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Effect of Drip Irrigation with Treated Wastewater on Some Field Crops in Sandy Soil

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Abstract: This work was undertaken in order to investigate the problems of using drip irrigation system in field crops irrigation with treated wastewater. Another object of the study was to evaluate treated wastewater as additional water resource under water scarce conditions. Large scale field trials were conducted in sandy soil to investigate the effect of legume crops irrigation with secondary treated wastewater from wastewater treatment plant in Cairo in two successive seasons of winter 2017/2018 and 2018/2019 in Berka site located about 20 km north east of Cairo. Faba bean and lupin were grown and irrigated either with surface or drip systems. The results showed some advantages of using treated wastewater where considerable amounts of macronutrients (NPK) were applied to the grown crops during treated wastewater irrigation *i.e.*; N (61-64%), P (73-76%) and K (99-208%) of the recommended fertilizer rates according to the crop. Heavy metals derived from treated wastewater were very small. Crop yields showed significant differences when treated wastewater was combined with the recommended fertilizer rates for each crop. Irrigation by surface was more efficiently used by the crops, compared with drip irrigation on area basis. However at an individual plant level, drip irrigation produced larger yields than surface irrigation, although this method would not be employed commercially for such crops on economic grounds. It could be concluded from this study that there are some advantages of using treated wastewater in field crop irrigation through saving water and fertilizers and decreasing the pressure on Egyptian water budget. However some disadvantage appeared under drip irrigation practice through the lower plant density of field crops under this system which affect the final yield as well as the operational problems like clogging and blockage of the network components due to the total suspended solids in the treated.

Key words: Drip irrigation field crops · Sandy soil · Treated wastewater · Nutrients · Heavy metals

INTRODUCTION

The current water budget in Egypt show that the annual water demand exceeds the available fresh water by 6 billion m^3 $year^{-1}$ [1]. Water uses are rising because of the ambitious land reclamation programme, growing population, steady rural development and urbanization plans and expanding the industrial sector. Therefore, it is essential to develop water resources through untraditional ones. Wastewater has been used to support the agricultural production in many countries such as USA, Germany, India, Kuwait, Saudi Arabia, Oman, Jordan and Tunisia. Rowe and Abd-El Magid [2] and Libutti *et al*. [3] stated that many countries of the Mediterranean region, characterized by frequent drought periods, agricultural production often occurs under water deficiency or conditions that cause the depletion of the existing water resources. In these areas, the reuse of reclaimed wastewater for crop irrigation could contribute to mitigate/decrease water shortage, support the agriculture sector and protect groundwater resources. The area of land to be irrigated with wastewater increased significantly over two past decades due to the constrains on water supply and increasing the concerns over the environmental implications [4]. Several investigators indicated the beneficial role of wastewater in increasing crop yields without or with minimal risks to the plant , soil, groundwater and health [5-10].

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Currently, the secondary treated wastewater generated from Alexandria is about 351.5 million m^3 $year^{-1}$ and up to 87.5 million m^3 $year^{-1}$ is secondary treated [11]. From environmental point of view such quantities should be disposed off safely. At the same time this quantity is a valuable resource and potentially sufficient to irrigate about 100, 000 feddans (42, 000 hectare). Agriculture is one of the proposed outlets with an identified benefit from the recycling the nutrients in wastewater. WRc [12] estimated that wastewater could offer about 30% of the crop requirements of N and 100% or more from crop requirements of K in sandy calcareous soil in Alexandria. However, they pointed out that in the long-term monitoring for potential toxic elements (mainly heavy metals), groundwater and pathogen survival is necessary to to be considered to protect the environment and human health. Kadasiddappa and Rao [13] reported that irrigation application can be reduced by 50 to 80 per cent with drip irrigation compared to surface irrigation. Further, drip irrigation has the potential for improving two of the most common contributing factors to N leaching over fertilization and over irrigation. Therefore, optimum irrigation levels with suitable method would help in enhancing the economic yield as well as water use efficiency of maize crop under Egyptian conditions drip irrigation has introduced many distinct agricultural irrigation technologies that have contributed to a great economic development [14]. Many researchers have studied the effects of irrigation system and irrigation management at different levels and fertilizers and various plants on net profit. Estimation of net income in some of the previous studies, due to the loss in one or more fixed costs such as the cost of capital and the rent value of land where irrigation water is provided free of charge to the owners of farms [15].

Therefore, the aim of this work is to evaluate the effect of treated wastewater on crop yield and quality under calcareous soil conditions.

MATERIALS AND METHODS

This work was carried out in two sites using all the facilities installed by the project "Cairo East Bank Effluent Re-use Study", the client is the Cairo Wastewater Organuzation (CWO) and the study is partially funded by the Kuwait Fund for Arab Economic Development (KFAED). The study was implemented by a joint venture consortium of Montgomry Watson, Gibb International and some other Arab companies. After completing the study the facilities (irrigation networks, equipment) were used in this study. Large scale field trials were carried out in two successive seasons of winter 2017/2018 and 2018/2019 in Berka site l ocated about 20 km north east of Cairo, the soil is gravelly sand and could be classified as virgin soil. The area of the site was 10 feddans (4.2 hectars) close to the new Gabal El- Asfar wastewater treatment plant. The experimental site was cultivated using fixed tine-harrow, then leveling was carried out. The experimental area was divided to large experimental unites according to the crop and the irrigation method. The experiment was arranged as factorial where the the first factor (A) was irrigation systems and factor (B) was legume crops and factor (C) was fertilizer application unites where half of the experimental units received treated wastewater only and the other half received wastewater plus supplementary fertilizer to be adjusted for each crop according to the normal recommended rates. Two crops were planned to grow in the site.

