Improving Wheat Growth and Yield through Application of Compost and Plant Growth Promoting *Rhizobacteria* under Deficit Irrigation in a Sandy Soil

Ahmed A. El-Kharbotly and Osama M. Ghanem
Soil and Water Department, Faculty of Agriculture, Suez Canal University, 41522 Ismailia, Egypt

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Abstract: A greenhouse pot experiment was conducted at the Experimental Farm of the Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. The effectiveness of a mixture of two plant growth promoting rhizobacteria, PGPR, (i.e. *B. subtilis* EF1 and *P. fluorescens* KW1) and four compost application rates (0.00, 0.50, 0.75 and 1.0% W/W) under three irrigation water quantities (1.0, 0.8 and 0.6 from crop evapotranspiration, ETc) was studied in a sandy soil cultivated with wheat plant (*Triticum aestivum* L.). The results showed that, the shoot of 90-day old plants and straw and grain yields of 120-day old plants wheat were increased with increasing the added amount of both irrigation water and compost. The highest grain and straw yields were obtained under the treatment 1.0 ETc + 1.0% compost with the biofertilizer where the increases over the corresponding control were 87.1 and 34.4%, respectively. No significant difference was observed in water productivity between 1.0 and 0.8 ETc. Relative water content and electrolyte leakage of the 90-day old plants were found to be enhanced by raising the amounts of the studied factors. The current study suggested that, 20% of irrigation water used for wheat might be saved by applying 1.0% compost and the biofertilizer without any significant reduction in wheat yield.

Keywords: PGPR, wheat, soil enzymes, deficit irrigation and water productivity

INTRODUCTION

Present day crop production is highly dependent on intensive use of mineral fertilizers and irrigation water. The ultimate objective of any fertilization and irrigation treatments for any crop is to enhance the overall growth and consequently increasing yield production and improving water use efficiency by reducing applied irrigation water (Noreldin *et al*., 2015). But the extensive use of mineral fertilizers in developing countries in the recent past let to exacerbated environmental degradation, including reduction in water quality, eutrophication of marine ecosystems, development of photochemical smog and increasing concentration of the greenhouse gas nitrous oxide (Adesemoye *et al*., 2009). Also, intensive use of irrigation water caused lowering soil organic carbon content, increasing soil salinity, lowering soil quality and decreasing water and nutrient use efficiencies. Additionally, the production of mineral fertilizers consumes fossil fuel, which is unsustainable. Moreover, Egypt has been suffering from water scarcity in recent years. Abdelhaleem and Helal (2015) reported that, the Grand Ethiopian Renaissance Dam could significantly affect Egyptian water supply from the River Nile. They predicted losses of agricultural soils in the Upper Egypt between 12.7 to 46.24%. So, reducing irrigation water amounts and improving water productivity is imperative. However, the reduction of mineral fertilizers and irrigation water quantities cause drastically decreasing food production. At the same time, the harmful environmental side-effects of agrochemicals cannot go unabated. Hence, there is an urgent need for integrated water-nutrient management that promotes low agrochemical input but improves nutrient-use efficiency by combining natural and manmade sources in an efficient and environmentally prudent manner (Adesemoye and Egamberdieva, 2013). Plant growth promoting rhizobacteria (PGPR) are one of the main alternatives for crop production, those were thought to improve plant uptake of nutrients and thereby increase the use efficiency of applied mineral fertilizers (Parray *et al*., 2016).

The main objective of this research was introducing an integrated water-nutrient management strategy which based on reducing irrigation water quantity and the negative effect of agrochemicals by using combinations of compost and PGPR.

MATERIALS AND METHODS

Isolation, identification and characterization of PGPR

Two rhizobacterial strains (i.e. *B. subtilis* EF1 and *P. fluorescens* KW1) were obtained after Ghanem (2017) who assessed their phenotypic characters according to the scheme of identification of Mac Faddin (1976), Bergey's Manual of Systematic Bacteriology (volume 1, 2) (Krieg and Holt, 1984; Sneath *et al*., 1986) and Bergey's Manual of Determinative Bacteriology (Holt *et al*., 1994). Identification of the two bacterial strains was confirmed by 16S rRNA gene partial sequences by using the bacterial-specific primers, 27F (5' AGAGTTTGATCMTGGCTCAG 3') and 1492R (5' TACGGYTACCTTGTTACGACTT 3') (Ventosa *et al.,* 2004). PCR product was sequenced using commercial service of MACROGEN Seoul, Korea (http://macrogen.com/eng/). The obtained 16S rRNA sequences were analyzed using the BLASTn software in the GenBank at NCBI (http:// www.ncbi.n1m.nih.gov/blast). Ghanem (2017) also assessed the production of auxins like indole acetic acid (IAA) by the rhizobacterial strains using the qualitative and quantitative methods developed by Bric *et al.* (1991) and Sarwar *et al*. (1992), respectively. Insoluble inorganic phosphate solubilization potential by rhizobacterial strains was assayed according to Nautiyal (1999). Siderophore production by rhizobacterial isolates was detected as described by Schwyn and Neilands (1987) (Table 1).

*Corresponding author e-mail: osama_ramadan@agr.suez.edu.eg

Table (1): Some plant growth promoting traits of the plant growth promoting rhizobacteria (PGPR) (after Ghanem, 2017)

PGPR strains	IAA production, mg l^{-1}			P-solubilization			Siderophore† Production
	Without L-TRP	With L-TRP	On solid† medium	pH	mg l^{-1}	On solid† medium	
***P. fluorescens* KW_1**	5.56	12.8	+	5.76	101	+	+
***B. subtilis* EF1**	4.07	10.4	+	5.49	111	+	+

Abbreviations: IAA: Indole acetic acid, L-TRP: L-tryptophan, +: indicates that the strains possess the plant growth properties, pH: pH of the cultures after 10-day incubation period, †: qualitative methods

Preparation of inoculants and seed inoculation

PGPR strains were cultured in 100 ml flasks containing 50 ml of sterilized tryptic soy broth (TSB) medium (Starr *et al.,* 1981). Inoculant of each isolate was prepared by taking loopful from its stock culture and incubated at 28 °C for 72 h. At this time, the viable cell count ranged from 10^7 to 10^8 CFU ml^{-1} in the cell suspensions. For inoculation, 20 g of wheat seeds (*Triticum aestivum* cv. Misr 1) were surface sterilized by ethanol 95% for 5 min and then washed thoroughly with sterilized water. The sterilized seeds were soaked in 100 ml of cell suspension of the two strains mixture for 1h before cultivation. For uninoculated treatments, sterilized seeds were soaked in 100 ml of sterilized TSB medium.

