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The Response of Chickpea to Irrigation with Treated Waste Water

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Abstract: In a three-year study, the response of four cultivars of chickpea, Bulgarit, WIR-32, Jordan and ICC 11293 to irrigation with TW (treated wastewater) and FW (freshwater), using surface and subsurface drip irrigation was investigated. Wastewater generated from Al-Quds university campus included black, grey and storm water was treated by small scale pilot plant. The wastewater pilot plant consists of tailored made secondary biological activated sludge process with daily capacity of 50 m^3. The influent and effluent chemical and biological quality parameters were routinely monitored and analyzed. The data reveal that the average values for BOD, COD and EC for the effluent are 50 ppm, 136 ppm and 1.4 mS/cm over 2 years period. The results of chickpea growth parameters and the chemical and biological analysis of the seeds and leaves indicate that the cultivars Bulgarit and ICC 11293 can be irrigated with TW without any loss in yield and quality. Factor analysis reasonably favored Bulgarit Cultivar irrigated with treated effluent over other cultivars. WIR-32 and Jordan cultivars showed significant reduction in their growth parameters when irrigated with TW as compared with FW. Surface and subsurface drip irrigation gave similar results in most cases. Soil analysis in this study showed no significant difference between irrigation with TW and FW.

Key words: Chickpea, surface drip irrigation, sub-surface drip irrigation, treated wastewater.

1. Introduction

Water is scarce in Palestine where rural areas are suffering from shortage of water for domestic and agricultural use. Untreated wastewater is often disposed in open channels, reused for irrigation and presents a considerable public health risk [1, 2]. Therefore, rural wastewater management, including treatment and reuse should be of great interest in Palestine.

Chickpea, *Cicer arietinum* Linne, is an annual grain legume or pulse crop with multiple branch and spreading growth habit with a deep tap root system, having high quality protein. It is cultivated on a large scale in arid and semiarid environments and the demand for it is growing [3-6]. Chickpea is mostly rain fed and water limitation has been shown to reduce its yield [7-9]. Late winter or early spring planting of chickpeas as currently practiced in the Palestinian Territory, further restricts the grain yield. It was indicated that earlier autumn sowing of chickpea and supplementary irrigation with treated wastewater may enhance plant growth and yield [10].

This study aims to assess the effect of irrigation of four chickpea cultivars, Bulgarit, Jordan, WIR 32 and ICC 11293 with treated wastewater on yield and soil parameters.

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2. Methods and Materials

2.1 Experimental Site and Setup

The experimental site is situated at Al-Quds University Campus in Abu-Dies, 5 km east of Jerusalem. The average wastewater production from the campus kitchen, cafeteria and dormitories is 40 m^3/day. The duration of the experiment was 3 years (2009-2011).

The field adjacent to the treatment plant was divided into two main plots (125 m^2 each). One received surface and the other subsurface (25-30 cm deep) drip irrigation. Each main plot was divided into two sub-plots, one irrigated with FW (fresh water), and the other with TW (treated wastewater). Both were irrigated with 4 mm of water per day, over 100 days of the growing season.

Three cultivars of chickpea: Jordan, WIR-32 and Bulgarit were sawn on March 2009 and 2010, on both sides of the trickle line with 12 seeds/m in four replicates for each cultivar in a given treatment. The same experiment was repeated in March 2011 with two cultivars: Bulgarit and ICC 11293.

Three plants from each replicate were collected after harvest dried at 70 °C for three days and analyzed. Microbiological tests were done on fresh plants, soil and water samples using standard procedure [11]. The same standards procedure was used for nutrient determination in the seeds and leafs.

For biological growth parameters (efficiency, biomass, grain yield, harvest index and day to 50% flowering), four plants from each replicate were taken randomly. The mean value and standard deviation of the indicator were calculated.

Two of the chickpeas cultivars were Disi type, including Bulgarit and WIR-32 and the other two were Kabuli type, including Jordan and ICC 11293. The Disi cultivars are more resistant to Ascochyta blight, than the Kabuli type.

Ambient temperatures were ranging from minimum of 4.5 °C to a maximum of 40.7 °C. Humidity was ranging between 64% and 74%. The average precipitation rate for the winters 2008/2009, 2009/2010 and 2010/2011 is 200, 273 and 315 mm, respectively.

The soil in the reuse site is a loam brown earth having water permeability of 7.1×10^{-6} cm/s. Soil samples were collected before plantation and after harvest and physical, chemical and biological analysis performed according to standard procedures [11]. In the 2010/2011 cropping season, soil samples were taken from three depths: 0-5 cm, 5-30 cm and 30-60 cm.