Irrigation type	Fertilizer	Crop	Irrigation type	Fertilizer	Crop
Surface	-F	Faba bean	Drip	-F	Lupin
Surface	+F	Faba bean	Drip	+F	Lupin
Surface	-F	Lupin	Drip	-F	Faba bean
Surface	+F	Lupin	Drip	+F	Faba bean
Drip	-F	Faba bean	Surface	-F	Lupin
Drip	+F	Faba bean	Surface	+F	Lupin
Drip	-F	Lupin	Surface	-F	Faba bean
Drip	+F	Lupin	Surface	+F	Faba bean
Surface	-F	Lupin	Drip	-F	Lupin
Surface	+F	Lupin	Drip	+F	Lupin
Surface	-F	Faba bean	Drip	-F	Faba bean
Surface	+F	Faba bean	Drip	+F	Faba bean
Drip	-F	Lupin	Surface	-F	Lupin
Drip	+F	Lupin	Surface	+F	Lupin
Drip	-F	Faba bean	Surface	-F	Faba bean
Drip	+F	Faba bean	Surface	+F	Faba bean

Fig. 1: The experimental layout

Irrigation systems were included in the trial to demonstrate and compare their respective effects on water use efficiency crop production and potential health and environmental hazards. Drip irrigation for lupin and fababean as well as surface irrigation. The irrigation water was filtered in pressure filters to avoid emitters clogging. The irrigation water was measured by water meter for each plot. The detailed scheduled irrigation quantities applied to each crop under different irrigation systems are presented in the Appendices (Tables A1, 2 and B1, 2).

Irrigation Network Details: The drip irrigation network included (1) Control head: It is located at the water source supply. It consists of centrifugal pump 4``/4``, driven by diesel engine (pump QRM charge of 100 m^3 h^{-1} and 50 m lift), sand media filter 48`` (two tanks), screen filter 2`` (120 mesh) back flow prevention device, pressure regulator, pressure gauges, flow-meter, control (2) Main line: PVC pipes of 125 mm in diameter (OD) to convey the water from the source to the main control points in the field. (3) Sub-main lines: PVC pipes of 75 mm diameter (OD) were connected to with the main line through a control unit consists of a 2`` ball valve and pressure gauges. (4) Manifold lines: PVC pipes of 40 mm in diameter (OD) were connected to the sub main line through control valves 1.5``. (5) Emitters: These emitters Built in (GR) dripper from Polyethylene (PE) tubes 16 mm in diameter (OD) and 50 m in long (emitter QRM charge of 4 lph at 1.0 bar operating pressure, 0.3 m spacing between emitters, 1.0 m spacing between lateral lines.

Crop selection included faba bean (Giza 3 variety), lupine (Giza 1 variety). Fertilizers were applied according to the normal recommended rates in Egypt. Nitrogen phosphorus and potassium were applied as ammonium nitrate (33.5% N), calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O), respectively.

Crop Growth and Yield Assessment: During the two crop cycles the crops were routinely inspected for diseases, pests and weed control. At crop maturity, the growth characteristics and yield components were assessed. The individual plant measurements included plant height and weight, number of branches per plant as well as number, weight of fruiting organs (pods, seeds). The conventional assessment practices were followed to provide mean individual plot performance as well as biological, straw and grain or seed yield fed^{-1}.

Treated Wastewater Analysis: Samples of treated wastewater from El Berka were taken during crop cycles and analysed for a range of agronomic and environmental parameters. Nutrient and heavy metal loading rates to field trials were calculated according to the irrigation quantities applied to each crop in order to assess the acceptability of these wastewaters for reuse in short and long-term of full-scale operation of the wastewater treatment plants. Another objective of these analyses was to determine wastewater compliance with the Egyptian limit values of Egyptian Code, 501 [16]. Treated wastewaters were analysed according to [17].

Statistical Analysis: The data were subjected to statistical analysis of variance of split plot design was carried out using MSTAT-C Computer Software [18]. Since the trend was similar in both seasons the homogeneity test Bartlet's equation was applied and the combined analysis of the two seasons was done. Means were compared by using least significant difference (LSD) at 5%.

RESULTS AND DISCUSSION

Wastewater Quality: Inspecting water clogging for the drip irrigation network during irrigation practice recorded that about 15-20 % 0f the drippers suffered from clogging and affected the surrounded wetting area for the plants . This was considered to be due to bacterial or algal flocs present in the tank from which the effluent was pumped for the trial and frequent flushing of the irrigation filters was required. This is crucial for drip irrigation to avoid blockage of the emitters.

Final wastewater samples collected El Berka WWTP over the period of the trials were routinely analysed for nutrients and heavy metals. All of the results are summarised in Table 1 giving means, minimum and maximum values, the number of analyses (n) and the coefficient of variation (CV%) to indicate the overall variability of the data. Since these analyses are based on grab samples, the CVs would be expected to be relatively large and particularly for those parameters (e.g. heavy metals) where the concentrations were close to their analytical detection limits.

