 2004/2005 were 103.91 and 90.50 and in the season 2005/2006 were 68.49 and 57.99 over the uninoculated treatment. The present results could be ascribed to the favorable effect of co-inoculation with *Rhizobium* and mixture of PGPR, which exerted their influence via the production of specific compounds by different mechanisms that have the ability to enhance the nodulation, N_2-fixation, nutrients availability, as well as improvement of nutrient and water uptake in sandy soil. Such mechanisms were reported by many investigators (Dileep Kumar *et al.,* 2001 ; Kloepper, 2003 ; Tilak *et al.,* 2005 and Abdel-Wahab *et al.,* 2006).

Taking the interaction between rhizobacteria and compost tea into consideration, results in Table (5) demonstrated that all the inoculated treatments exhibited significant increases in both seed and straw yields over the uninoculated treatment. This behavior was true in both tested seasons either with or without addition of the compost tea. However, these increases were higher with the compost tea than those achieved by the same treatments without the compost tea. The highest values of seed yield (2.49 and 2.48 ton/ha) and straw yield (3.53 and 4.40 ton/ha) in the first and second seasons, respectively were achieved by joint application of the enriched compost tea and mixture of PGPR. Hence, it is possible to confirm again that co-inoculation of chickpea with *Rhizobium* and rhizobacteria under foliar application of the enriched compost tea may enhance the plant vigour, biological nitrogen fixation and chickpea yield in the sandy soil used. Similar findings were observed by Abdel-Wahab *et al.* (2003), Abdel-Wahab and Said (2004) and Abdel-Wahab *et al.* (2006) who concluded the important role of compost (either solid compost or compost extract), on enhancement of the root traits, plant vigour and productivity of legumes, as well as encouraging the PGPR activity in the rhizosphere particularly under sandy soil conditions.

Concerning some yield attributes, data presented in Table (5) exerted that spraying of chickpea plants with the compost tea led to significant increases in hundred seed weight and their protein content. This trend was true in both growing seasons. In both seasons, the higher values of 100-seed weight (25.38 and 25.77g) and the highest crude protein percentage (25.09 and 25.65) were obtained by the chickpea plants foliared with the enriched compost tea. This may elucidated that the enriched compost tea has many factors to help the plant growth, enhancing the crop yield and yield components, for example, it harbors beneficial microorganisms, which act to make nutrients be available to plants and building up the soil structure. The promotive effect of enriched compost tea on the yield and yield components of legumes had been demonstrated by many investigators (Ingham, 2001 ; Merrill and Mckeon, 2001 ; Quarles, 2001 ; Abdel-Wahab and Said, 2004 and Tartoura *et al.*, 2005).

The effect of rhizobacterial strains, data in Table (5) illustrated also that *Rhizobium* inoculation individually or in combination with any of the tested bacterial strains caused significant increases in 100-seed weight and crude protein percentage of the chickpea seeds. Here too, results confirmed again the superiority of using the mixture of rhizobacteria followed by using *R.+Serratia* treatments in achieving the highest values of 100-seed weight (27.15 and 26.05 g) and the highest crude protein percentage (25.94 and 25.19) in the first season, respectively. In the second season, the uppermost values of 100-seed weight were (27.42 and 26.58 g) and the highest crude protein percentage were (26.95 and 25.61), respectively, in the same order. This synergistic effect of rhizobacteria my be elucidated by their ability to enhance the N_2-fixation performance and nutrients availability and uptake from soil, which resulted in the production of hormones like substances and siderophores, as well as phosphte solubilization and improvement of nutrient and water uptake. These results are in conformity with those of (Kloepper, 2003 ; Tilak *et al.*, 2005 and Abdel-Wahab *et al.*, 2006).