Water is pumped from the storage pond to the field experiment. A pressure regulator controls the water pressure and a flow meter the quantity. Fertilizer pumps (Dositron international, DI 16 and non-electric proportional liquid dispenser) regulate and control fertilizer application. A filtration system (Arkal) following the fertilizer pump removes impurities and large particles. Trickle lines have pressure compensation drippers [12] delivering 2 L/h. The irrigation system was fully computerized.

2.2 Water Quality and Treatment

The TW was generated and collected from Al-Quds University campus and the FW was received from municipal sources. Monthly wastewater samples were taken from the raw (influent) and the treated (effluent). Analysis of pH, EC, BOD, solids and COD were according to standard methods [13].

A liquid fertilizer with a ratio of 5:3:8 of $N-P_2O_5-K_2O$ was applied through the irrigation system, dosed to supply 80 kgN/ha to all plots.

A package wastewater treatment plant (produced by DOTAN ecology—Israel) was installed at Al-Quds University main campus at Abu-Dies. It is based on the activated sludge-extended aeration treatment process [14]. The wastewater is collected in a two-stage primary settling basin and then pumped to the treatment plant. The treated wastewater from the aeration compartment is further treated by flocculation, chlorination and sand filtration and then stored in a storage pond for reuse. Average values of influent and effluent wastewater quality parameters over three years of the study are given in Table 1. The daily influent and effluent water quality values were highly fluctuating due to the variability of water use within the campus. However, all parameters are within the acceptable international health guidelines for the use of wastewater in agriculture [15].

3 Results and Discussion

3.1 Effect of TW on Soil Parameters

Tables 2-4 summarize the soil analysis for the experimental plot. There was no clear trend for soil pH between irrigation with TW as compared to FW both in surface and subsurface irrigation. The EC of soil before plantation in the season 2009 was higher than that of the season 2010. The data also indicated that the chloride and potassium content in soil before plantation in season 2009 were also higher than that obtained in season 2010. This is might be due to the high annual precipitation rate in year 2010 in addition to irrigation, causing increase soil leaching and thus lowering the salt content of soil. The results show that for the same year, no clear trend between the measured soil parameters irrigated with TW as compared to FW with both irrigation technologies. Similar results were also obtained for the season 2011.

The soil microbiology results (Table 5) indicate that both the soil TC (total coliform) and fecal coliform were reduced after harvest as compared to that of before plantation. These high removal rates of FC and TC after harvest indicate that the initial soil microbiology is not highly affected by the irrigation method and water quality. Furthermore, irrigation with TW yielded in low and acceptable microbial activity especially with subsurface drip irrigation, see Table 5.

Table 1 Chemical and biological analysis of wastewater before treatment (influent) and after treatment*(effluent).

Parameters	Influent	Effluent
pH	7.1 s.d. 0.2	7.5 s.d. 0.3
EC (ms/cm)	1.65 s.d. 0.2	1.4 s.d. 0.3
TS (ppm)	1120 s.d. 200	823 s.d. 120
TDS (ppm)	876 s.d. 200	747 s.d 104
TSS (ppm)	244 s.d 50	30 s.d 20
NO_3 (ppm)	12.4 s.d. 10	15.5 s.d. 10
Cl^- (ppm)	196 s.d. 100	192 s.d 100
SAR	21	11
BOD (ppm)	250 s.d. 100	50 s.d 30
COD (ppm)	420 s.d. 100	136 s.d 50
Fecal Coliform (count/100 mL)	> 1600	0
Total Coliform (count/100 mL)	1.6 ± 10^5	0

Data are the average values obtained between the years 2009-2011.
s.d. = Standard Deviation.

Table 2 Soil parameters of the 0-5 cm layer for the Cropping Seasons 2009 and 2010.

Parameter	Irrigation System	2009*		2009**		2010*		2010**	
		FW	TW	FW	TW	FW	TW	FW	TW
pH s.d. 0.1	Surface	7.22	7.33	7.47	8.00	8.01	7.99	7.80	8.00
	Subsurface	8.15	7.35	7.80	8.60	7.88	7.86	7.80	8.60
EC (ms/cm) s.d. 0.04	Surface	0.24	0.32	0.27	0.17	0.21	0.18	0.14	0.17
	Subsurface	0.22	0.28	0.27	0.28	0.21	0.24	0.18	0.12
Cl^- (mg/g) s.d. 0.08	Surface	0.59	0.36	0.23	0.27	0.07	0.04	0.20	0.30
	Subsurface	0.18	0.28	0.20	0.40	0.03	0.03	0.40	0.20
HCO_3^- (mg/g) s.d. 0.05	Surface	0.20	0.15	0.10	0.01	2.10	2.33	0.55	0.49
	Subsurface	0.10	0.13	0.07	0.02	0.03	2.04	0.67	0.70
K (mg/g) s.d. 0.03	Surface	0.06	0.06	0.05	0.06	0.02	0.02	0.01	0.02
	Subsurface	0.05	0.06	0.01	0.05	0.01	0.02	0.03	0.02

* Before plantation; ** After harvesting.