The pH of the wastewaters was within the acceptable range for reuse, normally 6.5 - 8.5. The nutrient contents of the wastewater were broadly as may be expected. Based on these analyses, El Berka treated wastewater had a superior nutrient content and NPK ratio in relation to general crop requirements. The heavy metal concentrations were very small and are well below the limit values for secondary wastewater reuse, usually by at least one order of magnitude. Most of heavy metals occur at comparable concentrations, the zinc content was high, but still well below the limit value for reuse of 2 mg/l. Since zinc deficiency is widespread in Egyptian agriculture, wastewater may provide useful alternative source of this essential trace element. It is worthy to mention that although the analysis of treated wastewater complied with the Egyptian cod of practice, 501 [16] according to the guidelines by WHO [19] all the precautions for preventing exposing of the workers to the irrigation practice were done. Also, since all of the treated wastewaters used for the field trials pass through sand filters prior to irrigation.

Table 1: Mean concentrations of treated wastewater chemistry from El Berka WWTP

Parameters	Mean	Min.	Max.	n	CV
pH	7.78	7.65	7.86	9	0.8
Total N	12.8	7.4	18.7	25	23.9
Total P	3.4	1.2	5.3	26	29.3
K	13.8	8.3	24.1	27	23.3
B	0.4	0.4	0.4	1	-
Fe	0.58	0.064	0.980	13	54.8
Mn	0.12	0.010	0.320	11	67.4
Cr	0.03	0.006	0.087	11	120.0
Ni	0.039	0.007	0.082	11	68.7
Zn	0.094	0.011	0.180	11	67.7
Cu	0.049	0.014	0.093	11	56.2
Cd	<0.005	<0.005	<0.005	13	-
Pb	0.079	0.031	0.130	13	31.7
Mo	<0.01	<0.01	<0.01	11	-
Co	<0.005	<0.005	<0.005	11	-

Units: All determinands in mg/l except: pH

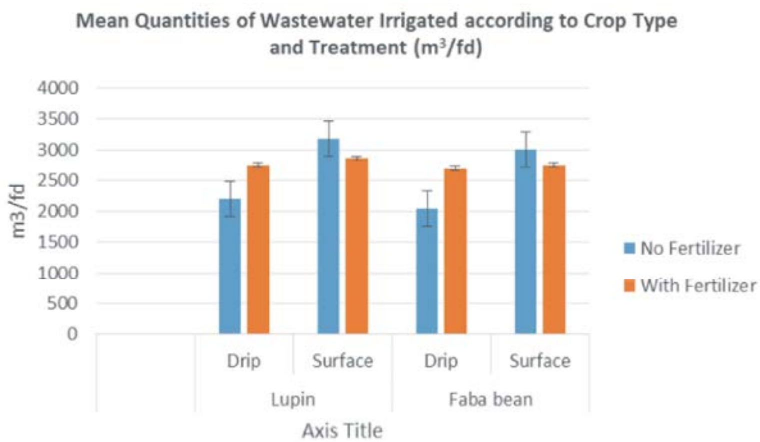

Fig. 2: Total wastewater quantities irrigated to lupin and faba bean with drip and surface irrigation

Table 2: Mean quantities of wastewater irrigated according to crop type and treatment (m^3 fd^{-1})

		Fertilizer	
Crop	Irrigation method	None	Applied
Lupin	Drip	2204	2149
Lupin	Surface	3177	2858
Faba bean	Drip	2041	2093
Faba bean	Surface	3001	2742

Wastewater and Chemical Additions: Irrigation quantities were accurately recorded for each plot at both crops during the growing seasons. Table (2) and Fig. 2 summarises the amounts of wastewater irrigated to each crop and fertilizer treatment, as means of the plots of each treatment. Although a fixed irrigation schedule was envisaged, this had to be adapted according to crop water requirements as observed in the field. As anticipated, the irrigation requirement was much greater than the capacity of this soil and need for more leaching to control salinization of the soil surface.

The quantities of wastewater applied were broadly in line with normal practice and these are related to the basic water requirement which varies between crops and the length of the growing season. Conversely, faba bean has a small water requirement, as indicated by the quantities irrigated in order to achieve satisfactory growth. Kadasiddappa and Rao [13] reported that irrigation application can be reduced by 50 to 80 per cent with drip irrigation compared to surface irrigation. Further, drip irrigation has the potential for improving two of the most common contributing factors to N leaching–over fertilization and over irrigation. Therefore, optimum irrigation levels with suitable method would help in enhancing the economic yield as well as water use efficiency of maize crop. Table (3) lists the normally recommended application rates of inorganic fertilizer to the crops tested in these trials. Nevertheless, the wastewaters provide a significant proportion of the normal recommended fertilizer rates under infertile soil conditions. The amount of nitrogen applied in wastewater

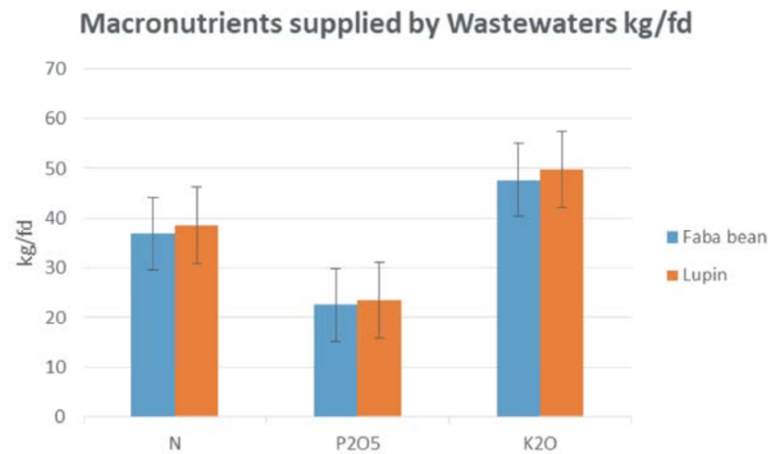

Fig. 3: Fertilizer additions by treated wastewater irrigated (kg fd^{-1}) for faba bean and lupin