Greenhouse pot experiment

A pot experiment was conducted in a greenhouse at the Experimental Farm of the Faculty of Agriculture, Suez Canal University, Ismailia, Egypt from December 4, 2017 to April 2, 2018. The recorded climatic parameters for the experimental site indicate that it was a warm winter (Table 2). Generally, the climate of Ismailia Gov. is classified as hot dessert (BWh) according to Köppen-Geiger system (Peel *et al.,* 2007). The effectiveness of a mixture of two rhizobacterial strains (*i.e. B. subtilis* EF1 and *P. fluorescens* KW1) was evaluated with four levels of compost as an organic matter (0.00, 0.50, 0.75 and 1.00% W/W) under three irrigation water quantities (1.0, 0.8 and 0.6 ETc). The soil samples and compost were air-dried, crushed, sieved through a 2 mm sieve and analyzed for some selected properties according to Gee and Bauder (1986) and Sparks (1996) as shown in Table (3). The soil used is classified as *Typic Torripesamments* (Soil Survey Staff, 2014). The Soil samples were uniformly packed in plastic pots each of 30 cm height and 24.5 cm mean diameter at a rate of 15.0 kg pot^{-1} (ρ_b= 1.63 Mg m^{-3}). A drainage hole of about 1 cm in diameter was made in the bottom of each pot and covered with filter paper. Compost was mixed with the upper 10 Kg of the soil in each pot according to the treatments. The experiment was laid out in a randomized complete block (factorial) with six replications. Eight wheat seeds were sown in each pot and irrigated to almost soil field capacity with Ismailia canal water (0.40 dSm^{-1}). Ordinary superphosphate (15.5% P_2O_5) was mixed with the soil in each pot before sowing at a rate of 31 mg P_2O_5 Kg^{-1} soil (almost equivalent to 31 Kg P_2O_5 fed^{-1}). Potassium sulfate (50% K_2O) was applied to all pots at a rate of 50 mg K_2O Kg^{-1} soil (almost equivalent to 50 Kg K_2O fed^{-1}) at two equal doses after 45 and 70 days from sowing. Ammonium sulfate (20.5% N) was applied to all pots at a rate of 100 mg N Kg^{-1} soil (almost equivalent to 100 Kg N fed^{-1}) at three doses (20, 30 and 50% of the total amounts) after 21, 45 and 70 days from sowing, respectively. The seedlings were thinned to five uniform plants pot^{-1} after two weeks from cultivation.

Irrigation scheduling

Penman-Monteith equation (Allen *et al*., 1998) was used to calculate local potential evapotranspiration ETo. The climatic data were provided by CLIMWAT (ver. 2.0) software and integrated in CROPWAT (ver. 8.0) to calculate crop water requirements ETc for wheat plants grown in Ismailia, Egypt (Clarke *et al*., 1998; Munoz and Grieser, 2006).Three irrigation water quantities were used. Full irrigation (1.0 ETc) and two levels of deficit irrigation namely: 80 and 60% of full irrigation donated as 0.8 and 0.6 ETc, respectively.

The quantities of water per pot for each irrigation were calculated using this simple formula:

$$Water\ quantity\ (L\ pot^{-1}) = \frac{\theta_{fc} - \theta_{in}}{100} \times Soil\ depth \times Area \times CF$$

Where θ_{fc} and θ_{in} = field capacity and the initial (before irrigation) volumetric soil moisture contents (%), respectively. θ_{in} values were estimated from the loss of pot weight, and CF is a conversion factor. The time periods between each two successive irrigations were monitored with caution not to exceeds the maximum allowable soil moisture depletion of wheat plants of 0.55 from field capacity (Allen *et al*., 1998).

Table (2): Some climatic parameters for the experimental site during the growing season

Month	DEC 2017	JAN 2018	FEB 2018	MAR 2018	APR 2018
Minimum Temperature °C	12.25	9.30	11.28	12.93	14.90
Maximum Temperature °C	21.49	18.94	22.49	27.50	28.86
Relative Humidity (%)	64.92	68.27	59.46	47.75	50.70
Precipitation (mm day^{-1})	4.81	1.05	0.23	0.04	0.49
Wind Speed ($m.s^{-1}$)	2.46	3.28	2.28	2.68	2.76
Surface Pressure (kPa)	101.4	101.4	101	100.8	100.7
Radiation ($MJ.m^{-2}.day^{-1}$)	11.19	12.72	16.11	20.94	24.61

Table (3): Properties of the soil and compost used in the current research

Properties	Soil	Compost
Particle size distribution (%)		
Sand	92.6	-
Silt	2.55	-
Clay	4.85	-
Textural class	Sand	-
Bulk density (Mg m^{-3})	1.63	-
Field Capacity (%)	14.8	-
pH	8.16†	7.33‡
EC_e (dS m^{-1}) §	1.72	10.1
Soluble cations (meq l^{-1}) §		
Ca^{2+}	7.92	24.6
Mg^{2+}	5.43	10.2
Na^{+}	3.07	30.1
K^{+}	0.78	36.1
Soluble anions (meq l^{-1}) §		
CO_3^{2-}	0.00	0.00
HCO_3^{-}	4.84	30.3
Cl^{-}	6.48	57.4
SO_4^{2-}	5.88	13.3
Organic C (g kg^{-1})	1.21	191
Total N (g kg^{-1})	0.131	17.6
Available N (mg kg^{-1})	5.61	183
Available P (mg Kg^{-1})	8.90	156

† In soil-water suspension (1:2.5)
‡ In compost-water suspension (1:5)
§ In compost and soil saturated paste extracts

Samples collection and determinations

Plant samples were taken after 90 days (anthesis stage) and 120 days (ripeness stage) from sowing, dried at 65°C and the dry weights were recorded. After 90 days from cultivation and immediately before irrigation, one flag leaf was cut from each pot for leaf relative water content (RWC) and membrane permeability determination. RWC was determined by the method described by (Sade *et al*., 2015). Membrane permeability was determined using 1 cm leaf segments as sated by Lutts *et al*. (1996), and its results were expressed as Electrolyte Leakage EL percent. Soil samples were collected after 90 and 120 days and analyzed for EC, pH, available phosphorus according to Gee and Bauder (1986) and Sparks (1996) and phosphomonoesterase activities was assayed according to Tabatabai (1994).

Water productivity for each treatment was calculated after Van Halsema and Vincent (2012) using the following equation:

$$WP = \frac{grain\ yield\ (g\ pot^{-1})}{applied\ irrigation\ water\ (l\ pot^{-1})}$$

Where: WP = water productivity in g grains L^{-1}

All obtained data were subjected to analysis of variance (ANOVA) using Costat statistical software (1990), Version 6.311 (Cohort Program). The least significant difference test (LSD) was applied to make comparison between the means ($P<0.05$).

