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Water conservation by wastewater reuse through modern irrigation systems

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Abstract: - The aim of the present work was to investigate the effects of irrigation with treated municipal wastewater through subsurface drip irrigation method, on growth characteristics of a lawn, to detect any changes on irrigated soil properties and consequently to evaluate the use of wastewater in water saving terms compared to freshwater use. The experiment was conducted at the farm of the University of Thessaly. The experimental field was separated in two parts. The first part, constituted the first treatment, which was irrigated only with fresh water from the borehole of the farm. The second part, constituted the second treatment, and was irrigated periodically with wastewater, provided by the treatment plant of the city of Volos and with fresh water. Each irrigation with wastewater was followed by two irrigation applications with fresh water, because of the lightly increased salinity that existed in the wastewater and the increased concentration of ions of chloride. Observations of plant growth parameters included the measurements of lawn height and biomass production in regular time intervals. Measurements of qualitative characteristics of wastewater were taken, as well as soil analysis at the beginning and at the end of irrigation period. The experimental results revealed that wastewater treatment exceeded freshwater in lawn's growth characteristics, yet no statistically significant differences were observed between the two treatments. Also, from the soil analysis that conducted in treatment that received wastewater, not any concentration of toxic elements was recorded. No significant changes in pH, electrical conductivity Fe, Zn, Cu, and Mn concentration were recorded after soil analysis in treatment received wastewater before and after the irrigation. As regards the water consumption, the use of wastewater resulted in a 32.6 % saving of fresh water.

Key-Words: - wastewater reuse, subsurface drip, water saving, lawn irrigation

1 Introduction

As the demand for potable water resources increases, wastewater is receiving attention as an alternate irrigation source [1], [2], [3], [4], [5]. Research studies in Greece have investigated the possibility of use of liquid wastes for irrigation of agricultural row crops [6], [7], [8], greenhouse tomato and pepper, as well as for gerbera flower [4] and forest plantation [9]. From these works has been evident that the irrigation with treated liquid wastes has given better or the same results in crop yield compared to fresh water while there was no important differences in the yield qualitative characteristics between wastewater and fresh water irrigated crops.

Presently, effluent used in irrigation is normally delivered through surface or sprinkle irrigation systems; however, in recent years interest in microirrigation systems for this purpose has increased. According to Shrivastava et al. [10] and Ruskin [11], prevention of pollution and efficient use of water from wastewater effluent can be achieved with microirrigation systems. Oron et al. [12] reported that subsurface microirrigation reduced the risk of pollution associated with wastewater to a minimum since the soil acts as a living filter, cleaning the water.

Subsurface drip is an emerging alternative wastewater technology with a great deal of merit. Advantages over other subsurface and surface effluent distribution systems include the potential for highly uniform distribution of effluent over the entire irrigated area; shallow distribution enabling effluent to be placed at maximum vertical distance above unsuitable soil horizons or wetness conditions, while keeping effluent from being exposed at the ground surface; injection of effluent from emitters at extremely slow rates which allow for soil uptake without the need for temporary storage or ponding; the potential to maximize nutrient attenuation by placing the effluent in the most biologically active soil/root zone; since the drip system is buried, irrigation system performance is unaffected by surface infiltration characteristics; the relatively dry soil surface permits farm equipment access and movement during the whole irrigation period and eliminates weed growth. Research supporting these beneficial attributes includes works several researchers [13], [14], [15], [16], [17], [18], [19], [20], [21].

Limited research has been reported from operating subsurface drip wastewater systems, as the basis for evaluating and refining system design criteria and to further assess the potential role of subsurface drip as a viable wastewater management option. Recent published results [22] provide a detailed assessment of hydraulic conductivity changes in soils surrounding drip emitters at two sites in use over five years. Other aspects of system design which have been evaluated include the importance of laterals being installed level, and concerns related to drainback of effluent into the lower laterals at the end of each scheduled irrigation event [23], [24].

The aim of present work was to investigate the effects of irrigation with treated municipal wastewater through subsurface drip method, on growth characteristics of *Festuca arundinacea* cv. Fine Lawn I, to detect any changes on irrigated soil properties and consequently to evaluate the use of wastewater in water saving terms compared to freshwater use.

2 Materials and Methods

The experiment was conducted at the farm of the University of Thessaly. The experimental field occupied an area of approximately 150 m^2, separated in two parts. Each part constituted a treatment in 4 replications. Each replication (experimental plot) was 2 x 6 m. The first part, constituted the first treatment, which was irrigated only with fresh water from the borehole of the farm (Freshwater, FW). The second part, constituted the second treatment, and was irrigated periodically with wastewater (Wastewater, WW) provided by the treatment plant of the city of Volos and with fresh water, due to the lightly increased salinity that existed in the wastewater and also because of its increased concentration of ions of chloride. Each irrigation with wastewater was followed by two irrigation applications with fresh water.