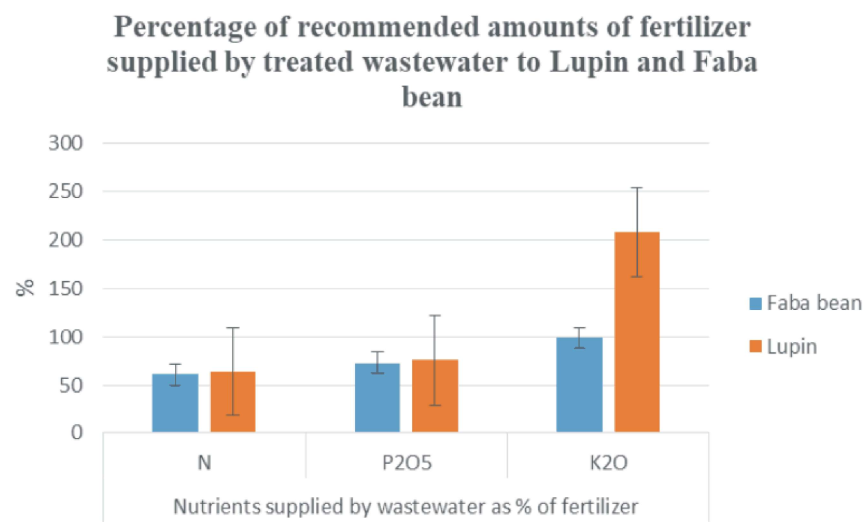

Fig. 4: Fertilizer addition % of the recommended rates supplied by treated wastewater

Table 3: Proportion of nutrients supplied by wastewaters to faba bean and lupin % of recommended rates of fertilizer

	Fertilizer recommended (kg fd^{-1})			Addition in wastewater (kg fd^{-1})			Nutrients supplied by wastewater as % of fertilizer		
Crop	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Faba bean	60	31	48	36.8	22.5	47.7	61	73	99
Lupin	60	31	24	38.5	23.5	49.8	64	76	208

were less than the recommended rates (range 61-64%). These observations are important because one of the problems encountered by wastewater reuse in other countries has been the over-supply of nitrogen at normal crop irrigation duties due to the high concentrations in the wastewater. This can lead to luxurious growth at the expense of economic yield and give rise to nitrate leaching and pollution of groundwater. This is not likely to occur in Egypt as wastewaters generally have relatively low nitrogen contents. The addition of phosphorus by the wastewaters were closer to the recommended rates for the crops (73-76). However, if there were surplus P addition, it is not a significant environmental concern since this element is readily fixed in the soil, particularly under calcareous conditions where it forms insoluble calcium phosphate.

The potassium contents of the wastewaters was large relative to crop requirements (99-208 %), compared with those for N and P. Consequently, crop requirements for potassium (as K_2O) were general exceeded by large margins for most crops. However, potassium is held strongly by soils, particularly those with high cation exchange capacities and even where this is exceeded and leaching occurs, this will be adsorbed further down the soil profile. In the long-term, groundwater quality could be affected but not adversely as there are no environmental problems associated with this, other than its contribution to salinity levels [20].

The data of of chemical additions through treated wastewater varies according to crop water requirements at the duration of cropping. The data show that under such sandy soils small additions of heavy metals were received, moreover some elements as Cd, Mo and Co were below the detection limit as shown in Table 1. These results clearly reflect minimum pollution in the short and long terms and indicate the suitability of Cairo wastewater for reuse on the agricultural land. Similar results were obtained by Mahmoud *et al*. [21] in Jordan, WRc [13] and Abd El Lateef *et al*. [20] in Egypt. Several investigators indicated that in spite of gradual accumulation of heavy metals in the soil, the stability of heavy metals in the environment will cause to pollution since they could not be decomposed like organic pollutants by biological or chemical processes [22]. Propagation of heavy metals in biological food chain is one of the important issues of this behavior, as increasing the amount of several heavy metals in higher stages of food chain is many times more than initial levels [23]. Also, Mousavi *et al.* [24] came to similar conclusion.

Crop Yields: The results of lupin growth and yield parameters are summarised in Table (4). The addition of fertilizer increased crop performance of all parameters, with significant effects being recorded for plant height, number of branches and pods per plant and 100 seed weight. The results showed that the performance of individual plants under drip irrigation were superior to those under flood irrigation, but on an area basis reversible magnitude was reported although none of the effects were statistically significant. This was due to the large difference in plant densities: there were 26, 000 plants per feddan due to the wider row spacing to allow for drip irrigation, compared with 49, 600 plants per feddan under surface irrigation.

Data presented in Table (5) show that there were no significant effects of irrigation method on the yield parameters of faba bean although the quantities of treated wastewater irrigated by drip irrigation were less (mean about 2065 m^3 fd^{-1}). As expected, the lower plant density under drip irrigation produced larger individual plants with more pods, but seed weight was smaller. Consequently, the harvest index was better under surface irrigation (normal method of irrigation) and had the largest seed and straw yields on an area basis. The addition of fertilizer increased all yield parameters insignificantly except for plant height and seed yield (P = 0.0012 and 0.0409, respectively). There were insignificant interactions between irrigation method and fertilizer addition. Surface irrigation on an area basis produced greater yields of faba bean than drip irrigation, but this was principally due to the different crop densities as the crop rows under drip irrigation were spaced more widely than under surface irrigation and as a result had about half the number of plants per unit area. Both methods of irrigation applied similar quantities of wastewater and at an individual plant level, drip irrigation produced larger plants than surface irrigation. Considering the large difference in plant stands, drip irrigation performed well, although this method would not be employed commercially for such crop on economic grounds.