Table 3 Soil parameters at different depths before plantation for the cropping season 2011.

Parameters	Irrigation System	Soil Depth in cm 0-5 FW	0-5 TW	5-30 FW	5-30 TW	30-60 FW	30-60 TW
pH s.d. 0.1	Surface	8.10	8.00	8.00	7.80	8.00	8.30
	Subsurface	8.30	8.00	8.20	8.00	8.20	7.90
EC (ms/cm) s.d. 0.04	Surface	0.17	0.20	0.15	0.14	0.15	0.17
	Subsurface	0.21	0.16	0.17	0.181	0.17	0.13
Cl^- (mg/g) s.d. 0.08	Surface	0.29	0.46	0.30	0.12	0.31	0.17
	Subsurface	0.53	3.61	0.39	1.63	0.41	1.40
HCO_3^- (mg/g) s.d. 0.05	Surface	0.91	1.16	0.88	0.90	0.82	0.92
	Subsurface	1.07	0.83	1.01	0.86	0.92	0.70
K (mg/g) s.d. 0.03	Surface	0.21	0.29	0.16	0.15	0.14	0.14
	Subsurface	0.28	0.40	0.20	0.15	0.14	0.10
Na (mg/g) s.d. 0.1	Surface	0.29	0.82	1.27	1.21	1.87	1.53
	Subsurface	0.96	0.37	1.07	0.59	0.94	0.66
Organic N(mg/g) s.d. 0.01	Surface	0.01	0.55	0.02	0.03	0.02	0.03
	Subsurface	0.02	0.03	0.03	0.03	0.02	0.01
P (mg/g) s.d. 0.05	Surface	0.30	0.68	0.43	0.85	0.38	0.53
	Subsurface	0.53	0.90	0.45	0.50	0.35	0.68

Table 4 Soil parameters at different depths after harvesting for the cropping season 2011.

Parameter	Irrigation System	Soil Depth in cm 0-5 FW	0-5 TW	5-30 FW	5-30 TW	30-60 FW	30-60 TW
pH s.d. 0.1	Surface	8.20	8.00	8.40	8.00	8.40	8.00
	Subsurface	8.50	8.20	8.10	8.10	8.40	8.40
EC (ms/cm) s.d. 0.04	Surface	0.15	0.15	0.12	0.14	0.11	0.15
	Subsurface	0.10	0.13	0.11	0.11	0.12	0.11
Cl^- (mg/g) s.d. 0.08	Surface	0.18	0.33	0.38	0.21	0.26	0.24
	Subsurface	0.20	0.21	0.21	0.24	0.32	0.22
HCO_3^- (mg/g) s.d. 0.05	Surface	0.87	0.59	0.63	0.57	0.53	0.63
	Subsurface	0.51	0.65	0.59	0.42	0.57	0.51
K (mg/g) s.d. 0.03	Surface	0.01	0.02	0.01	0.02	0.01	0.27
	Subsurface	0.01	0.22	0.02	0.02	0.01	0.01
Na (mg/g) s.d. 0.1	Surface	0.15	0.15	0.16	0.15	0.10	0.17
	Subsurface	0.08	0.14	0.10	0.14	0.14	1.01
Organic N(mg/g) s.d. 0.01	Surface	1.36	3.72	1.65	2.42	1.26	1.42
	Subsurface	2.50	4.00	1.68	4.00	1.36	2.20
P (mg/g) s.d. 0.05	Surface	1.20	1.30	1.10	1.20	0.20	1.20
	Subsurface	1.20	1.30	1.10	1.30	1.00	1.40

Table 5 FC (fecal coliform) and TC in soil 0-5 cm layer for cropping season 2011.

Sample	TC before	TC after	FC before	FC after
F.S	14,000	300	400	< 20
W.S	11,000	3,000	400	< 20
F.SUB	30,000	900	600	40
W.SUB	50,000	500	400	< 20

3.2 Effect of TW on Chickpea Growth Efficiency

Table 6 displays the results for the efficiency of forming pods of the different chickpea cultivars for the seasons 2009 and 2010. The chickpea growth efficiency is defined as the number of pods forming seeds divided by the total pods and nods in the growing window. Field data indicates that the efficiency in the year 2010 is higher than that in the year 2009. No significant difference found between irrigation with TW and FW in both years. In addition, no difference was found between surface and subsurface drip irrigation for all the three cultivars. Table 7 shows the efficiency for the cultivar ICC11293 in the third year. It also shows similar efficiency values between irrigation with TW and FW when using both irrigation technologies.

