

EFFECT OF IRRIGATION WATER DEFICIT ON BACTERIAL DIVERSITY, WATER USE EFFICIENCY AND PRODUCTIVITY OF CALCAREOUS SOIL

Elkasass, M. S. A. ; M. A. N. Mohamed and Esraa A. M. Rahema
Soil and Water Depart., Faculty of Environmental Agricultural Sciences,
Suez Canal University, Egypt.

Mailing address: E-mail: elkasass2003@yahoo.com

ABSTRACT

Two experiments were carried out in calcareous sandy loam soil of Experimental Farm of the Faculty of Environmental Agricultural Science, El-Arish Suez Canal University, North Sinai Governorate, Egypt. The first experiment (pot experiment) aimed to study the effect of deficit irrigation water on enumeration of microorganisms associated with roots of wheat (*Triticum aestivum vulgare cv. Sakha 93*) and bacterial diversity. The obtained data indicated that there is no obvious effect of deficit irrigation water on the enumeration of total bacterial and actinomycetes count. Bacterial strains were classified into 14 clusters according to morphological characteristics, gram staining and growth curves. The bacterial strains were grouped into ten clusters when soils were irrigated by 100 and 75% ET_m whereas fourteen clusters were obtained when soils were irrigated by 50 and 25% ET_m causing an appearance of new strains having the ability to survive in water stress conditions.

The second experiment (field experiment) aimed to investigate the effect of deficit irrigation water under drip irrigation system on water relations, yield and growth parameters of wheat crop. The actual evapotranspiration (ET_a) of wheat crop was decreased with increasing applied deficit irrigation water. The highest ET_a value of wheat crop was found at applied deficit irrigation water of 100% ET_m followed by 75, 50 and 25% ET_m. The highest water use efficiency was found at deficit irrigation water level of 25% ET_m followed by 100, 50, 75% ET_m. The deficit of irrigation water of 100 % ET_m had the highest values for plant height and number of tillers per m², while the deficit irrigation water of 25 % ET_m had the lowest ones. The deficit of irrigation water of 100 % ET_m had the highest values of grains, straw yields and weight of 1000 grain, while the deficit irrigation water of 25 % ETP had the lowest ones.

Keywords: water irrigation deficiency, water relations, microorganisms enumeration, bacterial diversity, wheat plants, calcareous soil.

INTRODUCTION

Irrigated agriculture is still practiced in many areas in the world with complete disregard to basic principles of resource conservation and sustainability. Therefore, irrigation water management in an era of water scarcity will have to be carried out most efficiently, aiming at saving water and at maximizing its productivity. Insufficient water supply for irrigation will be the norm rather than the exception, and irrigation management will shift from emphasizing production per unit area towards maximizing the production per unit of water consumed, the other productivity, Fereres and Soriano (2007). The environmental stresses such as drought, temperature, salinity, air pollution, heavy metals, pesticides and soil pH are major limiting factors in

crop production because, they affects almost all plant functions, Shao *et al.*, (2007).

Growth of wheat plants affected by water stress during vegetative and fruiting stages was studied by Farahat (1978). She reported that increasing the depletion of available soil moisture caused a significant decrease in height of the main stem, number of tillers per plant, number of plant spikes, wheat grain, straw yield and weight of 1000 seeds. Choudhury and Kumar (1980) in their study on the response of dwarf wheat to different levels of water stress (at sowing to maximum tillering, maximum tillering to flowering and flowering to maturity growth stages) concluded that moderate and severe water stress treatments for all growth stages decreased plant length. The same trend was observed in recent studies, Zhang *et al.*, (2004); El-Kassas (2008) and Ibrahim *et al.* (2010).

Plant adaptations to water stress may cause changes in below ground C input through higher root production and turnover. This may in turn influence the functional structure and activity of the microbial community in the rhizosphere (Bolton *et al.*, 1992; Grayston *et al.*, 1998). Drought also directly affects the soil microorganisms by creating osmotic stress, which leads to microbial death and cell lysis (Turner *et al.*, 2003). The mechanism of plant drought tolerance may involve promotion of root extension, allowing efficient water up take as illustrated by Bethlenfalvay and Linderman (1992) and Ruíz-Lozano *et al.*, (1995). Thus, an alternate plant strategy for coping with water deficiencies is the interaction with beneficial soil microorganism. Plants can interact with several soil microorganisms including bacteria having plant growth promoting (PGP) abilities and/or mycorrhizal fungi that enhance plant water uptake and nutrition status, improving plant stress tolerance (Glick, 1995; Barea *et al.*, 2002; Marulanda *et al.*, 2007 ; Marulanda *et al.*, 2009 and Azcon and Barea, 2010).

The present study aims to determine the effect of deficit of water irrigation on microbial enumeration, diversity and water relations. Another main objective is to determine to which extent the deficit of water irrigation can influence wheat growth and production.