An excavation of the field in 15 cm depth took place for the placement of subsurface drip laterals. The lateral pipes that were placed in the depth of excavation, having 0.4 m spacing, 24 m length, were of RAM type manufactured by Netafim, with 0.17 m nominal diameter with integrated emitters. Emitters were self-regulated and shelf-cleaned, having 0.3 m spacing, discharging 1.6 l/h in operation pressure range from 50 to 400 Kpa. The head of irrigation network consisted of a control panel and the reservoir of wastewater made of PE, with a capacity of 5 m^3. The control panel contained the central control valve, a disk filter enriched with *trifluralin* for avoiding root intrusion, electrovalves for controlling the initiation and the end of irrigation, manometers for pressure monitoring and two screen filters. The irrigation was initiated by an irrigation controller. In each manifold a water-meter was placed for the recording of consumed volume of water. In the end of manifolds, special relief valves had been placed for avoiding clogging of subsurface lateral pipes.

The meteorological data were recorded in hourly base by a completely automated meteorological station installed in the University farm. Irrigation was applied every two days, unless rain had preceded and therefore the irrigation was applied less frequently. The irrigations were applied during the period from May to October 2004. Soil water content monitoring and measurement was done using Time Domain Reflectometry (TDR) instrumentation (ESI model manufactured by Soil Moisture Corp.), [18]. Observations of plant growth parameters included the measurements of lawn height and biomass production in regular time intervals. Measurements of qualitative characteristics of wastewater were taken, as well as soil analyses at the beginning and at the end of irrigation period.

3 Results and Discussion

3.1 Physical and chemical properties of soil and water

According to soil analyses and taxonomy conducted by the Institute of Soil Classification and Mapping of Larissa prior to irrigation, the soil is well-drained, calcareous, clay loam that belongs in the subgroup of Typic Xerochrepts of Inceptisols. The analyses of water from the treatment plant (Table 1) show that the electric conductivity (E.C.) was marginally suitable for irrigation of crops, and also, the concentration of ions of chloride was very high (ranged from 1000 mg/l to 1550 mg/l, with allowable limits 355 mg/l according to Bahri and Brissaud, [25]. Chloride ions' concentration was high due to the chlorination of wastes in treatment plant for decontamination. For this reason alternate irrigations were applied with fresh water in wastewater treatment.

Table 1: Analysis of treated wastewater used in the experiment.

Parameter	Average	Parameter	Average
Cl^- (mg/l)	1310	C.O.D. (mg/l)	32
SS (mg/l)	4.0	B.O.D. (mg/l)	11
P_t (mg/l)	1.2	E.C. (dS/m)	3.2
$N\text{-}NH_4$ (mg/l)	0.4	Fe^{3+} (mg/l)	0.32
$N\text{-}NO_3$ (mg/l)	5.4	Cu^{2+} (mg/l)	0.01
pH	7.8	Zn^{2+} (mg/l)	0.05

3.2 Soil attributes

At the end of the irrigation period no significant changes were observed in pH, E.C. and the trace elements as shown in Table 2. Because the irrigation was applied underground through the subsurface drip system and the wastewater did not come in direct contact with the humans, there were not any limits established regarding the microbiological characteristics of wastewater, [25].

Table 2: Soil analysis of wastewater treatment

Depth (cm)	pH	E.C. (dS/m)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)
Beginning of irrigation period						
0-30	8.18	4.18	6.97	1.06	4.44	11.08
30-60	8.11	2.24	14.16	0.92	2.94	8.00
60-90	8.26	2.32	20.60	0.96	3.30	7.66
End of irrigation period						
0-30	8.01	4.66	11.04	1.30	4.48	8.58
30-60	8.16	3.81	14.34	1.48	2.82	7.28
60-90	8.18	3.71	17.76	0.70	2.43	6.90

3.3 Plant growth

Measurements of lawn's change in height were conducted during the period from June to October 2004. Eight measurements were taken in 2-week time intervals. The mean height of each plot was derived after measurements in 12 points within each plot. As shown in Fig. 1 where the lawn height measured before every cutting is presented, wastewater treatment exceeded the fresh water one throughout the season, yet not statistically significant at the level of 0.05. The high concentration of wastewater in chloride ions is probably the reason of lower than expected lawn growth in wastewater plots since chloride is considered as one of the most toxic elements for the plants [4], [26].