RESULTS AND DISCUSSION

Soil properties

Soil pH and available P

Respecting the main effects of irrigation water quantities and compost application rates, results indicate that, the soil pH values were significantly reduced by increasing the two factors levels at both growth stages. As for PGPR inoculant, results also reveal that, the values of pH in all soil samples were found to be significantly reduced due to seed inoculation with the mixture of the two PGPR strains used when compared to uninoculated control (Table 4).

Concerning the effect of the interaction between irrigation water quantities, compost application rates and the PGPR inoculant on soil pH values, Table (5) indicates that the pH values reached their lowest of 7.51 and 7.52 after 90 days and 7.57 and 7.59 after 120 days from wheat sowing, under the treatments 1.00 ETc + 1.00% compost + PGPR and 1.00 ETc + 0.75% compost + PGPR respectively. Decreasing values of pH in soil cultivated with wheat due to the inoculation with the PGPR strains was reported several times (Vessey, 2003; Altomare and Tringovska, 2011; Ghanem *et al*., 2013; Ghanem, 2017). These significant decreases in soil pH might be attributed to (i) the ability of the PGPR strains to produce organic acids (Perez-Montano *et al*., 2014) (ii) nitrification of the NH_4^+-N, and / or (iii) possible increase in partial pressure of CO_2 of the soil atmosphere due to the increased activity of microorganisms (Ghanem, 2017).

Respecting the main effects of irrigation water quantities, compost application rates and the PGPR inoculant on available P concentrations in the soil samples after 90 and 120 days from wheat sowing, the soil available P increased significantly due to raising any of the abovementioned factor levels at both growth stages when compared to the control (Table 4).

Regarding the impact of the interaction between the abovementioned factors on the P availability in the soil, Table (5) shows that the highest levels of available P in the soil at 90 and 130 days were observed under the treatments 1.00 ETc + 1.00% compost + PGPR and 1.00 ETc+0.75% compost + PGPR. The significant increases in the availability of P in the soil due to the interaction between irrigation water quantities, compost application rates and PGPR could be partially interpreted by the ability of the used microorganisms to solubilize inorganic phosphate (Table 1), and/or the crucial role of the rhizobacteria in increasing the activity of soil phosphatases and production of organic acids which led to significant reductions in soil pH values.

Enzyme activities in the soil

Soil enzymes play a crucial role in organic matter decomposition and can be used as index of changes occurring in the microbial functioning in a soil. Among extracellular enzymes, phosphatases are more abundant in the rhizosphere. Soil phosphatases include phosphomonoesterases which involve acid and alkaline phosphatases.

Table (4): The main effects of irrigation water quantities, compost application rates and the PGPR inoculant on pH, Available P (mg kg^{-1}) and alkaline and acid phosphatase activities (µg ρNP g^{-1} soil h^{-1}) in the soil after 90 and 120 days from wheat sowing

Treatments	pH†		Available P (mg kg^{-1})		Alkaline phosphatase (µg ρNP g^{-1} soil h^{-1})		Acid phosphatase (µg ρNP g^{-1} soil h^{-1})	
	90 days	120 days	90 days	120 days	90 days	120 days	90 days	120 days
ETc								
1.00	7.68	7.74	21.99	19.10	147	114	121	92.0
0.80	7.81	7.87	19.58	16.70	130	97.1	104	75.3
0.60	7.99	8.05	15.14	12.25	97.1	64.1	71.2	43.0
L.S.D.$_{0.05}$	**0.040**	**0.038**	**0.219**	**0.235**	**6.82**	**5.54**	**6.79**	**5.66**
Compost rates %								
0.00	7.93	7.99	16.58	13.68	106	74.2	81.5	53.0
0.50	7.87	7.93	18.52	15.64	121	88.0	95.1	66.1
0.75	7.78	7.84	19.92	17.04	133	101	108	78.9
1.00	7.75	7.81	20.59	17.71	138	104	111	82.4
L.S.D.$_{0.05}$	**0.020**	**0.015**	**0.351**	**0.301**	**3.47**	**3.25**	**3.20**	**3.31**
PGPR inoculation								
Noninoculated	7.88	7.94	17.99	15.11	117	83.6	90.8	62.0
EF1 + KW1	7.78	7.84	19.82	16.93	132	100	107	78.3
L.S.D.$_{0.05}$	**0.017**	**0.017**	**0.215**	**0.140**	**2.44**	**2.15**	**2.34**	**3.81**

Table (5): Effect of the interaction between irrigation water quantities, compost application rates and the PGPR inoculant on pH, Available P (mg kg-1) and alkaline and acid phosphatase activities (µg ρNP g-1 soil h-1) in the soil after 90 and 120 days from wheat sowing

Treatments			pH†		Available P (mg kg^{-1})		Alkaline phosphatase (µg ρNP g^{-1} soil h^{-1})		Acid phosphatase (µg ρNP g^{-1} soil h^{-1})	
Water requirement	Compost level (%W/W)	Biofertilizer	90 days	120 days	90 days	120 days	90 days	120 days	90 days	120 days
1.0 ETc	**0.00**	**Noninoculated**	7.87	7.93	18.8	15.9	121	88.1	95.9	65.9
		EF1 + KW1	7.77	7.84	20.1	17.1	135	108	116	85.7
	0.50	**Noninoculated**	7.77	7.83	20.8	17.9	137	101	108	77.6
		EF1 + KW1	7.67	7.73	22.9	20.0	148	116	123	94.1
	0.75	**Noninoculated**	7.69	7.76	22.3	19.4	144	110	118	87.6
		EF1 + KW1	7.52	7.59	23.8	21.0	165	133	139	112
	1.00	**Noninoculated**	7.66	7.72	23.2	20.3	152	119	126	97.8
		EF1 + KW1	7.51	7.57	24.1	21.2	171	138	145	116
0.8 ETc	**0.00**	**Noninoculated**	7.96	8.01	15.5	12.6	104	71.7	78.8	49.6
		EF1 + KW1	7.85	7.90	18.3	15.5	120	89.6	96.7	68.0
	0.50	**Noninoculated**	7.86	7.92	18.7	15.8	120	85.9	93.0	63.5
		EF1 + KW1	7.82	7.87	20.1	17.2	135	103	110	81.3
	0.75	**Noninoculated**	7.86	7.92	19.1	16.2	130	96.9	104	74.9
		EF1 + KW1	7.69	7.75	21.9	19.0	143	112	119	90.8
	1.00	**Noninoculated**	7.75	7.81	20.7	17.8	139	104	111	81.9
		EF1 + KW1	7.70	7.76	22.3	19.5	147	114	121	92.3
0.6 ETc	**0.00**	**Noninoculated**	8.12	8.17	12.8	9.90	73.4	40.4	47.5	22.1
		EF1 + KW1	8.04	8.08	13.9	11.1	80.1	47.1	54.2	26.3
	0.50	**Noninoculated**	8.08	8.14	13.8	11.0	86.2	53.3	60.3	32.7
		EF1 + KW1	8.04	8.10	14.8	11.9	103	69.7	76.8	47.6
	0.75	**Noninoculated**	7.90	7.96	14.6	11.7	101	67.7	74.8	45.9
		EF1 + KW1	7.89	7.95	17.9	15.0	117	84.0	91.1	62.2
	1.00	**Noninoculated**	8.02	8.08	15.6	12.7	98.5	65.4	72.8	43.6
		EF1 + KW1	7.88	7.92	17.7	14.8	118	85.0	92.1	63.3
LSD $_{0.05}$			0.056	0.052	0.748	0.576	8.75	8.00	8.85	9.86