MATERIALS AND METHODS

Two experiments were carried out for the calcareous sandy loam soil of Experimental Farm of the Faculty of Environmental Agricultural Science, El-Arish Suez Canal University, North Sinai Governorate, Egypt, during two successive seasons 2008/2009 and 2009/2010. The first experiment (pot experiment) aimed to study the effect of deficit of irrigation water on enumeration of microorganisms in soil, especially those associated with roots of wheat (*Triticum aestivum vulgare* cv. Sakha 93) and bacterial diversity. The second experiment (field experiment) aimed to study the effect of deficit of irrigation water under drip irrigation system with irrigation efficiency of 85 % on water relations, yield and growth parameters of wheat crop.

Experiment 1

A surface calcareous sandy soil sample (0-15cm) from the Experimental Farm of the Faculty of Environmental Agricultural Sciences, El-Arish, Suez Canal University, North Sinai Governorate, Egypt, was air dried, sieved through a 2 mm sieve mesh. The soil studied was a sandy loam (sand 67.48%, silt 27.17% and clay 5.35%; 16% CaCO₃, pH 8.1). The source of irrigation water was well water which collected from the Experimental Farm of the Faculty of Environmental Agricultural Science with total salinity of 5.5 dSm⁻¹ and pH of 7.4.

The first experiment was assigned for wheat cultivation in pots. Four seeds were sown in each pot containing 2Kg soil and irrigated with 100, 75, 50 and 25 % of maximum evapotranspiration (ET_m) in a completely randomized design with three replications. Nutritive solution contains salts illustrated by Mohamed and El Tantawy, 2009, was used as fertilization. Soil was manured by 1% organic material. Sixty days after planting, roots were lifted out of soils and root system was then transferred to a 1 liter Erlenmeyer flask containing 100 ml sterilized distilled water. The samples were shaken for 15 min on a rotary shaker and the 100 ml soil suspension was considered as rhizosphere soil suspension. Serial dilutions were plated on 1/10 TSA (Tryptone Soybean Agar) medium. The weights of rhizospheric soil were determined in a sample of the 100 ml soil suspension. After 5 days of incubation, bacterial and actinomycetes colony forming units (CFU) were recorded. Weights of fresh and dry roots were determined.

Comparison of bacterial strains isolated under studied deficit of irrigation water:

Fifty-eight colonies of each treatment were isolated from plates of the same dilution and grown in microplates in 1/10 tryptone soybean broth (TSB). Each well contains 150 µl 1/10 TSB. Growth curves for the isolated strains were compared by inoculating each strain in a sterilized 96 well microplate. This was achieved by adjusting the optical density, OD, at 600 nm by a microplate reader, Model Stat Fax-2100, Awareness Technology Inc. USA. Optical densities were measured at 0, 9, 15, 21, 33, 39, 45, 57, 63, 69, 81, 87, 93, 105, 111, 117 and 129 hours after inoculation and initial OD was subtracted from the subsequent readings. Growth curves were achieved between the obtained OD and the time of measurement, Mohamed (2004). Based on different morphological colonies on TSA medium, the selected isolates were classified by cultural, morphological characteristics and gram staining according to the scheme of identification of Bergey's Manual of Systematic Bacteriology, (1976).

According to the similarity between isolated strains from studied deficit irrigation water, strains were regrouped in clusters. The distribution of strains at 100, 75, 50 and 25% from ET_m in classes were compared by the Stat X act program (version 3). The test was used to compare the distribution of strains in their classes for the four populations, Mohamed (2009).

Experiment 2

The initial of some physical and chemical properties of the studied soil in the field experiment (second experiment) are given in Table (1).

Table (1): Some physical and chemical properties of the initial soil for the field experiment.

| Soil properties | Season 2009-2010 | | | | |
|---|------------------|-------|-------|-------|-------|
| | Soil depth, cm | | | | |
| | 0-15 | 15-30 | 30-45 | 45-60 | 60-75 |
| Sand % | 69.20 | 78.20 | 55.20 | 65.20 | 55.20 |
| Silt % | 15.00 | 10.00 | 25.00 | 15.00 | 34.00 |
| Clay % | 15.80 | 11.80 | 19.80 | 19.80 | 10.80 |
| Soil texture class | Sandy loam | | | | |
| Soil moisture constants at tension | | | | | |
| Bulk density mg m ⁻³ | 1650 | 1660 | 1470 | 1460 | 1330 |
| Organic matter % | 0.19 | 0.15 | 0.14 | 0.12 | 0.12 |
| Saturation percentage(0kPa) | 29.77 | 30.22 | 36.46 | 28.75 | 26.43 |
| Soil water content of field capacity, (-10 kPa),% | 11.90 | 11.89 | 13.67 | 11.18 | 10.88 |
| Soil water content of wilting point, (-1500 kPa),% | 5.17 | 5.06 | 5.14 | 5.84 | 5.68 |
| Chemical properties (soluble ions in 1:5 soil water extract) | | | | | |
| Ca ⁺⁺ me l ⁻¹ | 4.45 | 2.90 | 1.92 | 2.40 | 3.60 |
| Mg ⁺⁺ me l ⁻¹ | 3.55 | 2.45 | 2.28 | 2.61 | 2.90 |
| Na ⁺ me l ⁻¹ | 7.95 | 6.63 | 6.85 | 7.05 | 7.53 |
| K ⁺ me l ⁻¹ | 2.55 | 1.02 | 0.45 | 0.94 | 0.97 |
| CO ₃ ⁻⁻ me l ⁻¹ | - | - | - | - | - |
| HCO ₃ ⁻ me l ⁻¹ | 3.00 | 2.00 | 1.63 | 1.65 | 3.25 |
| Cl ⁻ me l ⁻¹ | 13.0 | 9.25 | 8.50 | 9.55 | 9.50 |
| SO ₄ ⁻⁻ me l ⁻¹ | 2.50 | 1.75 | 1.37 | 1.80 | 2.25 |
| EC(dS m ⁻¹) in 1:5 soil water extract | 1.85 | 1.30 | 1.15 | 1.30 | 1.50 |
| pH in 1:2.5 soil water suspension extract | 7.94 | 8.12 | 8.26 | 7.93 | 8.09 |
| CaCO ₃ % | 14.39 | 22.58 | 22.65 | 22.60 | 21.85 |