3.2.1 Biomass Production

The biomass definition is the weight of plant above the ground (from the surface of field) after it is completely dried. The data indicates that the biomass of the three cultivars of chickpea is higher for 2010 as compared to 2009 (Table 6). In 2009 Jordan and WIR-32 cultivars gave less biomass when irrigated with TW, as compared to FW. On the other hand, the cultivar Bulgarit gave better results when irrigated with TW as compared to FW. In the year 2010 the same trend for Bulgarit was observed. However, Jordan and WIR-32 showed different trends, while WIR-32 maintained its decrease in biomass as a result of irrigation with TW, the cultivars Jordan changed this trend and showed similar results when compared to irrigation with FW. This can be explained by the

Table 6 Biological growth parameters and the phonology for Bulgarit, Jordan, and WIR 32 irrigated with TW and FW using surface and subsurface irrigation technology during 2009 and 2010 seasons.

FW										
	Surface					Subsurface				
	Biomass kg	Grain yield g/m^2	HI	Efficiency	Days 50% flowering	Biomass kg	Weight seeds gm	HI	Efficiency	Days 50% flowering
Bulgarit (2009)	0.277 s.d.0.06	121.86 s.d.48	0.43 s.d.0.11	0.278 s.d.0.1	71	0.344 s.d.0.02	149.23 s.d.2.0	0.435 s.d.0.03	0.244 s.d 0.07	71
Bulgarit (2010)	0.337 s.d 0.05	79.15 s.d 18	0.232 s.d 0.02	0.761 s.d 0.09	69	0.504 s.d 0.07	107.95 s.d 17.8	0.216 s.d 0.05	0.744 s.d 0.1	69
Jordan (2009)	0.364 s.d 0.11	189.17 s.d 32.2	0.52 s.d 0.07	0.214 s.d 0.09	63	0.464 s.d 0.07	205.25 s.d 25	0.445 s.d 0.04	0.339 s.d 0.1	63
Jordan (2010)	0.447 s.d 0.1	201.92 s.d 63.3	0.447 s.d 0.05	0.899 s.d 0.1	63	0.741 s.d 0.2	286.9 s.d 95.6	0.390 s.d 0.01	0.584 s.d 0.1	63
WIR-32 (2009)	0.514 s.d 0.04	212.89 s.d 26.2	0.413 s.d 0.02	0.229 s.d 0.05	63	0.552 s.d 0.3	214.43 s.d 25.0	0.389 s.d 0.03	0.301 s.d 0.08	63
WIR-32 (2010)	0.847 s.d 0.07	296.4 s.d 39.6	0.392 s.d 0.009	0.824 s.d 0.1	69	0.680 s.d 0.2	232.4 s.d 62.5	0.342 s.d 0.015	0.812 s.d 0.1	69

TW										
	Surface					Subsurface				
	Biomass kg	Weight seeds	HI	Efficiency	Days to 50% flowering	Biomass kg	Weight seeds gm	HI	Efficiency	Days 50% flowering
Bulgarit (2009)	0.402 s.d 0.02	134.52 s.d 14.3	0.337 s.d 0.05	0.306 s.d 0.1	54	0.402 s.d 0.05	142.07 s.d 24.17	0.353 s.d 0.02	0.306 s.d 0.1	62
Bulgarit (2010)	0.620 s.d 0.06	183.28 s.d 23.6	0.294 s.d 0.01	0.744 s.d 0.1	69	0.680 s.d 0.2	167.6 s.d 68.1	0.241 s.d 0.01	0.881 s.d 0.1	69
Jordan (2009)	0.349 s.d 0.09	120.26 s.d 22	0.354 s.d 0.07	0.176 s.d 0.05	63	0.264 s.d 0.05	101.43 s.d 28	0.384 ±0.1	0.225 s.d 0.06	54
Jordan (2010)	0.770 s.d 0.1	285.92 s.d 29.5	0.372 s.d 0.02	100 s.d 0.01	63	0.620 s.d 0.26	200.58 s.d 10.7	0.315 s.d 0.03	0.762 s.d 0.20	63
WIR-32 (2009)	0.331 s.d 0.03	87.16 s.d 26.0	0.269 s.d 0.09	0.161 s.d 0.06	54	0.331 s.d 0.03	100.47 s.d 9.1	0.304 s.d 0.01	0.159 s.d 0.05	63
WIR-32 (2010)	0.907 s.d 0.06	284.17 s.d 45.30	0.311 s.d 0.03	0.669 s.d ±0.1	66	0.455 s.d 0.07	90.01 s.d 16.6	0.186 s.d 0.05	0.783 s.d 0.1	66

Table 7 Biological growth parameters and phonology for the chickpea cultivar ICC 11293 irrigated with TW and FW during 2011 season.