† In soil-water suspension (1:2.5)

Tables (4 and 5) present the fluctuations of alkaline and acid phosphatase activities in the soil at the two growth stages. It indicates that overall activity of acid and alkaline phosphatases reached their highest levels at 90 days and then decreased up at 120 days.

This result was in concomitant with Kunze *et al*. (2011) and Akmal *et al*. (2012) who reported that, soil enzymes reached their maximum activities at the anthesis stage and decreased up at crop ripening time. This observation could be attributed to numerous soil microorganisms which are considered the main source of most soil enzymes and were reported to behave the same trend (Gianfreda, 2015).

Tables (4 and 5) also indicate that the alkaline phosphatase was always more active than acid phosphatase in all soil samples. This could be attributed to the alkaline soil reaction (Table 3) which supports alkaline phosphatase predominance. In this respect, Tabatabai (1994) and Nannipieri *et al*. (2011) reported that soils with acidic nature would be expected to contain primarily acid phosphatase activity while in neutral to alkaline ones, both acid and alkaline phosphatases are active with predominance of the latter.

Concerning the main effects of irrigation water quantities, compost application rates and biofertilizer on the phosphomonoesterase activities in the soil, Table (4) shows that the activities of both acid and alkaline phosphatases were found to be significantly enhanced due to raising of irrigation water and compost levels and inoculation with the biofertilizer relative to the control.

Regarding the interaction between the three studied factors on the activity of the abovementioned enzymes in the soil, Table (5) shows that acid and alkaline phosphatases reached their highest levels under the treatment 1.0 ETc + 1.00% compost + biofertilizer which was not differed significantly with the treatment 1.0 ETc + 0.75% compost + biofertilizer. Table (5) also indicates that no significant difference was observed between 1.00 and 0.75 of compost application rates when the latter was combined with the biofertilizer under the same irrigation level. Similarly, acid and alkaline phosphatase activities were not significantly differed under 1.0 or 0.8 ETc when the latter irrigation level was combined with the biofertilizer under the same compost application rate. Thus, the use of the microbial inoculant with only 0.75% of compost and 0.8 ETc was as effective as the 1.00% of compost and 1.0 ETc without microbial inoculation.

Wheat growth and yield

Wheat response to the irrigation water quantities (1.0, 0.8, 0.6 ETc), compost application rates, (0.00, 0.50, 0.75, 1.00% W/W) and the PGPR inoculant was evaluated by measuring shoot dry weights of 90-day old plants and grain and straw yields of 120-day old plants. Concerning the main effects of irrigation water quantities, compost application rates and biofertilizer application on wheat yield parameters Table (6) reveals that, the higher the irrigation water level, the greater was the shoot, grain and straw yield production. Similarly, the raising of compost application rate resulted in a significant increase in all measured parameters of wheat response. Results presented in Table (6) also show that, all inoculated wheat plants gave significant increases in shoot dry weights of 90-day old plants and grain and straw yields of 120-day old plants when compared with the noninoculated plants. These results agreed with those reported by Adesemoye *et al*. (2009) and Rosas *et al*. (2009).

Regarding the effect of interaction between the three studied factors on wheat growth and yield, Table (7) shows that shoot dry weight and grain and straw yields reached their maxima under the treatment 1.0 ETc with 1.00% of compost and the PGPR inoculant. The results in Table (7) also show that under 1.0 ETc, shoot dry weight of 90-day old plants and grain and biological yields of 120-day old plants were significantly higher under the treatment 0.75% compost + PGPR than those under 1.00 of compost without inoculation indicating that the applied quantity of compost could be reduced by 25% in the presence of microbes.

These results were in concomitant with those reported by Ghanem (2017) who recommended these PGPR strains as promising inoculants for wheat grown in a sandy soil after proving them to possess several mechanisms for promoting wheat growth and yield (Abd El-Azeem *et al*., 2007; Yazdani *et al*., 2009; Ghanem *et al.,* 2013). At the same context, Table (7) shows that at 0.8 ETc, application of compost at all abovementioned level with the biofertilizer or compost at the rates 0.75 and 1.0% without the biofertilizer caused significant increases in shoot dry weight of 90-day old plants and grain and biological yields of 120-day old plants compared to 1.0 ETc without any additions. These results prove the importance of organic matter and biofertilizer in sandy soils and irrigation water quantity required for wheat in the sandy soil used could be saved by 20% through application of abovementioned levels of compost and PGPR. In this respect, Wang *et al*. (2017) reported that using organic matter could increase water use efficiency.

Some plant-water relationship parameters

Leaf relative water content

Plant-water status is highly reflected by leaves RWC, because it provides a good indicator of stress and water deficit under unfavorable conditions (Torres *et al*., 2019). Wanjiku *et al*. (2019) concluded that, RWC could be used effectively to manage water stress and monitor biological water activity in plant tissue. Respecting the main effect of irrigation water quantities on leaf RWC Table (8) reveals that, three irrigation quantities were significant differed, as 1.0 ETc gave the highest RWC followed by 0.8 ETc and 0.6 ETc. The obtained values were 75.99, 70.92 and 64.09% for the three water quantities, respectively. Regarding the levels of compost application, it also provides significant effects on RWC. The obtained values were 73.46, 71.57, 69.52 and 66.7% for 1.0, 0.75, 0.50 and 0.00% compost applications, respectively. PGPR inoculation also gave significant difference compared to the noninoculated treatments. The RWC values were 71.02 and 69.64% for the inoculated and non-inoculated treatments, respectively (Table 8).