The source of irrigation water of the experiment 2 was well water from Experimental Farm of the Faculty of Environmental Agricultural Science. The chemical composition of the irrigation water is given in **Table (2)**.

Table (2):Some chemical composition of irrigation water for the field experiment.

| EC, dSm ⁻¹ | pH (1:2.5) | Soluble cations, me l ⁻¹ | | | | Soluble anions, me l ⁻¹ | | | |
|-----------------------|------------|-------------------------------------|------------------|-----------------|----------------|------------------------------------|-------------------------------|-----------------|-------------------------------|
| | | Ca ⁺⁺ | Mg ⁺⁺ | Na ⁺ | K ⁺ | CO ₃ ⁻⁻ | HCO ₃ ⁻ | Cl ⁻ | SO ₄ ⁻⁻ |
| 7.73 | 8.31 | 11 | 24 | 40 | 2.25 | - | 4.25 | 55 | 18 |

Different soil and water parameters were analysed according to (Piper, 1950; Richards, 1954; Jackson, 1967). Air temperature and relative humidity were recorded from the meteorological station at El-Arish, North Sinai Governorate (Table 3).

The second experiment was assigned for cultivating wheat. It included 4 treatments for the deficit irrigation water of 100, 75, 50 and 25% as amount of applied water from the ETP. One plant row was considered as a plot with a 10 m long. Each plot area was 2 m². Seeds were sown for successive season, 2009/2010, at a rate of 50 kg/fed on 20/11. After 34 days pretreatment period, irrigated every 2 days, irrigation treatments started for all plots on 24/12. The 100% ETm deficit irrigation water ended on 28/3. Its last irrigation occurred on 21/3. The 75% ETm deficit irrigation water ended on 25/3. Its last irrigation took place on 18/3. The 50% ETm deficit irrigation water, ended on 20/3. Its last irrigation occurred on 13/3. The 25% ETm deficit

irrigation water, ended on 12/3. Its last irrigation occurred on 5/3. The experimental design was completely randomized design with four replications.

Table (3): Monthly minimum, maximum and average values for temperatures,

| Parameters | | Month | | | | |
|-----------------------|---------|----------|----------|---------|----------|-------|
| | | November | December | January | February | March |
| Temperature (C°) | Maximum | 30.56 | 27.71 | 26.52 | 28.04 | 32.95 |
| | Minimum | 12.91 | 10.02 | 8.78 | 8.84 | 10.14 |
| | Average | 21.74 | 18.87 | 17.65 | 18.44 | 21.55 |
| Relative Humidity (%) | Maximum | 78.60 | 79.30 | 80.60 | 78.90 | 80.00 |
| | Minimum | 23.60 | 24.60 | 26.20 | 27.90 | 24.40 |
| | Average | 51.10 | 51.95 | 53.40 | 53.40 | 52.20 |
| Wind speed (m/s) | | 1.86 | 1.74 | 1.96 | 2.13 | 2.17 |
| Rain rates (mm) | | 7.03 | 12.45 | 19.45 | 14.05 | 10.35 |

Recorded Data

Soil-Water Relations

Consumptive Use of Water (CU)

Consumptive use of water (CU) was calculated using the equation given by **Israelsin and Hansen (1962)** as follows:

$$CU = D * AD * \frac{ez - ei}{100}$$

Where:

CU = Consumptive use in cm.

D = Irrigated soil depth in cm.

AD = Bulk density, g cm.⁻³, of the chosen irrigated soil depth.

ez = Soil moisture content percent after irrigation.

ei = Soil moisture content percent before irrigation.

Water Use Efficiency (WUE)

The consumed water by wheat was calculated according to **Yaron et al., (1973)** as follows:

$$WUE = \frac{Y}{ETa}$$

Where:

WUE = water use efficiency, kgm⁻³.