Regarding the combined effect of the enriched compost tea and rhizobacteria, data in Table (5) noted that plants inoculated with any of the tested bacterial strains with or without compost tea gave higher values of 100-seed weight and higher crude protein percentage, compared to the uninoculated treatment. Here, it should be noted that effect of the tested bacterial strains on the traits was more pronounced in case of the plants treated with the enriched compost tea as compared with the untreated ones. Although all parameters were reacted insignificantly for this interaction, the obtained data emphasized the superiority of using the compost tea along with the mixture of promoting rhizobacteria. Using such treatment achieved percentage increases in 100-seed weight (41.54 and 39.56) and crude protein content of seeds (25.07 and 28.84) over the absolute control in the first and second seasons, respectively. From these results, it is possible to conclude that combination between the compost tea spraying and co-inoculation with PGPRs may be acting as a good practice for improving the yield quality of leguminous plants grown in sandy soils (Abdel-Wahab and Said, 2004 ; Abdel-Wahab *et al.*, 2005 and Abdel-Wahab *et al.*, 2006).

Effect of the enriched compost tea and rhizobacteria on some soil characters after harvesting of chickpea crop:

Results in Table (6) showed the changes occurring in some chemical and biological properties of the sandy soil used as affected by the rhizobacterial inoculation and foliar application of the enriched compost tea after chickpea harvesting. Data indicated that the co-inoculation with any of the tested

Table (6): Effect of enriched compost tea and rhizobacteria on some soil characters after harvesting of chickpea in both seasons of study.

Treatments	Season 2004/2005							Season 2005/2006						
	pH	O.C (%)	Total -N (%)	Available nutrients (ppm) N	P	K	Dehydrogenase activity (mg TPF/100 g soil)	pH	O.C (%)	Total -N (%)	Available nutrients (ppm) N	P	K	Dehydrogenase activity (mg TPF/100 g soil)
	Without enriched compost tea													
Control	7.47	0.13	0.015	10.5	5.6	25.8	36.20	7.44	0.14	0.016	11.3	5.5	24.0	38.54
Rhizobium (*R.*)	7.46	0.14	0.017	20.1	9.8	27.2	104.36	7.43	0.15	0.017	19.1	8.9	28.3	107.66
R. + *Serratia* (*S.*)	7.49	0.16	0.019	25.4	13.4	33.8	120.16	7.46	0.16	0.019	25.6	12.9	32.4	122.66
R.+Bacillus megaterium(B.M)	7.48	0.15	0.017	22.1	15.8	32.4	112.50	7.47	0.15	0.018	22.1	15.6	32.0	116.43
R. + *Pseudomonas* (*Ps.*)	7.50	0.16	0.018	24.8	12.3	35.4	116.22	7.47	0.17	0.018	23.1	12.1	34.7	114.80
R. + *S.* + *B.M* + *Ps.*	7.46	0.17	0.021	27.2	16.0	37.2	127.80	7.48	0.18	0.020	28.2	15.8	38.1	130.14
	With enriched compost tea													
Control	7.38	0.39	0.022	16.6	10.8	40.2	72.14	7.39	0.40	0.021	17.5	11.1	41.3	54.80
Rhizobium (*R.*)	7.37	0.43	0.026	28.4	14.3	43.8	124.65	7.38	0.42	0.027	30.1	15.6	43.4	122.68
R. + *Serratia* (*S.*)	7.35	0.46	0.032	35.7	19.8	42.4	158.41	7.37	0.45	0.034	37.9	18.2	44.6	164.35
R.+Bacillus megaterium(B.M)	7.39	0.44	0.027	32.1	20.6	45.4	149.63	7.40	0.43	0.029	33.3	22.2	44.9	152.48
R. + *Pseudomonas* (*Ps.*)	7.40	0.42	0.030	33.3	17.7	46.6	136.20	7.40	0.41	0.031	34.4	17.0	47.1	138.40
R. + *S.* + *B.M* + *Ps.*	7.38	0.47	0.034	38.2	22.2	51.8	174.34	7.39	0.48	0.035	40.2	23.0	52.6	182.42

bacterial strains tended to achieve relatively higher values of total-N, available N,P and K, as well as enhanced the activity of dehydrogenase in the sandy soil, compared to the uninoculated treatment. However, there was a very slight effect in organic carbon% and pH value. More flourishing in chemical and biological properties of the sandy soil was attained due to the foliar application of the enriched compost tea.