Table (9) showed the effect of the interactions between irrigation water quantities, organic manure application rates and inoculation with PGPR. The highest value of RWC of 81.5% was recorded for the treatment (1.0ETc - 1.0% compost - biofertilizer), while the lowest value of 55.1% was recorded for (0.6ETc – 0.0% compost - Without biofertilizer) treatment.

Table (6): The main effects of irrigation water quantities, compost application rates and the PGPR inoculant on some growth and yield parameters (g pot^{-1}) of wheat plants sampled at 90 and 120 days from wheat sowing

Treatments	Shoot yield at 90 day (g pot^{-1})	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})	Grain: straw ratio	Biological yield (g pot^{-1})
ETc					
1.00	15.81	15.11	18.01	0.831	33.12
0.80	13.55	12.11	15.69	0.768	27.79
0.60	10.83	8.09	11.43	0.708	19.52
L.S.D.$_{0.05}$	**0.243**	**0.288**	**0.421**	**0.035**	**0.311**
Compost rates %					
0.00	11.49	9.21	12.99	0.708	22.20
0.50	12.82	11.11	14.63	0.749	25.73
0.75	14.17	12.94	15.59	0.816	28.52
1.00	15.10	13.82	16.97	0.802	30.79
L.S.D.$_{0.05}$	**0.340**	**0.198**	**0.175**	**0.019**	**0.249**
PGPR inoculation					
Noninoculated	12.68	10.89	14.42	0.743	25.30
EF1 + KW1	14.11	12.66	15.66	0.795	28.32
L.S.D.$_{0.05}$	**0.142**	**0.175**	**0.134**	**0.016**	**0.172**

Table (7): Effect of the interaction between irrigation water quantities, compost application rates and the PGPR inoculant on some growth and yield parameters (g pot^{-1}) of wheat plants sampled at 90 and 120 days from wheat sowing

Treatments			Shoot yield at 90 day (g pot^{-1})	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})	Grain: straw ratio	Biological yield (g pot^{-1})
Water requirement	Compost level (%W/W)	Biofertilizer					
1.0 ETc	**0.00**	**noninoculated**	12.1	10.1	15.1	0.673	25.2
		EF1 + KW1	13.1	12.5	16.4	0.763	28.9
	0.50	**noninoculated**	13.7	12.8	17.1	0.751	29.9
		EF1 + KW1	16.3	15.3	18.0	0.853	33.3
	0.75	**noninoculated**	16.2	15.1	17.8	0.851	32.9
		EF1 + KW1	18.8	18.7	19.9	0.942	38.6
	1.00	**noninoculated**	17.0	17.3	19.5	0.887	36.9
		EF1 + KW1	19.3	18.9	20.3	0.929	39.2
0.8 ETc	**0.00**	**noninoculated**	11.4	8.70	12.8	0.680	21.5
		EF1 + KW1	12.2	10.2	14.4	0.713	24.6
	0.50	**noninoculated**	12.5	10.7	14.4	0.744	25.1
		EF1 + KW1	13.3	12.4	15.6	0.794	27.9
	0.75	**noninoculated**	13.1	12.5	15.5	0.804	28.0
		EF1 + KW1	14.4	14.4	17.0	0.844	31.4
	1.00	**noninoculated**	15.0	13.2	17.5	0.751	30.7
		EF1 + KW1	16.5	14.9	18.3	0.812	33.1
0.6 ETc	**0.00**	**noninoculated**	9.72	6.08	8.87	0.686	15.0
		EF1 + KW1	10.4	7.59	10.4	0.731	18.0
	0.50	**noninoculated**	10.0	7.01	10.9	0.640	18.0
		EF1 + KW1	11.2	8.40	11.8	0.713	20.2
	0.75	**noninoculated**	10.7	8.29	10.9	0.763	19.2
		EF1 + KW1	11.8	8.64	12.4	0.695	21.1
	1.00	**noninoculated**	10.7	8.70	12.7	0.687	21.4
		EF1 + KW1	12.1	10.0	13.5	0.745	23.5
LSD $_{0.05}$			0.625	0.544	0.487	0.052	0.589

Table (8): The main effects of irrigation water quantities, compost application rates and the PGPR inoculant on Leaf RWC and Leaf EL (%) in 90-day-old plants and Relative yield (%) and Water Productivity (g grains. L^{-1}) after wheat harvest

Treatments	Leaf RWC at 90 day (%)	Leaf EL at 90 day (%)	(Ya/Ym) % Relative yield	Water Productivity (g grains L^{-1})
ETc				
1.00	75.99	24.35	0.872	1.104
0.80	70.92	32.06	0.699	1.097
0.60	64.09	53.40	0.466	0.969
L.S.D.$_{0.05}$	**1.185**	**2.505**	**0.017**	**0.025**
Compost rates %				
0.00	66.77	45.25	0.532	0.835
0.50	69.52	38.40	0.640	0.999
0.75	71.57	33.29	0.747	1.156
1.00	73.46	29.48	0.798	1.238
L.S.D.$_{0.05}$	**1.027**	**0.993**	**0.012**	**0.021**
PGPR inoculation				
Noninoculated	69.64	35.11	0.628	0.978
EF1 + KW1	71.02	38.10	0.731	1.136
L.S.D.$_{0.05}$	**0.631**	**0.802**	**0.010**	**0.016**

Table (9): Effect of the interaction between irrigation water quantities, compost application rates and the PGPR inoculant on leaf RWC and leaf EL (%) in 90-day-old plants and relative yield (%) and water productivity (g grains L^{-1}) after wheat harvest

Treatments			Leaf RWC at 90 day (%)	Leaf EL at 90 day (%)	(Ya/Ym) % Relative yield	Water Productivity (g grains L^{-1})
Water requirement	**Compost level (%W/W)**	**Biofertilizer**				
1.0 ETc	**0.00**	**noninoculated**	73.1	28.0	58.5	0.741
		EF1 + KW1	73.4	27.7	72.2	0.915
	0.50	**noninoculated**	73.6	27.2	74.1	0.938
		EF1 + KW1	74.5	26.1	88.4	1.120
	0.75	**noninoculated**	76.2	23.5	87.4	1.107
		EF1 + KW1	77.4	22.9	108.1	1.369
	1.00	**noninoculated**	78.1	21.5	100.0	1.266
		EF1 + KW1	81.5	17.9	108.9	1.379
0.8 ETc	**0.0**	**noninoculated**	69.0	35.9	50.2	0.788
		EF1 + KW1	69.6	35.2	59.1	0.928
	0.50	**noninoculated**	69.9	34.3	61.8	0.970
		EF1 + KW1	70.8	31.4	71.4	1.121
	0.75	**noninoculated**	71.3	30.7	71.9	1.130
		EF1 + KW1	71.9	30.0	82.8	1.301
	1.00	**noninoculated**	72.1	29.6	75.9	1.192
		EF1 + KW1	72.8	29.3	85.7	1.346
0.6 ETc	**0.00**	**noninoculated**	55.1	80.1	35.1	0.729
		EF1 + KW1	60.5	64.6	43.8	0.909
	0.50	**noninoculated**	63.5	57.3	40.4	0.839
		EF1 + KW1	64.8	53.9	48.4	1.006
	0.75	**noninoculated**	65.9	48.1	47.8	0.993
		EF1 + KW1	66.6	44.5	49.9	1.035
	1.00	**noninoculated**	67.7	40.8	50.2	1.042
		EF1 + KW1	68.5	37.8	57.9	1.201
LSD $_{0.05}$			2.27	2.87	3.15	0.052