These results derived from the legume crops clearly show that faba bean respond well to irrigation with treated wastewater. However, lupin, showed less response for irrigation with treated wastewater under the poor desert conditions. Several investigators obtained yield increases due to wastewater application [8, 25-27, 10, 12]. Such increase in crop yields due to wastewater irrigation could be attributed to the nutrient content in relation to specific crop requirements. In this respect, Campbell *et al*. [28] stated that weekly application of 25 mm wastewater was enough to supply 40-80% of corn requirements and all of P requirements while other researchers pointed out that the increase in corn yield was due to the enhancement of nutrient uptake and the improvement of the physical properties of the soil. Similar results were obtained by Kadasiddappa and Rao [13] they concluded that adaptation of drip irrigation in rabi maize which is one of the amenable crop for drip irrigation system is gaining momentum because of its higher productivity coupled with higher price. Irrigation application can be reduced by 50 to 80 per cent with drip irrigation compared to surface irrigation. Further, drip irrigation has the potential for improving two of the most common contributing factors to N leaching-over fertilization and over irrigation. Therefore, optimum irrigation levels with suitable method would help in enhancing the economic yield as well as water use efficiency of maize crop. Also, Libutti *et al*. [3] stated that the yield of tomato and broccoli crops as well

Table 4: Effect of treated wastewater irrigation and fertilizer application on yield and yield components of lupain

Treatment	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	Pod weight plant^{-1} (g)	Seed yield plant^{-1}(g)	Seed yield weight (g)	Plant weight (g)	Plant stand fd^{-1} (x1000)	Seed yield fd^{-1} (kg)	Straw yield fd^{-1} (kg)	Bio. yield fd^{-1} (kg)	Harvest index
CV%	17.1	50.99	59.2	47.8	48.11	13.21	48.32	42.15	50.56	72.56	61.73	30.58
Irrigation mean												
Surface	62.2	3.0	9.9	23.8	14.1	32.5	42.8	49.6	0.252	0.834	1.086	0.337
Drip	69.7	5.2	18.2	32.7	18.2	35.3	60.7	26.0	0.164	0.434	0.597	0.316
Probability	-	-	0.032	0.048	-	-	-	0.007	-	-	-	-
Significance	ns	ns	*	*	ns	ns	ns	**	ns	ns	ns	ns
LSD at 0.05	-	-	7	8.81	-	-	-	11.56	-	-	-	-
Fertilizer mean												
Treated wastewater	62.1	3.7	12.2	25.6	14.6	31.5	46.9	39.6	0.189	0.476	0.664	0.318
Treated wastewater+F	69.8	4.5	15.8	30.9	17.7	36.3	56.6	36.0	0.227	0.793	1.020	0.336
Probability	0.003	0.020	0.037	-	-	0.045	-	-	-	-	-	-
Significance	**	*	*	ns	ns	*	ns	ns	ns	ns	ns	ns
LSD0.05	4	0.61	3.3	-	-	4.64	-	-	-	-	-	-
Interaction (irrigation × fertilizer)												
Surface -F	56.6	2.4	7.5	23.0	13.3	30.9	41.0	53.9	0.231	0.522	0.753	0.335
Surface +F	67.8	3.6	12.2	24.5	14.9	34.1	44.7	45.3	0.272	1.147	1.419	0.340
Drip -F	67.6	5.0	17.0	28.2	15.8	32.1	52.8	25.3	0.146	0.428	0.574	0.301
Drip +F	71.9	5.4	19.5	37.3	20.6	38.6	68.5	26.7	0.181	0.439	0.620	0.332
Probability	-	-	-	-	-	-	-	-	-	-	-	-
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
LSD at 0.05	-	-	-	-	-	-	-	-	-	-	-	-

Table 5: Effect of treated wastewater irrigation and fertilizer application on yield and yield components of fababean

Treatment	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	Pod weight plant^{-1} (g)	Seed yield plant^{-1} (g)	100 seed weight (g)	Plant weight (g)	Plant stand fd^{-1} x1000)	Seed yield fd^{-1} (t)	Straw yield fd^{-1} (t)	Bio. yield fd^{-1} (t)	Harvest index
CV%	17.86	11.71	28.19	25.04	27.27	6.82	26.99	47.17	41.51	56.47	49.2	27.73
Irrigation mean												
Surface	87.6	3.4	13.3	59.7	48.6	95.8	116.0	45.9	0.884	1.524	2.408	0.437
Drip	93.5	3.9	18.0	65.6	43.6	91.8	130.7	24.6	0.695	1.205	1.906	0.336
Probability	-	-	-	-	-	-	-	0.0394	-	-	-	-
Significance	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
LSD at 0.05	-	-	-	-	-	-	-	19.348	-	-	-	-
Fertilizer mean												
Treated wastewater	81.7b	3.7	14.3	57.7	43.1	92.8	114.9	34.6	0.701b	1.221	1.922	0.378
Treated wastewater +F	99.5a	3.6	17.0	67.5	49.1	94.8	131.8	35.9	0.878a	1.507	2.392	0.395
Probability	0.0012	-	-	-	-	-	-	-	0.0409	-	-	-
Significance	**	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns
LSD at 0.05	7.57	-	-	-	-	-	-	-	0.167	-	-	-
Interaction (irrigation × fertilizer)												
Surface -F	77.1	3.4	13.0	56.6	45.9	93.6	109.9	46.2	0.785	1.314	2.100	0.418
Surface +F	98.2	3.4	13.7	62.8	51.3	97.9	122.1	45.5	0.983	1.734	2.717	0.455
Drip -F	86.3	3.9	15.6	58.9	40.3	92.1	119.8	22.9	0.617	1.128	1.745	0.338
Drip +F	100.8	3.8	20.4	72.1	46.9	91.6	141.6	26.3	0.772	1.281	2.067	0.334
Probability	-	-	-	-	-	-	-	-	-	-	-	-
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
LSD at 0.05	-	-	-	-	-	-	-	-	-	-	-	-