Parameters	FW		TW	
Growth parameter	Surface	Subsurface	Surface	Subsurface
Biomass (kg/m^2)	0.41 s.d 0.06	0.5 s.d 0.06	0.56 s.d 0.07	0.45 s.d 0.06
Grain yield (g/m^2)	169 s.d 12	170 s.d 14	142 s.d 22	155 s.d 22
Harvest index	0.41 s.d 0.04	0.34 s.d 0.05	0.23 s.d 0.07	0.35 s.d 0.05
Efficiency	0.45 s.d 0.06	0.52 s.d 0.04	0.42 s.d 0.06	0.50 s.d 0.10
Days to 50% flowering	60	60	58	60

increase in annual precipitation in the year 2010 (273 mm) as compared to the year 2009 (200 mm) which resulted in the observed tolerance of Jordan. Upon comparing the results of the two years, it is obvious that in 2009 the cultivar Bulgarit gave higher biomass when using TW as compared to FW, while Jordan and WIR-32 showed a decrease in their biomass. In the second year Bulgarit and Jordan cultivars display a pronounced performance in their biomass when irrigated with TW under lower salt stress as compared to FW in contrast to the year 2009 where only Bulgarit showed this behavior. The biomass of cultivar ICC 11293 (Table 7) when irrigated with TW were 0.56 kg/m^2 and 0.45 kg/m^2 for surface and subsurface irrigation respectively. On the other hand, the FW gave biomass of 0.41 kg/m^2 and 0.5 kg/m^2 for surface and subsurface irrigation respectively. These data indicates that while TW gave no significant effect on the biomass of ICC 11293 cultivars as compared to FW using subsurface irrigation technology an improvement with surface drip irrigation using TW was observed.

3.2.2 Grain Yield

The grain yield definition is the weight of dried seeds per 1 m^2 of plant in grams. In 2009 the grain yield of Bulgarit when irrigated with TW was similar to that when irrigated with FW using surface and subsurface technologies. Jordan and WIR-32 showed a decrease in their grain yield when irrigated with TW for both technologies (Table 6).

In year 2010 the cultivars Bulgarit and Jordan show improvement in the grain yield for TW and surface drip irrigation. The cultivar WIR-32 shows a decrease in its grain yield in both surface and subsurface drip irrigation using TW as compared to (FW). Irrigation of the cultivar ICC11293 for the season 2011 with treated effluent as compared to the results of FW gave similar results (Table 7). This means that no significant effect of irrigation with TW using both irrigation technologies as compared to FW. These results may be attributed to difference in salt tolerance of the three cultivars induced by irrigation with TW. However, we can not rule out other effects on yield such as the hindrance of molybdenum uptake by the plant. Further experiments to verify this explanation is currently under investigation.

3.2.3 Harvest Index

The harvest index (the dry weight of seeds divided by the dry weight of the above the ground biomass of the plant) was altered in the different seasons and by changing the irrigation technique. The harvest index in 2009 is higher than that in 2010 for all cultivars using the two different irrigation technologies (Table 6).

In 2009 the harvest index for all cultivars using TW are less than that of FW. In 2010 the harvest index of Bulgarit cultivar increased when using TW. Jordan and WIR-32 suffered from irrigation with TW although the cultivars Jordan shows some resistant to TW in year 2010 compared to year 2009, due to the difference in annual precipitation. The harvest index for the cultivars ICC 11293 (Table 7) displayed opposing trends. While surface drip irrigation decreased the harvest index using TW as compared to FW, subsurface drip irrigation gave the opposite result. This may be explained by the increase of the biomass with TW using surface drip irrigation and hence the decrease in the harvest index is the expected result. Irrigation with TW increases the biomass production and decreases the grain yield. This can be attributed to the surplus of nutrients in TW as compared to FW.

3.2.4 Phenology

The phenology of all cultivars used was classified by the irrigation with FW, TW and for surface and subsurface systems (Tables 6 and 7). The Days to 50% flowering definition is the time at which the plants have at least one flowering for each. The data indicate that no difference between the times for 50% flowering upon irrigation with TW as compared to FW using both irrigation technologies.