Y = Crop yield in kg fed⁻¹.

ETa = Actual Evapotranspiration in m³ fed⁻¹.

The actual evapotranspiration, ETa, is assumed to be synonymous to the calculated consumptive use of water (CU). Consequently, daily and monthly consumptive use of water was calculated for specified soil depths for all treatments.

Plant Growth parameters

Random samples of wheat plants were taken from each plot at the end of the season in order to determine plant height, number of tillers per m², weight of grains, ton fed⁻¹, weight of straw, ton fed⁻¹ and weight of 1000 grains,

grams. Analysis of variance was used to test the degree of variability among the obtained data. Duncan's Multiple rang test was used for the comparison among treatment means, Duncan, (1955). MSTATC program was used for the statistical analysis.

RESULTS AND DISCUSSION

First experiment was carried out to examine the effect of deficit OF irrigation water on bacterial and actinomycetes enumeration and diversity.

Effect of deficit OF irrigation water on bacterial and Actinomycetes counts

Results of the total rhizospheric bacterial, actinomycetes counts values are given in Table (4). The numbers of total bacterial recovered from the rhizospheric soil ranged between 5.2×10^9 to 2.22×10^{10} CFU g⁻¹ dry soil. These results are in agreement with those obtained by Mohamed (2004) and Söderberg *et al.*, (2004), who found that the rhizosphere has a high microbial activity since the counts of total rhizospheric bacteria were more than 10^9 CFU g⁻¹ dry soil.

Table (4): Effect of deficit OF irrigation water on bacterial and actinomycetes colony forming unit (CFU) counts in the rhizosphere of wheat plants cultivated in calcareous sandy loam soil.

| | CFU g ⁻¹ dry soil, at deficit irrigation water | |
|--------------------|---|----------------------|
| | 100 % ETm treatment | |
| | Bacterial counts | Actinomycetes counts |
| Rhizospheric soil | 5.2×10^9 | 6.04×10^7 |
| Fresh root | 2.8×10^9 | 3.2×10^7 |
| Dry root | 1.9×10^{10} | 2.2×10^8 |
| 75 % ETm treatment | | |
| | Bacteria | Actinomycetes |
| Rhizospheric soil | 9.5×10^9 | 5.3×10^7 |
| Fresh root | 5.2×10^9 | 3.5×10^7 |
| Dry root | 3.9×10^{10} | 2.4×10^8 |
| 50 % ETm treatment | | |
| | Bacteria | Actinomycetes |
| Rhizospheric soil | 1.51×10^{10} | 1.39×10^8 |
| Fresh root | 1.77×10^{10} | 1.4×10^8 |
| Dry root | 1.4×10^{11} | 1.01×10^9 |
| 25 % ETm treatment | | |
| | Bacteria | Actinomycetes |
| Rhizospheric soil | 2.22×10^{10} | 4.3×10^8 |
| Fresh root | 2.41×10^{10} | 4.4×10^8 |
| Dry root | 2.4×10^{11} | 4.7×10^9 |

The numbers of total actinomycetes recovered from the rhizospheric soils ranged between 6.04×10^7 to 4.3×10^8 CFU g⁻¹ dry soil. The obtained data indicated that there is no obvious effect of deficit water on the enumeration of total bacterial and actinomycetes count. The composition and counts of microorganisms in the rhizosphere of different plants may differ due to variations in the quantity and quality of compounds exuded by the different

plants (Duah *et al.*, 1998; Aldén *et al.*, 2001). The rhizodeposition of easily available carbon makes the rhizosphere an area of high microbial activity (Ramos *et al.*, 2000; Söderberg *et al.*, 2004). Root exudates selectively influence the growth of bacteria that colonize the rhizosphere by altering the chemistry of soil in the vicinity of the plant roots and by serving as selective growth substrates for soil microorganisms. Consequently, different rhizosphere microbial communities are associated with different plants (Kremer *et al.*, 1990).

Effect of deficit of irrigation water on bacterial diversity

The effect of deficit of irrigation water on bacterial clusters on rhizospheric calcareous sandy loam soil is represented in Table (5). Bacteria strains were classified into 14 clusters according to morphological characteristics, gram staining and growth curves. The bacterial strains were grouped into ten clusters when soils were irrigated by 100 and 75% ETm whereas bacterial strains were grouped into fourteen clusters when soils were irrigated by 50 and 25% ETm.