as the most important qualitative parameters of tomato fruits *i.e.*, dry matter content, soluble solid content, titratable acidity, pH and broccoli heads *i.e.*, dry matter content and diameter were not influenced by the irrigation with treated wastewater.

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Appendices

Table 1: Quantity of treated wastewater surface irrigated to lupin (mean of two seasons)

Block 1		Block 2		Block 3		Block 4	
Date	Quantity (m^3)	Date	Quantity (m^3)	Date	Quantity (m^3)	Date	Quantity (m^3)
19-Nov	12.3	13-Nov	25.9	02-Nov	25.9	13-Oct	25.9
25-Nov	40.1	20-Nov	40	11-Nov	25.9	07-Nov	26.0
02-Dec	28.6	27-Nov	28.4	18-Nov	25.9	14-Nov	26.0
09-Dec	28.4	11-Dec	24.9	25-Nov	40.3	21-Nov	40.2
16-Dec	35.2	21-Dec	47.2	02-Dec	28.1	28-Nov	28.5
23-Dec	36.8	25-Dec	32.2	09-Dec	26.8	05-Dec	28.2
30-Dec	36.9	01-Jan	45.3	16-Dec	36.4	12-Dec	31.2
06-Jan	41.2	08-Jan	39.3	23-Dec	38.5	19-Dec	38.2
13-Jan	39.3	15-Jan	36.5	30-Dec	43.3	30-Dec	33.2
20-Jan	35.4	22-Jan	32.5	06-Jan	41.3	09-Jan	39.3
27-Jan	36.5	29-Jan	33.5	13-Jan	40.1	16-Jan	36.5
03-Feb	32.5	05-Feb	30.5	20-Jan	35.4	23-Jan	34.2
10-Feb	30.2	12-Feb	32.5	27-Jan	39.5	30-Jan	32.9
17-Feb	30.5	19-Feb	30.6	03-Feb	32.5	06-Feb	30.1
25-Feb	22.5	27-Feb	26.1	10-Feb	30.6	13-Feb	30.5
05-Mar	23.5	07-Mar	24.1	17-Feb	32.5	20-Feb	30.6
13-Mar	22.4	15-Mar	24.5	25-Feb	26.7	28-Feb	24.7
21-Mar	22.6	24-Mar	23.6	05-Mar	25.1	08-Mar	24.0
29-Mar	27.2	01-Apr	24.5	13-Mar	25.1	17-Mar	24.5
07-Apr	22.1	09-Apr	22.4	21-Mar	24.1	25-Mar	24.3
15-Apr	22.3			29-Mar	25.3	02-Apr	22.5
				07-Apr	22.5	10-Apr	22.8
				15-Apr	22.1		

Table 2: Quantity of treated wastewater drip irrigated lupin (mean of two seasons)

Block 1		Block 2		Block 3		Block 4	
Date	Quantity (m^3)	Date	Quantity (m^3)	Date	Quantity (m^3)	Date	Quantity (m^3)
11-Nov	25.9	07-Nov	12.3	01-Nov	12.2	01-Nov	12.3
18-Nov	25.9	11-Nov	12.3	05-Nov	12.2	05-Nov	12.3
21-Nov	20.1	14-Nov	12.3	08-Nov	12.3	08-Nov	12.3
25-Nov	20.1	18-Nov	12.3	12-Nov	12.3	12-Nov	12.3
28-Nov	14.2	21-Nov	20.0	15-Nov	12.3	15-Nov	12.3
02-Dec	14.2	25-Nov	20.3	19-Nov	12.3	19-Nov	12.3
05-Dec	14.9	28-Nov	14.2	22-Nov	20.1	22-Nov	20.1
09-Dec	16.2	02-Dec	14.3	26-Nov	20.2	26-Nov	20.1
12-Dec	20.7	05-Dec	14.6	29-Nov	14.3	29-Nov	14.2
16-Dec	8.5	09-Dec	14.9	03-Dec	15.0	03-Dec	14.9
19-Dec	6.8	12-Dec	9.2	06-Dec	15.1	06-Dec	16.2
23-Dec	6.7	16-Dec	9.2	10-Dec	12.4	10-Dec	12.6
25-Dec	9.1	19-Dec	6.1	13-Dec	8.7	13-Dec	8.6
31-Dec	10.3	23-Dec	6.2	17-Dec	7.1	17-Dec	5.7
06-Jan	10.3	25-Dec	8.3	20-Dec	6.3	20-Dec	6.3
09-Jan	10.2	31-Dec	10.5	24-Dec	7.5	24-Dec	7.4
13-Jan	9.2	06-Jan	10.3	30-Dec	5.3	30-Dec	5.2
16-Jan	9.5	09-Jan	10.2	03-Jan	8.1	03-Jan	7.5
20-Jan	10.2	13-Jan	10.1	07-Jan	10.2	07-Jan	10.2
23-Jan	10.2	16-Jan	9.5	10-Jan	10.1	10-Jan	10.1
27-Jan	12.7	20-Jan	10.2	14-Jan	9.5	14-Jan	9.5
30-Jan	12.5	23-Jan	10.3	17-Jan	10.1	17-Jan	10.1
03-Feb	13.6	27-Jan	12.4	21-Jan	9.6	21-Jan	9.6
06-Feb	13.5	30-Jan	12.5	24-Jan	12.7	24-Jan	12.5
10-Feb	12.5	03-Feb	13.6	28-Jan	13.5	28-Jan	12.5
13-Feb	30.2	06-Feb	7.5	31-Jan	12.6	31-Jan	12.6
17-Feb	22.3	10-Feb	12.5	04-Feb	12.5	04-Feb	12.5