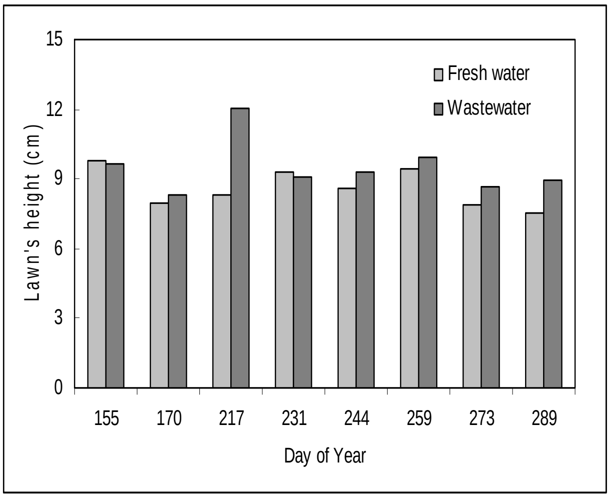

Figure 1: Mean height of lawn for freshwater and wastewater treatments before every cutting.

Measurements of biomass production were taken during the period from 3/5/2004 until 6/10/2004. Ten measurements in 2-week intervals were conducted. From the results was revealed that the biomass production was slightly higher in freshwater plots as shown in Fig. 2 as the cumulative dry biomass, although there was not any clear predominance of one treatment to the other during the season. In any case and in both treatments the difference was not statistically significant at the level of 0.05.

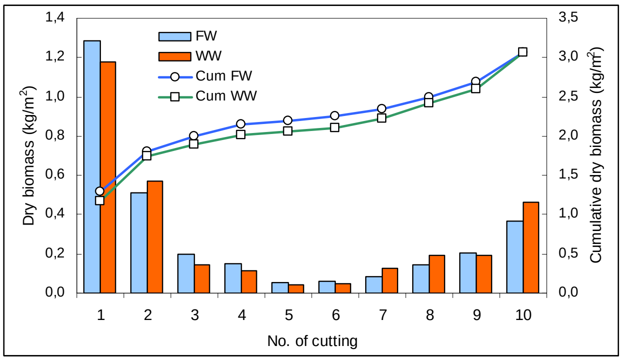

Figure 2: Cumulative dry biomass for freshwater and wastewater treatments.

3.4 Water saving

A total amount of approximately 730 mm of irrigation water was supplied to each one of the two treatments. In wastewater treatment the 239 mm were wastewaters. That resulted in a saving of fresh water of 32.6%.

4 Conclusion

The possibility of irrigation of lawn with treated wastewater was investigated. The experimental results revealed that wastewater treatment exceeded freshwater in lawn's growth characteristics, yet no statistically significant differences were observed between the two treatments. Also, from the soil analysis that conducted in treatment that received wastewater, not any concentration of toxic elements was recorded. No significant changes in pH, electrical conductivity Fe, Zn, Cu, and Mn concentration were recorded after soil analyses in treatment received wastewater before and after the irrigation. As regards the water consumption, the use of wastewater resulted in a 32.6 % saving of fresh water. The treated municipal wastewaters by their utilisation for irrigation of crops constitute an important mean for saving fresh water for other uses. The use of treated wastewater is encouraged in crops where humans do not come in direct contact with them. Such cases are recreation areas, parks, ornamental plants in pavements. The performance of subsurface drip irrigation as a wastewater distribution system appeared to be very effectiveness. The applicability of this method in wastewater systems should increase, as future research succeeds in establishing proper system sizing criteria and continuing improvements in the reliability of system components.

References:

[1] Gushiken E.C., 1995, Irrigating with reclaimed wastewater through permanent subsurface drip irrigation systems, *In Microirrigation for a Changing World: Preserving Resources/Preserving the Environment*, ed. F.R. Lamm, ASAE, pp.269–274.

[2] Tanji K.K., 1997, Irrigation with marginal quality waters: Issues, *J. of Irrig. and Drainage Engineering, ASCE*, 123(3):165–169.

[3] Angelakis A.N., M.H. Marecos do Monte, L. Bontoux and T. Asano, 1999, The status of wastewater reuse practice in the Mediterranean basin, *Water Resources*, 33(10):2201-2217.

[4] Panoras A. and A. Ilias, 1999, *Irrigation with reclaimed municipal wastewater*, Yiachoudi-Yiapouli Publications, Thessaloniki, Greece, (in Greek).

[5] Angelakis A.N. and L. Bontoux, 2001, Wastewater reclamation and reuse in EU countries, *Water Policy*, 3:47-59.

[6] Vakalis P.S. and H.D. Tsantilas, 2002, Effect of irrigation of cotton and maize with urban waste in the agricultural income, *Agricultural Research*, N.AG.RE.F. Publication, (in Greek with English abstract), 25(1):13-20.

[7] Panoras A., A. Ilias, G. Skarakis, A. Papadopoulos, F. Papadopoulos, G. Parisopoulos, A. Papayiannopoulou and A. Zdragas, 2000, Reuse of treated municipal wastewater for sugar beet irrigation, *Journal of Balkan Ecology*, 3(4):91-95.