The pH value of the sandy soil was very slightly affected by any of the tested bacterial strains, while diminution of the pH value was much pronounced with foliar application of the enriched compost tea. This trend was true in both seasons. Such results might be attributed to the enriched compost tea as a source of inorganic nutrients and beneficial organic compounds. These results are in agreement with those obtained by Hadas and Rosenberg (1992), Rao and Shaktawat (2002) & Laxminarayana and Patiram (2005).

Results of organic-C, total-N and available-N given in Table (6) revealed that addition of PGPR led to a relative increase in such chemical parameters as compared with absolute control. Moreover, PGPR, particularly mixture of the tested bacterial strains attained the highest values of O.C, total-N and available-N. In addition, application of the enriched compost tea to the same preceded treatments exhibited more advancement in the obtained values. The highest values of O.C (0.47 and 0.48%), total-N (0.034 and 0.035%) and total soluble-N (38.20 and 40.20 ppm) appeared in both experimental seasons, respectively, by using the compost tea with mixtures of rhizobacteria. It is merit to clear that the increases in soil carbon and nitrogen may be due to the enriched compost tea applied and/or their stimulating effect on atmospheric nitrogen fixation. Similar findings were obtained by Mekail (1998) and Badran *et al.* (2000) who concluded that the increases in soluble and total N in sandy soil may be related to the release of N from the supplied organic materials and biological fixation of atmospheric N and their reflection on soil fertility.

Concerning the available-P and K in the soil, data in Table (6) declared that addition of PGPR tended to increase available P and K in the soil, particularly with the combined inoculation treatment (*R.+S.+B.m.+Ps.*) as compared with other treatments. The obtained results again confirmed the superiority of using the compost tea particularly when accompanied with the mixture of rhizobacteria. The highest values of available-P were (22.20 and 23.00 ppm) and available-K were (51.8 and 52.6 ppm) in the first and second seasons, respectively. This result was mainly related to the ability of rhizobacteria (*Serratia*, *Bacillus* and *Pseudomonas*) to dissolve insoluble phosphate via formation of organic acids and chelating substances. Similar trend was obtained by Khanna *et al.* (1979), Bowen and Rovira (1999) and Laxminarayana and Patiram (2005). Moreover, the presence of organic materials can exhibit same trend for phosphate solubilization beside their vital role in enhancement of phosphate dissolvers, as well as increasing soil moisture retention and thus more availability of phosphorus and potassium. These results are closed to those reported by Trivedi *et al.* (1995) and Badran *et al.* (2000).

In respect of dehydrogenase activity (DHA) which concerns with the overall biological activity in soil, data in Table (6) showed that addition of PGPR resulted in great increases in DHA as compared with the absolute control. In absent of the compost tea, values of DHA ranged from 36.20 to 127.80 mg TPF/100 g soil in the first season and from 38.54 to 130.14 mg TPF/100 g soil in the second one, respectively. Addition of the compost tea led to a marked increase in DHA attaining figures which ranged from 72.14 to 174.34 mg TPF/100 g soil in the first season and from 54.80 to 182.42 mg TPF/100 g soil in the second season, respectively. In general, co-inoculation with mixtures of rhizobacteria combined with the compost tea gave higher values of DHA (174.34 and 182.42 mg TPF/100 g soil). Indeed, foliar application of the enriched compost tea has a promotive effect on biological activity in soil either for the added or native microorganisms. These findings are in accordance with Chander *et al.* (1997), Merrill and Mckeon (2001) and Abdel-Wahab *et al.* (2002).