Table 2: (continued) Quantity of treated wastewater drip irrigated lupin (mean of two seasons).

Block 1		Block 2		Block 3		Block 4	
Date	Quantity (m^3)	Date	Quantity (m^3)	Date	Quantity (m^3)	Date	Quantity (m^3)
20-Feb	16.6	13-Feb	20.3	07-Feb	12.5	07-Feb	12.5
24-Feb	22.5	17-Feb	22.3	11-Feb	20.1	11-Feb	17.5
27-Feb	17.5	20-Feb	12.6	14-Feb	22.3	14-Feb	22.3
03-Mar	18.3	24-Feb	22.5	18-Feb	23.5	18-Feb	20.5
06-Mar	16.9	27-Feb	17.5	21-Feb	15.3	21-Feb	15.3
10-Mar	20.9	03-Mar	18.4	25-Feb	23.0	25-Feb	23.0
13-Mar	21.2	06-Mar	16.9	28-Feb	17.5	28-Feb	17.3
17-Mar	15.8	10-Mar	20.9	04-Mar	18.1	04-Mar	18.4
20-Mar	19.2	13-Mar	21.2	07-Mar	16.7	07-Mar	16.7
24-Mar	19.5	17-Mar	15.7	11-Mar	21.1	11-Mar	21.1
27-Mar	19.1	20-Mar	19.2	14-Mar	15.8	14-Mar	15.8
31-Mar	14.5	24-Mar	19.5	18-Mar	16.1	18-Mar	15.6
03-Apr	14.2	27-Mar	19.1	21-Mar	19.5	21-Mar	19.3
07-Apr	12.2	31-Mar	14.2	25-Mar	13.9	25-Mar	13.9
10-Apr	12.1	03-Apr	14.1	28-Mar	19.9	28-Mar	19.9
14-Apr	12.1	07-Apr	12.3	01-Apr	14.3	01-Apr	14.4
		10-Apr	12.1	04-Apr	12.4	04-Apr	12.3
		14-Apr	12.3	08-Apr	13.1	08-Apr	12.3
				11-Apr	12.1	11-Apr	12.1
				15-Apr	11.1	15-Apr	11.2

Table 3: Quantity of treated wastewater surface irrigated to faba bean (mean of two seasons)

Block 1		Block 2		Block 3		Block 4	
Date	Quantity (m^3)	Date	Quantity (m^3)	Date	Quantity (m^3)	Date	Quantity (m^3)
18-Nov	12.3	14-Nov	25.9	04-Nov	26.0	13-Oct	26.2
25-Nov	40.2	21-Nov	40.2	11-Nov	26.0	07-Nov	25.9
02-Dec	27.9	28-Nov	28.4	18-Nov	26.0	14-Nov	25.9
09-Dec	29.1	05-Dec	25.9	25-Nov	39.5	21-Nov	40.2
16-Dec	34.2	12-Dec	32.1	02-Dec	29.0	28-Nov	28.4
23-Dec	36.8	19-Dec	36.2	09-Dec	29.1	05-Dec	28.6
30-Dec	43.9	30-Dec	29.8	16-Dec	31.9	12-Dec	31.4
06-Jan	41.2	09-Jan	39.3	23-Dec	37.5	19-Dec	37.6
13-Jan	38.5	16-Jan	36.5	30-Dec	39.8	30-Dec	36.1
20-Jan	35.4	23-Jan	32.2	06-Jan	41.1	09-Jan	39.3
27-Jan	29.5	30-Jan	30.5	13-Jan	39.3	16-Jan	36.5
03-Feb	30.5	06-Feb	30.2	20-Jan	35.4	23-Jan	32.2
10-Feb	30.1	13-Feb	30.5	27-Jan	32.6	30-Jan	30.5
17-Feb	30.2	20-Feb	25.2	03-Feb	30.5	06-Feb	30.3
25-Feb	26.3	28-Feb	23.3	10-Feb	30.1	13-Feb	30.2
05-Mar	20.3	08-Mar	20.6	17-Feb	30.5	20-Feb	25.2
13-Mar	20.1	16-Mar	23.5	25-Feb	23.9	28-Feb	21.6
21-Mar	22.2	25-Mar	20.4	05-Mar	21.3	08-Mar	20.1
29-Mar	20.5	02-Apr	21.2	13-Mar	20.1	17-Mar	22.6
07-Apr	20.1	10-Apr	20.3	21-Mar	20.9	25-Mar	23.1
15-Apr	20.2			29-Mar	20.5	02-Apr	20.1
				07-Apr	20.1	10-Apr	20.3
				15-Apr	20.1		

Table 4: Quantity of treated wastewater drip irrigated to faba bean (mean of two seasons).