3.3 Effect of Effluent on Chickpea Chemical Uptake

Sodium, potassium, phosphorous, organic nitrogen and microbiological analysis of leafs and seeds were necessary to control if the irrigation with TW may have affected the composition of the seeds or/and leafs of plant.

The data are presented in Tables 8-10. It was found that the sodium content in season 2009 was higher than that of the season 2010 in all three chickpea cultivars (Tables 6 and 7). This can be attributed to the difference in rainfall between the two years, which resulted in leaching the soil. The sodium content for seeds and leafs shows no significant difference between TW as compared to FW using both irrigation technologies.

Sodium content in leafs of the ICC 11293 in the season 2011 is higher than that in seeds (Table 10). But both seeds and leafs show no difference, in sodium content, between irrigation with TW as compared to FW using surface and subsurface drip irrigation. On the other hand, potassium content in season 2010 was higher than the season 2009. However, similar to sodium, the potassium content for both seasons gave no significant difference between irrigated with TW as compared to FW using the two

Table 8 Chemical analysis of leafs for Bulgarit, Jordan and WIR 32 cultivars of chickpea that irrigated with TW and FW during 2009 and 2010 seasons.

Sample	Na mg/g		K mg/g		Organic nitrogen (%)		P mg/g	
	2009	2010	2009	2010	2009	2010	2009	2010
Bulgarit	5.74	4.88	11.57	12.9	0.96	1.78	5.64	5.56
FW-Surface	s.d. 1.7	s.d. 0.7	s.d.1.8	s.d.1.4	s.d.0.16	s.d. 0.58	s.d.1.9	s.d.0.4
Bulgarit	7.45	2.88	11.91	11.3	1.56	1.81	9.42	4.52
TW-Surface	s.d. 1.6	s.d. 0.2	s.d.1.0	s.d.0.9	s.d. 0.25	s.d.0.16	s.d.0.9	s.d. 0.5
Jordan	7.92	4.25	10.83	11.8	1.01	2.06	7.63	4.7
FW-Surface	s.d. 2.8	s.d. 1.7	s.d.1.1	s.d.1.7	s.d.0.16	s.d.0.41	s.d.2.3	s.d.0.8
Jordan	9.04	2.42	12.44	15.26	2.66	2.00	10.13	3.32
TW-Surface	s.d. 3.4	s.d. 0.8	s.d 1.3	s.d. 0.9	s.d 0.74	s.d. 0.33	s.d. 2.40	s.d. 0.7
WIR-32	6.89	5.08	13.5	10.6	0.89	1.45	7.49	5.11
FW-Surface	s.d. 1.6	s.d. 0.8	s.d.1.1	s.d.3.1	s.d.0.16	s.d.0.33	s.d.1.9	s.d.0.4
WIR-32	5.33	3.95	14. 29	16.7	2.32	3.05	7.45	4.85
TW-Surface	s.d. 1.0	s.d. 0.2	s.d.0.1	s.d.1.0	s.d. 1.0	s.d. 1.3	s.d. 1.0	s.d. 0.2
Bulgarit	6.37	3.98	11.3	19.33	1.15	2.51	7.63	4.99
FW-Subsurface	s.d. 0.9	s.d. 0.9	s.d. 0.6	s.d.0.5	s.d.0.82	s.d.1.07	s.d.1.8	s.d.0.9
Bulgarit	8.79	3.85	10.89	13.4	1.56	1.98	10.32	5.57
TW-Subsurface	s.d. 3.1	s.d. 0.3	s.d. 1.6	s.d.0.8	s.d.0.21	s.d.0.58	s.d.2.50	s.d.0.7
Jordan	6.11	3.95	12.27	10.8	1.1	2.36	7.53	4.972
FW-Subsurface	s.d. 1.9	s.d. 0.7	s.d.0.6	s.d.0.09	s.d.0.08	s.d.0.33	s.d.1.9	s.d.0.4
Jordan	8.69	3.63	13.51	13.4	1.87	1.74	8.69	4.62
TW-Subsurface	s.d. 2.5	s.d. 1.0	s.d.1.5	s.d.1.0	s.d.0.33	s.d. 0.58	s.d.1.6	s.d.0.5
WIR-32	6.14	5.81	12.89	6.95	1.04	1.56	7.22	6.03
FW-Subsurface	s.d. 1.1	s.d. 0.3	s.d.1.4	s.d.1.2	s.d.0.08	s.d.0.25	s.d.1.9	s.d.0.4
WIR-32	4.95	3.66	12.64	15.6	1.53	2.17	5.74	5.45
TW-Subsurface	s.d. 1.5	s.d. 0.9	s.d.4.8	s.d.2.0	s.d.0.25	s.d.0.41	s.d.1.4	s.d. 1.8

Table 9 Chemical analysis of seeds for Bulgarit, Jordan, and WIR 32 that irrigated with TW and FW during 2009 and 2010 seasons.