Table(5): Effect of deficit of irrigation water on bacterial diversity isolated from the rhizosphere of wheat plants cultivated in calcareous sandy loam soil.

| Clusters | Percentages of bacterial strains grouped to different clusters at deficit of irrigation water | | | |
|----------|---|---------|---------|---------|
| | 100% ETm | 75% ETm | 50% ETm | 25% ETm |
| C1 | 26.7 | 26.7 | 6.60 | 40.0 |
| C2 | 16.6 | 20.8 | 25.0 | 37.5 |
| C3 | 25.0 | 37.5 | 37.5 | - |
| C4 | 40.0 | 25.0 | 20.0 | 15.0 |
| C5 | 30.4 | 30.4 | 26.1 | 13.1 |
| C6 | 35.0 | 25.0 | 25.0 | 15.0 |
| C7 | 13.6 | 36.4 | 27.3 | 22.7 |
| C8 | 36.4 | 22.7 | 22.7 | 18.2 |
| C9 | 35.0 | 35.0 | 15.0 | 15.0 |
| C10 | 31.8 | 27.3 | 22.7 | 18.2 |
| C11 | - | - | 57.1 | 42.9 |
| C12 | - | - | 35.3 | 64.7 |
| C13 | - | - | 71.5 | 28.5 |
| C14 | - | - | 58.3 | 41.7 |

P<0.001

This indicates that as deficit of water irrigation increased, new strains appeared causing an increase in number of clusters indicating that these strains have the ability to survive in water stress conditions. The percentages of strains grouped to C1, C2 tend to increase in deficit irrigation water of 50 and 25% ETm, indicating that the strains grouped to these clusters have the ability to growth and survive in water stress conditions. On the other hand, the percentages of strains grouped to cluster C3, C4, C5, C6, C7, C8, C9 and C10 decreased as water moister decreased. This may indicates that the strains of these clusters were less tolerant to water stress than strains of

clusters C1, C2. Four new clusters appeared at deficit irrigation water of 50 and 25% ETm. The strains of these clusters may have special characteristics allow to their appearance in this water stress condition. The idea of strains classification into clusters when exposed to different conditions was used before by Delorme (2001) and Mohamed (2004).

Effect of deficit of irrigation water

The effect of deficit irrigation water levels on water relations, growth parameter, yield and component of wheat crop (*Triticum aestivum L.*) cultivated under drip irrigation system were investigated during the second experiment.

Actual evapotranspiration for wheat crop (ETa)

Actual daily and monthly evapotranspiration for wheat crop were calculated and presented in Table (6).

Table (6): Mean daily, monthly and total actual evapotranspiration of wheat crop (ETa, mm) as affected by deficit of irrigation water.

| Month | ETa at Deficit of Irrigation Water, mm | | | | | | | |
|-----------|--|---------|---------|---------|---------|---------|--------|---------|
| | 100% ETm | | 75% ETm | | 50% ETm | | 25%ETm | |
| | Daily | Monthly | Daily | Monthly | Daily | Monthly | Daily | Monthly |
| November* | 1.98 | 21.78 | 1.98 | 21.78 | 1.98 | 21.78 | 1.98 | 21.78 |
| December | 2.85 | 88.35 | 2.56 | 79.36 | 1.53 | 47.43 | 0.58 | 17.98 |
| January | 3.21 | 99.51 | 2.96 | 91.76 | 1.93 | 59.83 | 0.66 | 20.46 |
| February | 3.65 | 102.20 | 3.08 | 86.24 | 2.09 | 58.52 | 0.81 | 22.68 |
| March** | 4.04 | 109.08 | 3.20 | 76.8 | 2.66 | 50.54 | 1.27 | 13.97 |
| Total | | 420.92 | | 355.94 | | 238.10 | | 96.87 |

*11 days from November, **27 days from March for I₁, 24 days from March for I₂, 19 days from March for I₃ and 11 days from March for I₄

Monthly rates were always high for the 100 % ETm and continued to decreases as percent permissible soil moisture increased. During wheat growth period, ETa value was the highest one during March for the 100% ETm of deficit irrigation water. This result may be related to the vary high evapotranspiration demand. The reason for the variation in maximum ETa during wheat growth periods might be related to the interrelation for the variation in the distinction between wheat growth periods and wheat crop requirement growth stage as reported by Doorenbos and Kassam (1979).

Data obtained for daily ETa values, for wheat crop presented in, Table (7) indicated that they vary from 20 November to 27 March and from deficit irrigation water level to another. All values were obtained for daily ETa high during March. The maximum daily ETa values for the deficit irrigation water of 100 and 75% ETm were 4.04, 3.20 mm/day during March, respectively.

Data given in Table (7) reveal that actual wheat crop evapotranspiration (ETa) according to growth stage affected by deficit irrigation water levels. This data indicated that actual evapotranspiration increased with increasing the amount of applied irrigation water from the initial stage to lat-season stage. The maximum ETa values were in the mid-season stage for all deficit irrigation water levels, while, the minimum ETa values were in the initial stage for the same levels.

A severe or slight soil water deficit significantly reduces ETa, which mainly depends on irrigation amounts. Thus, it is possible to reduce ETa somewhat without significantly decreasing green yield, **Zhang et al (2004)**.