[8] Panoras A., G. Evgenidis, S. Bladenopoulou, B. Melidis, A. Doitsinis, I. Samaras, A. Zdragas and T. Matsi, 2001, Corn Irrigation with Reclaimed Municipal Wastewater, *Proc. of the 7th Int. Conf. on Environmental Science and Technology*, Ermoupolis, Greece, pp. 699-706.

[9] Vourdoubas I., 2000, Irrigation of forest plants with treated municipal wastewater, *Georgia-Ktinotrofia* 6, (in Greek).

[10] Shrivastava P.K., M.M. Parikh, N.G. Wawani and S. Raman, 1994, Effect of drip irrigation on tomato yield, *Agric. Water Manag.*, 25(2):179–184.

[11] Ruskin R., 1993, Subsurface drip irrigation can reduce pollution, In *Management of Irrig. and Drainage Systems Integrated Perspectives*, ed. R.G. Allen, N.Y., ASCE, 731–738.

[12] Oron G., Y. Malach, Z. Hoffman, Y. Manor and Y. De–Malach, 1993, Secondary wastewater reuse, *Water and Irrig. Review*, 13(1):17–20.

[13] Lesikar B., B. Neal, G. Sabbagh and I. Jnad, 1998, Subsurface drip systems for the disposal of residential wastewater, In *Proc. 8th National Symposium on Individual and Small Community Sewage Systems*, St. Joseph, MI., pp. 474-484.

[14] Oron G., J. de Malach and Z. Hoffman, 1988, Seven successive seasons of subsurface dripper irrigation, using effluent on field crops, *Wat. & Irrig. Rev*., 8(4):4-8.

[15] Oron G., J. de Malach, Z. Hoffman and R. Cibotaru, 1991, Subsurface micro-irrigation with effluent, J. *of Irrig. And Drain. Eng, ASCE*, 117(1):25-36.

[16] Phene C.J., M.F. Blume, M.M.S. Hile, D.W. Meek and J.V. Re, 1983, Management of Subsurface Trickle Irrigation Systems, *ASAE paper* No. 83-2598.

[17] Rubin A.R., S. Greene, T. Sinclair and A. Jantrania, 1994, Performance evaluation of drip disposal system for residential treatment, In *Proc. 7th International Symposium on Individual*

and Small Community Sewage Systems, ASAE, St. Joseph, MI., pp. 467-474.

[18] Sakellariou-Makrantonaki M., D. Kalfountzos and N. Papanikos, 2000, Evaluation of surface and subsurface drip irrigation in sugar beet crops, In *Proc. 2nd Nat. Congress of Hellenic Society of Agricultural Engineers*, Volos, pp. 157-164, (in Greek).

[19] Sakellariou-Makrantonaki M., D. Kalfountzos and P. Vyrlas, 2001, Irrigation water saving and yield increase with subsurface drip irrigation, *Proc. of the 7th International Conf. on Environmental Science and Technology*, Ermoupolis, Greece, pp. 466-473.

[20] Sakellariou-Makrantonaki M., D. Kalfountzos, P. Vyrlas and B. Kapetanos, 2002, Water saving using modern irrigation methods, *Hydrorama 2002*, EYDAP, Athens, pp. 96-102.

[21] Solomon K., 1993, Subsurface drip irrigation: Product selection and performance, In *Subsurface Drip Irrigation: Theory, Practices and Application*, (eds. G.S. Jorgensen and K. N. Norum), CATI Publication No. 921001.

[22] Persyn R., B. Lesikar and I. Jnad, 1999, Evaluating soil properties in subsurface drip distribution systems, In *Proc. 6th Northwest On-Site Wastewater Treatment Short Course*, Univ. of Washington, Seattle, WA., pp. 153-170.

[23] Amoozegar A., E. West, K. Martin and D. Weyman, 1994, Performance evaluation of pressurized subsurface wastewater disposal systems, In *Proc. 7th International Symposium on Individual and Small Community Sewage Systems*, ASAE, St. Joseph, MI., pp. 454-466.

[24] Berkowitz S., 1999, Subsurface drip wastewater systems - North Carolina's regulation and experience, In *Proc. 6th Northwest On-Site Wastewater Treatment Short Course*, Univ. of Washington, Seattle, WA., pp. 127-139.

[25] Bahri A. and F. Brissaud, 2002, *Guidelines for municipal water reuse in the Mediterranean countries*, World Health Organization, Regional Office for Europe, WHO/EURO Project Office, Mediterranean Action Plan.

[26] Ayers R.S. and D.W. Westcot, 1985, Water quality for agriculture, F*.A.O. Irrigation and Drainage Paper* 29 (Rev. 1), Food and Agriculture Organization, Rome.