- RWC: leaf relative water content
- EL: Electrolyte leakage

The effects of organic manure application on corn leaves RWC were reported by Khadem *et al*. (2010) who found that, the increase in leaves RWC was associated with a decrease in drought intensity that improved by manure application. Torres *et al*. (2019) proposed an irrigation decision support system based on leaf RWC rapidly measured by infrared spectroscopy.

Cell membrane permeability

The membrane permeability results were expressed as electrolyte leakage percent (EL %). Deficit irrigation caused very clear changes in cell membrane structure. Water stress changes lipid in cell membrane from liquid-crystalline phase to gel phase, which leads to increase in cell membrane permeability (Leprince *et al*., 2000). Considering the main effect of irrigation water quantities on EL %, significant differences were found between the three irrigation levels (Table 8). The obtained values for EL% were 53.4, 32.06 and 24.35% for the treatments 0.6, 0.8 and 1.0ETc, respectively. The percent of compost applications also resulted in significant differences in EL%. Its values were 45.25, 38.43, 3.30 and 29.48% for 0.0, 0.5, 0.75 and 1.0% compost application rates, respectively. Inoculation with PGPR gave EL% of 38.10 and 35.11% for the noninoculated and inoculated treatments, respectively. These results revealed that, membrane stability was improved by both manuring and PGPR inoculation. Similar results were found by Khadem *et al*. (2010).

The effect of the interaction between irrigation water quantities, Compost application rats and inoculation with PGPR on wheat leaves EL% at 90 days from cultivation are showed in Table 9. The highest cell membrane injury was reported under the treatment (0.6 ETc – 0.0% Compost – Without biofertilizer), where its EL value was 80.1%, while the lowest cell membrane injury was found under the treatment (1.0ETc - 1.0% Compost – Biofertilizer) with EL value of 17.9%.

Relative Yield (RY)

Relative yield was used to quantify the effect of each treatment in the obtained grain yield (Steduto *et al*., 2012). It was calculated by:

$$Relative\ Yield = \frac{Y_a}{Y_m} \times 100$$

Where: Y_a= actual grain yield for the selected treatment, in gram per pot,
Y_m= maximum grain yield, in gram per pot.

The value of Y_m here was taken for wheat production under common agricultural practices which was (1.0 ETc - 1.0% compost – without biofertilizer) treatment.

Respecting the obtained results are showed in Table (9), only two treatments gave RY higher than 100%. They were (1.0ETc - 1.0% Compost-Biofertilizer) and (1.0 ETc - 0.75 Compost - Biofertilizer) with RY values of 108.9 and 108.1%, respectively, without a significant difference between these two treatments. This result indicates that, the higher yield could be obtained under full irrigation practices and reducing organic matter application by 25% and inoculation with PGPR without a significant reduction in the wheat yield. The lowest RY was found under the treatment (0.6 ETc - 0.0% Compost - Without biofertilizer), with a value of 35.1%.

Water productivity

To quantify the relationship between the applied irrigation water and crop production, water productivity function was used (Van Halsema and Vincent, 2012).The main effect of applied irrigation water quantities on WP showed that, there is no significant differences in WP values between 1.0 ETc and 0.8 ETc, which were 1.104 and 1.097, respectively (Table 8). These results supported by Tari (2016) who reported that WP could be improved by practicing deficit irrigation. While 0.6 ETc gave the lowest WP value of 0.969 g grains per litter. WP values were significantly affected by organic matter application. The obtained values were 1.238, 1.156, 0.999 and 0.835 g grains per litter for 1.0, 0.75, 0.5 and 0.0% compost application rates, respectively (Table 8). The increase in WP with organic matter application may resulted from elevated photosynthesis and decreased transpiration and stomal conductance, which enable wheat plants to utilize water more efficiently under deficit irrigation (Wang *et al*., 2017). The inoculation with PGPR resulted in significant increase in WP, its obtained values were 0.978 and 1.136 g grains per litter for the non-inoculated and inoculated treatments, respectively (Table 8).

Table (9) also shows the effect of the interactions between irrigation water quantities, organic matter application rates and PGPR inoculation on water productivity of wheat plants. The data revealed that, there are no significant differences between three treatments namely: (1.0 ETc - 1.0% Compost - Biofertilizer), (1.0 ETc - 0.75% Compost - Biofertilizer) and (0.8 ETc - 1.0% Compost – Biofertilizer), which they gave the highest values of WP of 1.379, 1.369 and 1.346 g grains per litter, respectively. While the lowest values of WP were recorded for the two treatments (1.0 ETc - 0.0% Compost – Without biofertilizer) and (0.6 ETc - 0.0% Compost – Without biofertilizer) without a significant difference between them. Their values were 0.741 and 0.729 g grains per litter, respectively. Noreldin *et al*. (2015) reported WP values ranged from 1.49 to 0.91 g grains per litter for wheat plants grown in sandy soils under Egyptian conditions. They also recommended the use of 90% of irrigation water requirement to increase WP and save irrigation water.

CONCLUSION

The current research showed obvious increase in plant yield due to seed inoculation. Thus, the use of the microbial inoculant with only 0.75 % (W/W) of compost was more effective than 1.00 % (W/W) of compost without microbial inoculation in most cases. No significant difference was observed in water productivity between 1.0 and 0.8 ETc. Relative water content and electrolyte leakage of the 90-day old plants were found to be enhanced by raising the amounts of the studied factors. Based on the present results, these increments could be attributed to the increase in soil enzyme activities which could promote the availability of soil nutrients. Additionally, the significant reductions in soil pH due to utilization of microbial inoculants could enhance the nutrient status in the soil and therefore provide the plants with nutrients in adequate amounts. Finally, based on all the above consequent results, the Egyptian farmers could be recommended to

use this promising inoculant as a suitable biofertilizer for wheat grown in sandy soil to reduce the current irrigation water quantities by ca. 20% or reduce the common application rate of compost by ca. 25% without significant reduction in crop production and water productivity. However, this study needs to be evaluated under field conditions.