Block 1		Block 2		Block 3		Block 4	
Date	Quantity (m^3)	Date	Quantity (m^3)	Date	Quantity (m^3)	Date	Quantity (m^3)
11-Nov	26.0	07-Nov	12.3	04-Nov	12.3	31-Oct	12.3
18-Nov	26.0	11-Nov	12.3	06-Nov	12.3	05-Nov	12.3
21-Nov	20.1	14-Nov	12.3	08-Nov	12.3	08-Nov	23.3
25-Nov	20.1	18-Nov	12.2	12-Nov	24.6	12-Nov	12.2
28-Nov	14.2	21-Nov	20.2	15-Nov	12.7	15-Nov	12.3
02-Dec	14.3	25-Nov	21.0	19-Nov	12.2	19-Nov	12.3
05-Dec	14.5	28-Nov	14.3	22-Nov	20.2	22-Nov	20.1
09-Dec	15.3	02-Dec	14.3	26-Nov	19.8	26-Nov	18.5
12-Dec	10.3	05-Dec	14.7	27-Nov	14.3	29-Nov	14.2
16-Dec	7.9	09-Dec	16.2	29-Nov	14.2	03-Dec	14.9
19-Dec	7.1	12-Dec	9.5	03-Dec	14.3	06-Dec	15.3
23-Dec	5.8	16-Dec	8.3	06-Dec	16.2	10-Dec	13.1
25-Dec	8.3	19-Dec	6.3	10-Dec	13.2	13-Dec	9.2
31-Dec	11.2	23-Dec	6.2	13-Dec	9.1	17-Dec	6.1
06-Jan	10.3	25-Dec	8.5	17-Dec	5.8	20-Dec	5.7
09-Jan	10.1	31-Dec	10.5	20-Dec	5.4	24-Dec	6.3
13-Jan	11.0	06-Jan	10.3	24-Dec	6.2	30-Dec	5.1
16-Jan	9.5	09-Jan	10.2	30-Dec	5.2	03-Jan	9.2
20-Jan	10.2	13-Jan	10.1	03-Jan	7.5	07-Jan	10.2
23-Jan	9.4	16-Jan	9.5	07-Jan	10.2	10-Jan	10.1
27-Jan	10.2	20-Jan	10.2	10-Jan	10.1	14-Jan	9.5
30-Jan	10.5	23-Jan	9.4	14-Jan	9.5	17-Jan	10.1
03-Feb	10.6	27-Jan	10.2	17-Jan	10.1	21-Jan	9.3
06-Feb	10.5	30-Jan	10.5	21-Jan	8.9	24-Jan	10.2
10-Feb	12.5	03-Feb	10.6	24-Jan	10.5	28-Jan	10.5
13-Feb	18.2	06-Feb	10.5	28-Jan	10.5	31-Jan	10.6
17-Feb	20.3	10-Feb	12.5	31-Jan	10.6	04-Feb	10.5

Table 4: (continued) Quantity of treated wastewater drip irrigated to faba bean (mean of two seasons)

Block 1		Block 2		Block 3		Block 4	
Date	Quantity (m^3)	Date	Quantity (m^3)	Date	Quantity (m^3)	Date	Quantity (m^3)
20-Feb	12.6	13-Feb	18.3	04-Feb	10.5	07-Feb	12.5
24-Feb	22.5	17-Feb	22.3	07-Feb	12.5	11-Feb	18.5
27-Feb	17.5	20-Feb	12.6	11-Feb	17.5	14-Feb	20.3
03-Mar	18.3	24-Feb	22.5	14-Feb	20.3	18-Feb	18.0
06-Mar	16.9	27-Feb	17.5	18-Feb	22.5	21-Feb	12.3
10-Mar	20.9	03-Mar	18.3	21-Feb	15.7	25-Feb	23.0
13-Mar	21.2	06-Mar	16.9	25-Feb	23.0	28-Feb	18.0
17-Mar	15.7	10-Mar	20.9	28-Feb	16.5	04-Mar	17.6
20-Mar	19.2	13-Mar	21.4	04-Mar	18.9	07-Mar	16.9
24-Mar	19.5	17-Mar	15.7	07-Mar	16.7	11-Mar	21.1
27-Mar	19.1	20-Mar	19.2	11-Mar	21.1	14-Mar	15.8
31-Mar	12.9	24-Mar	19.5	14-Mar	15.8	18-Mar	15.6
03-Apr	11.9	27-Mar	19.1	18-Mar	15.6	21-Mar	19.6
07-Apr	10.2	31-Mar	12.8	21-Mar	19.6	25-Mar	13.9
10-Apr	10.2	03-Apr	10.4	25-Mar	13.9	28-Mar	19.9
14-Apr	10.1	07-Apr	10.1	28-Mar	19.9	01-Apr	12.2
		10-Apr	10.2	01-Apr	12.5	04-Apr	10.2
		14-Apr	10.1	04-Apr	10.2	08-Apr	10.1
				08-Apr	10.1	11-Apr	10.2
				11-Apr	10.3	15-Apr	10.1
				15-Apr	10.2		