Table (7): Actual wheat crop evapotranspiration (ETa) according to growth stages as affected by deficit of irrigation water levels .

| Deficit of irrigation water | ETa during growth stage, mm | | | | |
|-----------------------------|-----------------------------|-------------|------------|------------|--------|
| | Initial | Development | Mid-season | Lat-season | Total |
| 100% ETm | 36.03 | 77.31 | 180.25 | 127.33 | 420.92 |
| 75% ETm | 34.58 | 66.56 | 156.44 | 98.36 | 355.94 |
| 50% ETm | 29.43 | 38.25 | 101.07 | 69.35 | 238.10 |
| 25%ETm | 24.68 | 13.34 | 33.54 | 25.31 | 96.87 |

Water use efficiency (WUE)

Data in Table (8) indicate that the average WUE values for the investigated season decreased from 1.96 and 1.79 kg m⁻³ at the applied deficit irrigation water of 100 and 75% ETm, respectively. Then the values increased at the applied deficit irrigation water of 50 and 25% ETm and by 1.92 and 3.49 kg m⁻³, respectively. The average obtained values for grain production were 3.471, 2.672, 1.922 and 1.421 ton fed⁻¹ at the applied deficit irrigation water of 100, 75, 50 and 25% ETm, respectively. For the consumed water, the obtained values were 1767.86, 1494.95, 1000.02 and 406.85 m³fed⁻¹ at the applied deficit irrigation water of 100, 75, 50 and 25% ETm, respectively. Finally, if the economic use of water during wheat production is more important, then the deficit irrigation water of 25% ETm is recommended. However, if increasing the wheat grain yield is more important, then deficit irrigation water 100% ETm is recommended. Such results are in harmony with those obtained by Zhang et al., (2004); Waraich et al., (2008) and El-kassas (2008).

Table (8): Water use efficiency, WUE, for wheat crop as affected by applied deficit irrigation water.

| Deficit of irrigation water | Fresh yield, kg fed ⁻¹ | Total consumed water(ETa), m ³ fed ⁻¹ | Water use efficiency, kg m ⁻³ |
|-----------------------------|-----------------------------------|---|--|
| 100% ETm | 3471 | 1767.86 | 1.96 |
| 75% ETm | 2672 | 1494.95 | 1.79 |
| 50% ETm | 1922 | 1000.02 | 1.92 |
| 25%ETm | 1421 | 406.85 | 3.49 |

Plant growth parameters

The results in Table (9) show that wheat height decreased significantly with decreasing irrigation water quantity. These results are related to the decrease in wheat water consumption. Average number of tillers per m² was affected significantly by deficit irrigation water, Table (9). The average numbers of tillers per square meter were 354, 321, 285 and 218, respectively. This trend as well as that obtained for plant height reflects

the condition of straw production which is very useful. This result agrees with Alderfasi *et al* (1999).

Crop Yield

The effect of deficit of irrigation water on fresh grain, straw yields and 1000-grain weight for the investigated season is shown in Table (9). Data reveal that grains, straw yield and weight of 1000-grains, in general, significantly increased with decreasing deficit irrigation water level. These results are in agreement with those of Zhang *et al.*, (2004) and Ibrahim *et al.* (2010).

Table(9): Plant height (cm), number of tillers per m², fresh grain yield (ton fed⁻¹), Fresh straw yield (ton fed⁻¹) and weight of 1000 grain (g) for wheat crop as affected by deficit of irrigation water.

| Deficit of irrigation water | Plant height (cm) | Average number of tillers m ² | Fresh grain yield (ton fed ⁻¹) | Fresh straw yield (ton fed ⁻¹) | Weight of 1000 grain (g) |
|-----------------------------|-------------------|--|--|--|--------------------------|
| 2009-2010 season | | | | | |
| 100% ETm | 88.13 a | 354 a | 3.471 a | 3.562a | 56.25 a |
| 75% ETm | 84.75 ab | 321 ab | 2.672 b | 2.738b | 51.50 a |
| 50% ETm | 75.00 b | 285 b | 1.922 c | 1.941c | 39.63 b |
| 25%ETm | 58.50 c | 218c | 1.421 d | 1.469d | 27.38 c |
| Average | 76.595 | 294 | 2.366 | 2.427 | 43.69 |

REFERENCES

Aldén, L.; F. Demoling, and E. Baath, 2001. Rapid method of determining factors limiting bacterial growth in soil. *Appl. Environ. Microbiol.*, 67:1830-1838.

Alderfasi, A. A. ; M. O. Ghandorah and K. A. Moustsfa. 1999. Evaluation of some wheat genotypes under drought stress in arid region of Saudi Arabia. *Alex. J. Agric. Res*; 44, 209-217.

Azcon, R. and J. M. Barea. 2010. Mycorrhizosphere interactions for legume improvement. In: M. S. Khanf; A. Zaidi; J. Musarrat, editors. *Microbes for Legume Improvement*. Vienna: Springer; pp. 237–271.

Barea, J. M.; R. Azcón and C. A. Aguilar. 2002. Mycorrhizosphere interactions to improve plant fitness and soil quality; *Anton. Leeuw. Int. J. Gen. Mol. Microbiol.*, 81: 343-351.