REFERENCES

Abd El-Azeem, S. A., T. A. Mehana and A. A. Shabayek (2007). Some plant growth promoting traits of rhizobacteria isolated from Suez Canal region, Egypt. African Crop Sci. Conf. Proceed., 8: 1517-1525.

Abdelhaleem, F. and Helal, E. (2015). Impacts of Grand Ethiopian Renaissance Dam on Different Water Usages in Upper Egypt. British Journal of Applied Science & Technology, 8(5): 461-483.

Adesemoye, A. O. and D. Egamberdieva (2013). Beneficial Effects of Plant Growth-Promoting Rhizobacteria on Improved Crop Production: Prospects for Developing Economies. In: Bacteria in Agrobiology: Crop Productivity, Maheshwari, D. K. *et al*. (Eds.), Springer, Berlin, pp: 45-63

Adesemoye, A. O., H. A. Torbert and J. W. Kloepper (2009). Plant growth-promoting rhizobacteria allow reduced application rates of chemical fertilizers. Microb. Ecol., 58: 921-929.

Akmal, M., M. S. Altaf, R. Hayat, F. U. Hassan and M. Islam (2012). Temporal changes in soil urease, alkaline phosphatase and dehydrogenase activity in rain-fed wheat field of Pakistan. J. Anim. Plant Sci., 22: 457-462.

Allen, R., L. Pereira, D. Raes and M. Smith (1998). FAO Irrigation and drainage paper No. 56. Rome: Food and Agriculture Organization of the United Nations, 56: 26-40.

Altomare, C. and I. Tringovska (2011). Beneficial soil microorganisms, an ecological alternative for soil fertility management. In: Biofuels and Local Farming Systems, Sustainable Agriculture Reviews, Lichtfouse, E. (Ed.), Genet., pp. 161-214.

Bric, J. M., R. M. Bostock and S. E. Silverstone (1991). Rapid *in situ* assay for indoleacetic acid production by bacteria immobilized on a nitrocellulose membrane. Appl. Environ. Microbiol., 57: 535-538.

Clarke, D., M. Smith and K. El-Askari (1998). CropWat for Windows (Version 4.2). Southampton University, Southampton, October.

CoStat Statistical Software (1990). CoStat Manual Revision 4.2, pp: 271.

Gee, G. W. and J. W. Bauder (1986). Particle-size analysis. In Klute A. (Ed.) Methods of Soil Analysis. Part 1 2nd ed. Agron. Monogr. ASA and SSSA INCS., Madison, Wisconsin USA. pp. 383-409.

Ghanem, O. M. (2017). Role of Arbuscular Mycorrhizal Fungi, Plant Growth Promoting Rhizobacteria and their Interactions in Improving Plant Nutrition and Soil Fertility. Ph D. Thesis, Fac. Agric., Suez Canal Univ., Ismailia, Egypt.

Ghanem, O. M., R. K. Rabie, S. A. M. Abd El-Azeem and T. A. Mehana (2013). Response of wheat to inoculation with plant-growth promoting rhizobacteria at different P fertilization levels. J. Soil Sci. and Agric. Eng., Mansoura Univ., 4: 563-575.

Gianfreda, L. (2015). Enzymes of importance to rhizosphere processes. J. Soil Sci. Plant Nutr., 15: 283-306.

Holt, J. G., N. R. Krieg, P. H. A. Sneath, J. T. Staley and S. T. Williams (1994). Bergey's Manual of Determinative Bacteriology. 9th edn. Williams Wilkins, Baltimore, USA.

Khadem, S. A., M. Galavi, M. Ramrodi, S. R. Mousavi, M. J. Rousta and P. Rezvani-Moghadam (2010). Effect of animal manure and superabsorbent polymer on corn leaf relative water content, cell membrane stability and leaf chlorophyll content under dry condition. Australian Journal of Crop Science, 4(8): 642-647.

Krieg, N. R. and J. G. Holt (1984). Bergey's Manual of Systematic Bacteriology. Vol. I, Williams Wilkins, Baltimore, USA.

Kunze, A., M. D. Costa, J. Epping, J. C. Loffaguen, R. Schuh and P. E. Lovato (2011). Phosphatase activity in sandy soil influenced by mycorrhizal and non-mycorrhizal cover crops. R. Bras. Ci. Solo, 35: 705-711.

Leprince, O., F. J. M. Harren, J. Buitink, M. Alberda and F. A. Hoekstra (2000). Metabolic dysfunction and unabated respiration precede the loss of membrane integrity during dehydration of germinating radicles. Plant Physiology, 122(2): 597-608.

Lutts, S., J. M. Kinet and J. Bouharmont (1996). NaCl-induced senescence in leaves of rice (Oryza sativa L.) cultivars differing in salinity resistance. Annals of Botany, 78(3): 389-398.

Mac Faddin, J. F. (1976). Biochemical Tests for Identification of Medical Bacteria. Waverly press, INC. Mt. Royal and Guilford Aves. Baltimore, Md., U.S.A.

Munoz, G. and J. Grieser (2006). CLIMWAT 2.0. for CROPWAT. FAO Water Development and Management Unit, September.

Nannipieri, P., L. Giagnoni, L. Landi and G. Renella (2011). Role of phosphatase enzymes in soil. In: Phosphorus in Action, Bunemann, E.K.; Oberson, E. A. and Frossard E. (Eds.), Springer-Verlag Berlin Heidelberg, pp. 215-243.

Nautiyal, C. S. (1999). An efficient microbiological growth medium for screening phosphate solubilizing microorganisms. FEMS Microbiol. Lett., 170: 265-270.

Noreldin, T., S. Ouda, O. Mounzer and M. T. Abdelhamid (2015). CropSyst model for wheat under deficit irrigation using sprinkler and drip irrigation in sandy soil. Journal of Water and Land Development, 26(1): 57-64.

Parray, J. A., S. Jan, A. N. Kamili., R. A. Qadri, D. Egamberdieva and P. Ahmad (2016). Current perspectives on plant gowth-promoting rhizobacteria. J. Plant Growth Regul., 35: 877-902.

Peel, M. C., B. L. Finlayson and T. A. McMahon (2007). Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth System Sciences, 11(5): 1633-1644.

Perez-Montano, F., C. Alías-Villegas, R. A. Bellogin, P. Del-Cerro, M. R. Espuny, I. Jiménez-Guerrero, F. J. López-Baena, F. J. Ollero and T. Cubo (2014). Plant growth promotion in cereal and leguminous agricultural important plants: From microorganism capacities to crop production. Microbiol. Res., 169: 325-336.