Sample	Na mg/g 2009	Na mg/g 2010	K mg/g 2009	K mg/g 2010	Organic nitogen (%) 2009	Organic nitogen (%) 2010	P mg/g 2009	P mg/g 2010
Bulgarit	5.16	0.993	9.07	14.9	2.05	3.61	6.04	4.9
FW-Surface	s.d.0.72	s.d.0.24	s.d.0.2	s.d.0.8	s.d.0.23	s.d.0.36	s.d.0.70	s.d.0.25
Bulgarit	2.54	0.95	11.08	16.5	3.58	3.55	6.55	5.25
TW-Surface	s.d.6.82	s.d. 0.24	s.d.0.63	s.d.0.6	s.d.0.31	s.d.0.42	s.d.0.48	s.d.0.33
Jordan	3.02	1.06	8.82	14.4	2.76	3.40	5.84	4.7
FW-Surface	s.d.1.21	s.d.0.362	s.d.0.62	s.d.0.32	s.d.0.20	s.d.0.58	s.d.0.63	s.d. 0.17
Jordan	2.54	1.22	10.40	15.8	3.51	3.45	6.55	4.815
TW-Surface	s.d.0.87	s.d.0.55	s.d.0.97	s.d.0.34	s.d.0.20	s.d.0.66	s.d.0.48	s.d.0.28
WIR-32	2.41	1.312	10.33	14.14	2.93	3.40	5.19	4.24
FW-Surface	s.d.0.65	s.d.0.48	s.d.0.27	s.d.0.72	s.d.0.16	s.d.0.68	s.d.0.39	s.d.0.30
WIR-32	1.52	0.86	10.66	16.91	3.66	3.55	6.51	4.50
TW-Surface	s.d. 0.45	s.d.0.21	s.d.1.26	s.d.0.24	s.d.0.26	s.d.0.30	s.d.0.40	s.d.0.41
Bulgarit	3.75	0.94	9.33	15.3	2.54	3.33	5.36	5.17
FW-Subsurface	s.d. 0.77	s.d.0.35	s.d.0.77	s.d.0.19	s.d.0.16	s.d. 0.33	s.d.0.43	s.d.0.37
Bulgarit	2.97	1.213	10.53	15.99	3.79	4.24	6.40	5.73
TW-Subsurface	s.d.0.74	s.d.0.192	s.d.1.0	s.d.0.14	s.d.0.17	s.d.0.71	s.d.0.81	s.d.0.5
Jordan	2.54	1.055	9.90	14.8	2.62	3.20	5.52	4.77
FW-Subsurface	s.d.0.49	s.d.0.4	s.d.0.97	s.d.0.98	s.d.0.47	s.d.0.43	s.d.0.56	s.d.0.37
Jordan	1.43	1.08	10.19	15.41	3.96	3.75	6.62	5.192
TW-Subsurface	s.d 0.56	s.d 0.018	s.d 0.48	s.d 0.56	s.d 0.33	s.d 0.41	s.d 1.35	s.d 0.29
WIR-32	1.66	0.774	6.6	14.63	1.87	3.15	7.8	4.31
FW-Subsurface	s.d.0.30	s.d.0.18	s.d.0.26	s.d.0.51	s.d. 0.12	s.d.0.52	s.d.0.25	s.d. 0.24
WIR-32	0.91	1.03	10.19	17.5	3.45	4.31	5.8	5.38
TW-Subsurface	s.d. 0.28	s.d.0.14	s.d.0.04	s.d.1.2	s.d.0.34	s.d.0.7	s.d.0.67	s.d.0.53

Table 10 Chemical analysis of leafs and seeds of ICC 11293 cultivar irrigated with TW and F.W during 2011 season.