Bethlenfalvay, G. J. and R. G. Linderman. 1992. *Mycorrhizae in Sustainable Agriculture*. Am. Soci. of Agron., Madison, WI.

Bolton, H. J.; J. K. Fredrickson and L. F. Elliott. 1992. Microbial ecology of the rhizosphere. In: Metting, F.B.J. (Ed.) *Soil Microbial Ecology*, Marcel Dekker, New York, pp., 27–63.

Choudhury, P. N. and V. Kumar. 1980. The sensitivity for growth and yield of dwarf wheat to water stress at three growth stages. *Irrig. Sci*, 1 (14): 223-231. (c.f. *Field Crop Abst.* 34 (2) 734, 1981).

Delorme, S. 2001. Caractères bactériens associés à la compétitivité des *Pseudomonas* spp. fluorescent dans la rhizosphère, Thèse de Doctorat, Université de Bourgogne, Dijon.

- Doorenbos, J. and A. H. Kassam. 1979. Yield Response to Water. FAO, Irrigation and drainage, paper No.33, Rome.
- Duah, y. S.; R. Rønneb, and S. Christensenb. 1998. Nutrients limiting microbial growth in a tropical forest soil of Ghana under different management. Appl. Soil Ecol., 8:19-24.
- Duncan, D. B. 1955. Multiple range and multiple F-tests. Biometrics 11: 1-42.
- El-Kassas, M. S. A. 2008. Stude of water rquirements on some crop in north Sinai Governorate. PhD. Thesis, Faculty of Environmental Agricultural Sciences, Suez Canal University, El- Arish, Egypt.
- Farahat, R. M. 1978. Water regime of wheat plants during different stages of growth. M.Sc. Thesis, Agric. Dep., Ain Shams Univ.
- Fereres, E. and M. A. Soriano. 2007. Deficit irrigation for reducing agricultural water use. J. Exp., Bot., 58: 147–159.
- Glick, B. R. 1995. The enhancement of plant-growth by free-living bacteria. Can. J. Microbiol. 41: 109-117.
- Grayston, S. J. ;S. Wang; C. D. Campbell and A. C. Edwards. 1998. Selective influence of plant species on microbial diversity in the rhizosphere. Soil Biol. Biochem., 30: 369–378.
- Ibrahim, M. E.; S. M. Abdel-Aal; M. F. Seleiman; H. Khazaei and P. Monneveux. 2010. Effect of different water regimes on agronomical traits and irrigation efficiency in bread wheat (*Triticum aestivum* L.) grown in the Nile Delta. Wheat Inf. Serv., 109: 5-9.
- Israelsin, O. W. and V. C. Hansen. 1962. Irrigation Principles and Practices. 3rd. Edit. John Wiley and Sons Inc. New York pp: 240-253.
- Jackson, M. L. 1967. Soil Chemical Analysis. Prentice Hall, Inc., Engle wood cliff, N.J.
- Kremer, R. J.; M. F. T. Begonia,; L. Stanley, and T. Eric. 1990. Characterization of rhizobacteria associated with weed seedlings. Appl. Environ. Microbiol., 56:1649-1655.
- Marulanda, A.; J. M. Barea and R. Azcón. 2009. Stimulation of plant growth and drought tolerance by native microorganisms (AM fungi and bacteria) from dry environments. Mechanisms related to bacterial effectiveness. J. Plant Growth Regul. 28: 115-124.
- Marulanda, A.; R. Porcel; J. M. Barea and R. Azcón. 2007. Drought tolerance and antioxidant activities in lavender plants colonized by native drought-tolerant or drought-sensitive *Glomus* species. Microb. Ecol., 54: 543-552.
- Mohamed, M. A. N. 2009. Effect of repeating culture of cowpea plant on the competition of bacterial strains isolated from its rhizosphere. Res. J. Agric. Biol. Sci., 5: 293-300.
- Mohamed, M. A. N. 2004. Effect of isolation conditions and repeated culture of soybean (*Glycine max*) on culturable bacterial communities from the rhizosphere: New strategy for selecting competitive strains for inoculation, Ph. D. Thesis, Dijon, Bourgogne, France, P52.