Rosas, S. B., G. Avanzini, E. Carlier, C. Pasluosta, N. Pastor and M. Rovera (2009). Root colonization and growth promotion of wheat and maize by *Pseudomonas aurantiaca* SR1. Soil Biol. Biochem., 41: 1802-1806.

Sade, N., E. Galkin and M. Moshelion (2015). Measuring Arabidopsis, Tomato and Barley Leaf Relative Water Content (RWC). Bio-Protocol, 5(8).

Sarwar, M., M. Arshad, D. A. Martens and J. W. T. Frankenberger (1992). Tryptophan-dependent biosynthesis of auxins in soil. Plant Soil, 147: 207-215.

Schwyn, B. and J. B. Neilands (1987). Universal assay for the detection and determination of siderophores. Anal. Biochem., 160: 47-56.

Sneath, P. H. A., N. S. Mair, M. E. Sharpe and J. G. Holt (1986). Bergey's Manual of Systematic Bacteriology. Vol. II, Williams Wilkins, Baltimore, USA.

Soil Survey Staff - NRCS/USDA (2014). Keys to soil taxonomy. Soil Conservation Service, 12, 360 pp.

Sparks, D. L. (1996). Methods of Soil Analysis. Part 3: Chemical Methods, SSSA INCS., Madison, Wisconsin USA.

Starr, M. P., H. Stolp, H. G. Trüper, A. Balows and H. G. Schlegel (1981). The Prokaryotes: A Handbook on Habitats, Isolation and Identification of Bacteria. Springer-verlag, Berlin, Germany.

Steduto, P., T. C. Hsiao, E. Fereres and D. Raes (2012). Crop yield response to water. In FAO Irrigation and Drainage Paper No.66.

Tabatabai, M. A. (1994). Soil enzymes. In: Methods of Soil Analysis, Part II: Microbiological and Biochemical Properties, Weaver, R. W., J. S. Angle and P. S. Bottomly (Eds.), SSSA Book Series No. 5. Soil. Sci. Soc. Am. J. Madison, WI., pp. 775-833.

Tari, A. F. (2016). The effects of different deficit irrigation strategies on yield, quality, and water-use efficiencies of wheat under semi-arid conditions. Agricultural Water Management, 167: 1-10.

Torres, I., M. T. Sánchez, M. Benlloch-González and D. Pérez-Marín (2019). Irrigation decision support based on leaf relative water content determination in olive grove using near infrared spectroscopy. Biosystems Engineering, 180: 50-58.

Van Halsema, G. E. and L. Vincent (2012). Efficiency and productivity terms for water management: A matter of contextual relativism versus general absolutism. Agricultural Water Management, 108: 9-15.

Ventosa, A., M. C. Gutierrez, M. Kamekura, I. S. Zvyagintseva and A. Oren (2004). Taxonomic study of *Halorubrum distributum* and proposal of *Halorubrum terrestre* sp. nov. Int. J. Syst. Evol. Microbiol., 54: 389-392.

Vessey, K. J. (2003). Plant growth promoting rhizobacteria as biofertilizers. Plant Soil, 255: 571-586.

Wang, L., S. Wang, W. Chen, H. Li and X. Deng (2017). Physiological mechanisms contributing to increased water-use efficiency in winter wheat under organic fertilization. PLoS ONE, 12(6): 1-21.

Wanjiku, J. G., O. Kamuhia, O. Rono and M. Kavere (2019). Effectiveness of relative water content as a simple farmer's tool to determine plant water deficit. Afr. J. Hort. Sci., 16: 21-28.

Yazdani, M., M. A. Bahmanyar, H. Pirdashti and M. A. Esmaili (2009). Effect of phosphate solubilization microorganisms (PSM) and plant growth promoting rhizobacteria (PGPR) on yield and yield components of corn (*Zea mays* L.). Int. Sci. Res. Innov., 3: 50-52.

تحسين نمو ومحصول القمح بإضافة الكمبوست وبكتريا الجذور المنشطة لنمو النبات تحت استرتيجية الري المتناقص في الأراضي الرملية

أحمد عبدالعليم الخربوطلي و أسامة محمد غانم

قسم الأراضي والمياه - كلية الزراعة - جامعة قناة السويس - الاسماعيلية – مصر

أجريت تجربة أصص علي نبات القمح (صنف مصر 1) باستخدام تربة رملية في مزرعة كلية الزراعة بجامعة قناة السويس فى الفترة من ٤ ديسمبر ٢٠١٧ وحتي ٢ أبريل ٢٠١٨ وكانت تهدف إلي دراسة تأثير لقاح بكتيري مكون من خليط من سلالتين من بكتريا الجذور المنشطة لنمو النبات وهما : *B. subtilis* EF1 و*P. fluorescens* KW1 وتأثير إضافة عدة مستويات من الكمبوست وهي 0.00 ، 0.50، 0.75، 1.00% (وزن/وزن) وذلك تحت تأثير كميات مختلفة من مياه الري وهي: 1.0و 0.8 و0.6 من الاحتياج المائي المحصولي. أشارت النتائج إلي أن الوزن الجاف لنباتات القمح في عمر التزهير وكذلك محصولي الحبوب والقش قد زادا معنوياً مع زيادة كميات مياه الري وكذلك مع زيادة مستويات الإضافة من الكمبوست. كانت أفضل المعاملات من حيث محصولي الحبوب والقش عندما تم اضافة كمية مياه الري بمعدل 1.0 من الاحتياج المائي وأضيف الكمبوست بمعدل 1.0% ومع اللقاح البكتيري المستخدم. وكانت نسب الزيادة في محصولي الحبوب والقش تبلغ ٨٧.١ و ٣٤.٤% علي الترتيب بالمقارنة بالكنترول المقابل. كذلك لم يلاحظ وجود فروق معنوية في إنتاجية وحدة المياه بين كميتي مياه الري 1.0و0.8 من الاحتياج المائي. كما لوحظ وجود زيادة معنوية في محتوي الماء النسبي للأوراق والتسرب الاليكتروليتي لخلايا الورقة في نباتات القمح عند عمر ٩٠ يوم وذلك مع زيادة العوامل التي تم دراستها. تشير نتائج هذه الدراسة إلي توفير ٢٠% من كمية مياه الري اللازمة لنبات القمح في الأراضي الرملية عن طريق استخدام الكمبوست بمعدل ١% ومع استخدام اللقاح البكتيري المكون من خليط من السلالتين *B. subtilis* EF1 و*P. fluorescens* KW1 علماً بأن خفض مياه الري في ظل هذه الظروف لم يؤثر معنوياً على إنتاج محصول القمح.