As a conclusion, conjunctive use of the enriched compost tea and co-inoculation of chickpea with *Rhizobium* and mixtures of (*Serratia* sp., *Bacillus megaterium* and *Pseudomonas fluorescens*) resulted not only in highest and sustainable crop yield, but also enhanced the efficiency of added bacterial strains. Thus, the obtained results seemed that cultivation of sandy soil with legumes, which rely on biological nitrogen fixation is a good effective practice. In addition, when this practice is supported with effective rhizobacteria and mature organic matter, can encourage plant vigour, yield productivity and soil fertility, particularly under sustainable agricultural systems.

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تأثير شاى الكمبوست المخصب والرايزوبكتيريا على حالة التعقيد والنمو ومحصول الحمص فى الأراضى الرملية

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الملخص العربي

أجريت تجربتين حقليتين فى أرض رملية بمحطة البحوث الزراعية بالاسماعيلية خلال الموسمين الشتويين المتتالين ٢٠٠٤/٢٠٠٥ و ٢٠٠٥/٢٠٠٦ لدراسة تأثير الرش بشاى الكمبوست المخصب والتلقيح ببعض الرايزوبكتيريا (السراتيا ، الباسيلس ميجاتيريم و السيدوموناس فلورسينس) على حالة التعقيد والنمو والمحصول وبعض مكونات المحصول لنباتات الحمص الملقحة ببكتيريا الرايزوبيا تحت نظام الرى بالتنقيط. كذلك تم دراسة تأثير هذه المعاملات على بعض الصفات الكيماوية والبيولوجية للتربة الرملية بعد حصاد نباتات الحمص. وكانت أهم النتائج المتحصل عليها ما يلى:

* أن التلقيح المشترك بالرايزوبيا مع أى من البكتيريا المشجعة للنمو المختبرة قد أدى الى زيادة معنوية لجميع قياسات النمو الخضرية خلال موسمى الزراعة تحت الدراسة مقارنة بالمعاملة الغير ملقحة (الكنترول) أو الملقحة بالرايزوبيا فقط. وأيضاً أشارت النتائج الى أن جميع الصفات الخضرية تحت الدراسة استجابت معنوياً للرش بشاى الكمبوست المخصب.
* أدت الإضافة المشتركة لشاى الكمبوست المخصب مع التلقيح المشترك لخليط البكتيريا بالاضافة الى الرايزوبيا الى الحصول على أعلى قيم لجميع الصفات الخضرية المدروسة (عدد العقد الجذرية ووزنها الجاف ، الوزن الجاف للمجموع الخضرى ، محتوى المجموع الخضرى من النيتروجين والفوسفور) وذلك خلال موسمى الزراعة تحت الدراسة.
* أخذت نتائج محصول الحمص (بذور وقش) وبعض مكوناته (وزن الـ١٠٠ بذرة و النسبة المئوية للبروتين الخام بالبذور) نفس الاتجاه وهو أفضلية الإضافة المشتركة لشاى الكمبوست وخليط الرايزوبكتيريا.

* أكدت البيانات الخاصة ببعض التغيرات الحادثة فى الصفات الكيماوية والبيولوجية للتربة الرملية بعد الحصاد مرة أخرى أفضلية الإضافة المشتركة لكل من شاى الكمبوست المخصب وخليط الرايزوبكتيريا حيث ظهرت أعلى قيم للكربون العضوى والنيتروجين الكلى وكذلك الكمية الميسرة من النيتروجين و الفوسفور والبوتاسيوم مع تطور وزيادة ملحوظة لنشاط أنزيم الديهيدروجينيز بالأرض الرملية.

ويتضح من النتائج السابقة أن الإضافة المشتركة لشاى الكمبوست المخصب مع خليط البكتيريا تحت الدراسة لا تؤدى فقط الى تحسين إنتاجية محصول الحمص ولكنها تحسن أيضاً من كفاءة سلالات البكتيريا المضافة وحالة خصوبة الأراضى الرملية.