Irrigation technique	Leafs K (mg/g)	Leafs Na (mg/g)	Leafs Organic nitrogen (%)	Leafs P (mg/g)	Seeds K (mg/g)	Seeds Na (mg/g)	Seeds Organic nitrogen (%)	Seeds P (mg/g)
FW-Surface	1.40 s.d. 0.20	0.97 s.d. 0.20	2.87 s.d. 0.58	8.39 s.d. 0.10	1.81 s.d. 0.10	0.19 s.d. 0.10	8.22 s.d. 0.82	3.47 s.d. 0.10
TW-Surface	2.02 s.d. 0.40	1.19 s.d. 0.10	3.67 s.d. 1.48	10.3 s.d. 0.20	2.0 s.d. 0.02	0.31 s.d. 0.10	9.22 s.d. 0.58	5.45 s.d. 0.10
FW-Subsurface	1.45 s.d. 0.10	0.68 s.d. 0.40	2.46 s.d. 0.91	3.49 s.d 0.05	1.84 s.d. 0.05	0.23 s.d. 0.03	7.97 s.d. 1.24	3.80 s.d. 0.40
TW-Subsurface	2.02 s.d. 0.05	0.91 s.d. 0.20	3.13 s.d. 0.41	4.94 s.d. 0.80	1.74 s.d. 0.09	0.21 s.d. 0.06	7.78 s.d. 0.58	4.82 s.d. 0.30

irrigation technologies. Similar trend is also observed for ICC 11293 (Table 10). Phosphorous in season 2009 was higher than season 2010. The P content in leafs is higher than that in seeds for both seasons. In the two seasons the P content in seeds and leafs indicated that no different between irrigation with TW as compared to FW using surface and subsurface drip irrigation for all the cultivars.

The phosphorus content in the seeds and leafs of the cultivar ICC 11293 (Table 10) indicates that phosphorus content in the leaf is higher than the seed in surface drip irrigation and approximately the same in subsurface drip irrigation. Leafs and seeds show no difference between the irrigation with TW as compared to FW with two different irrigation technologies. Organic nitrogen content in leafs and seeds of the different cultivars of chickpea for the first two seasons indicated that seeds and leaves have approximately the same values for both season. In both seeds and leafs, no significant difference between the organic nitrogen content upon irrigation with TW as compared to FW for all cultivars.

Table 11 FC and TC (count/100 mL) of plant irrigated with TW and FW for 2009, 2010 and 2011 seasons.

Sample	TC (2009)	TC (2010)	TC (2011)	FC (2009)	FC (2010)	FC (2011)
FW-Surface	170	170	500	< 20	70	< 10
TW-Surface	210	220	600	< 20	20	20
FW-Subsurface	300	900	400	< 20	200	< 10
TW-Subsurface	450	330	900	< 20	110	< 10

The results of TC and FC (Table 11) of the different type of plant indicate that there is no clear trend between irrigation with TW as compared to FW. It can be concluded that there is no extra risk is involved upon irrigation with TW that have similar quality as compared to FW. This is not surprising since the TW is continuously chlorinated to kill all microorganisms.

3.4 Factor Analysis Results

Factor analysis, was used to analyze interrelationships among the various variables and to explain these variables in terms of their common underlying dimensions. SAS 2001 [16] was used to conduct these analyses.

From the component and principal factor analysis, one factor or component with eigenvalue greater than one was retained. This component accounted for 95.3% of the variance, a high adequate value to represent the data collected and a result that represent a strong evidence that this factor is strong enough for covering high percentage of the data (4.7% of the variance was left for all other factors making them comparably insignificant).

The pattern of the component or principal factor retained indicates highest partial correlation given to Bulgarit cultivar irrigated with treated effluent and using subsurface drippers—BTWSS (99.93%) followed by Bulgarit cultivar irrigated with treated effluent and using surface drippers (99.90%). Other variables (cultivars) were found to have high partial correlations but still less than the Bulgarit cultivar. Accordingly we can reasonably call the factor retained the Bulgarit cultivar irrigated with treated effluent.

4. Conclusions

The response of four cultivars of chickpea, namely Bulgarit, WIR-32, Jordan and ICC11293 to irrigation using TW and FW during three years revealed that irrigation TW is highly comparative with FW.

Two cultivars tested namely Bulgarit and ICC 11293 can be irrigated with TW, using surface and subsurface irrigation systems, without any loss in yield. Furthermore, irrigation with TW improved some biological growth parameters of these cultivars. WIR-32 and Jordan cultivars showed significance reduction in their biological growth parameters when irrigated with TW as compared with fresh water.

Factor analysis of the obtained field and laboratory results for the four tested chickpea cultivars including physical and chemical growth and yield data indicated reasonably that Bulgarit cultivar irrigated with treated effluent using either surface or subsurface irrigation drippers represent the best cultivar or reuse option.

Surface and subsurface drip irrigation gave similar results for the four cultivars. However, the overall efficiency in the growing season of year the 2010 was higher than that in the year 2009 for both systems. Chemical composition of seeds and leafs were also similar for the four cultivars. The soil analysis shows no significant difference between irrigation with TW and FW.

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