- Mohamed, M. A. N. and E. M. El-Tantawy. 2009. *Proton release, nodulation and nodules growth of soybean plants cultivated in hydroaerobic system as affected by salinity and (Brady rhizobium japonicum) strains. Accepted to be published in CATRINA.*
- Piper, C. S. 1950. *Soil and Plant Analysis.* Interscience publishers, Inc., New York.
- Ramos, C. ; L. Molbak and S. Molin. 2000. Bacterial activity in the rhizosphere analyzed at the single-cell level by monitoring ribosome contents and synthesis rates. *Appl. Environ. Microbiol.*, 66: 801-809.
- Richards, L. A. 1954. *Diagnosis and Improvement of Saline and Alkaline Soils.* U. S. D. A. Handbook No.60.
- Ruíz-Lozano, J. M. ; M. Gómez and R. Azcón. 1995. Influence of different *Glomus* species on the time-course of physiological plant-responses of lettuce to progressive drought stress periods. *Plant Sci.*, 110: 37-44.
- Shao, H. B. ; L. Y. Chuc; G. Wu; J. H. Zhang; Z. H. Lua, and Y. C. Hug. 2007. Changes of some anti-oxidative physiological indices under soil water deficits among 10 wheat (*Triticum aestivum* L.) genotypes at tillering stage. *Colloids Surf.B: Bio. Interfaces*, 54: 143–149.
- Söderberg, K. H. ; A. Probanza; A. Jumpponen and E. Baath. 2004. The microbial community in the rhizosphere determined by community-level physiological profiles (CLPP) and direct soil- and CFU-PLFA techniques. *Appl. Soil Ecol.*, 25:135-145.
- Waraich, E. A; R. Ahmad ; S. Ahmad and S. Ullah. 2008. Water use efficiency and yield performance of wheat (*Triticum aestivum* L.) under different levels of irrigation and nitrogen. *Bioline Inter.*, 20: 23-34.
- Yaron, B.; E. Danfors and Y. Vaddia. 1973. *Arid Zone Irrigation.* Springer-Verlag Berlin, Heidelberg, New York.
- Zhang, Y. ; EloiseKendy; Q. Yu ;C. Liu and S. H. ShenYanjun. 2004. Effect of soil water deficit on evapotranspiration, crop yield, and water use efficiency in the North China Plain. *Agric. Water Manage.*, 64: 107–122.

تأثير النقص المائي على التنوع البكتيري وكفاءة استخدام المياه وإنتاجية الأراضي
الجيرية

محمد سعد عبد الحميد القصاص، محمد أحمد نصر محمد و إسرائ عادل محمد رحيمه
قسم الأراضي والمياه - كلية العلوم الزراعية البيئية - جامعة قناة السويس - جمهورية مصر
العربية

أجريت تجربتين بالمزرعة التجريبية لكلية العلوم الزراعية البيئية بالعريش جامعة قناة
السويس خلال الموسمين الشتويين لموسمي 2009/2008-2010/2009. التجربة الأولى تناولت
دراسة تأثير معاملات نقص مياه الري المختلفة على تعداد الاحياء الدقيقة الموجودة في تربة
ريزوسفير نبات القمح "صنف سخا 93" والتنوع البكتيري. صممت التجربة لزراعة القمح في
أصص. زرعت أربع بذور في كل أصيص يحتوي على 2 كيلوجرام تربة تم ربيها بمعاملات
ري 100, 75, 50 و 25% من أقصى نتج بخر لمحصول القمح (ETm). تم استرجاع التربة
الريزوسفيرية بعد 60 يوما من الزراعة وتم تقدير أعداد البكتريا الكلية المسترجعة من التربة
الريزوسفيرية حيث وجد انها تتراوح بين $10^9 \times 5,2$ إلى $10^{10} \times 2,22$ وحدة مكونة للمستعمرة لكل
جرام تربة جافة. بينما تراوحت الأعداد الكلية للاكتينوميستيس من $10^7 \times 6,04$ إلى $10^8 \times 4$
جرام تربة جافة. أوضحت النتائج أنه لا يوجد تأثير ملحوظ على التعداد الكلي للبكتريا
والأكتينوميستيس لمعاملات نقص مياه الري. تم تقسيم السلالات البكتيرية الى 14 مجموعة طبقا الى
كل من الشكل المورفولوجي، صبغة جرام ومنحنيات النمو. تم تقسيم السلالات البكتيرية الى 10
مجموعات عندما استخدمت معاملات 100 و 75% من أقصى نتج بخر لمحصول القمح بينما
قسمت السلالات البكتيرية الى 14 مجموعة عند معاملات الري 50 و 25% من أقصى نتج
بخر مما يؤكد ظهور سلالات جديدة لها القدرة على تحمل ظروف الإجهاد المائي.

أما التجربة الثانية تناولت تأثير معاملات الري المختلفة تحت نظام الري بالتنقيط على
النتج بخر الفعلي وكفاءة استخدام المياه و محصول القمح. واحتوت التجربة على أربعة معاملات ري
وهي 100, 75, 50 و 25% من أقصى نتج بخر لمحصول القمح. وظهرت النتائج تزايد النتج-
بخر الفعلي مع زيادة كميات مياه الري للنباتات وكذلك ارتفاع النبات، وعدد التفرعات للمتر المربع،
المحصول الطازج لكل من الحبوب والقش، وكذلك وزن 1000 حبة بينما كفاءة استخدام المياه
انخفضت، وكانت أعلى كفاءة في استخدام المياه مع معاملة الري 25% تبعها معاملة الري 100
و 50 و 75% من أقصى نتج بخر للمحصول على التوالي.

قام بتحكيم البحث

كلية الزراعة - جامعة المنصورة
كلية الزراعة - جامعة قناة السويس

أ.د / السيد محمود الحديدي
أ.د / عطيه عبد الوهاب السيسى