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IRRIGATION OF VEGETABLES AND FLOWERS WITH TREATED WASTEWATER

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SUMMARY - Application of recycled water to agricultural land for irrigation could be an alternative water resource for Mediterranean countries facing severe water shortage. Rational use of the nutrients in recycled water could increase crop production and reduce environmental pollution. At the Agricultural Research Institute different studies were conducted to investigate the effect of treated wastewater and N applied on the yield of three field crops and three cut flowers.
The first study, included three field experiments with green pepper, eggplants and sudax, irrigated with borehole water or with secondary treated municipal wastewater. Both waters were supplemented with N applied continuously with the irrigation water at four levels 0 g/m^3, 50 g/m^3, 100 g/m^3 and 150 g/m^3. Yield results indicate the superiority of the treated wastewater and its ability to produce high yields with less N fertilizers.
The second study included the irrigation with treated wastewater of a) *Gerbera jasmesonii* and b) for hydroponic culture of *Limonium perezii* and Antirrhinum. *Gerbera jasmesonii* was irrigated with secondary treated wastewater, borehole water and fresh water with or without additional fertilization. Results on flower production per plant shown that freshwater produced significantly more flowers per plant than the other water qualities and fertilization had a significant effect on flower production for freshwater irrigated plants but no significant effect on wastewater irrigated plants. Results on *Limonium perezii* and Antirrhinum in hydroponics, show that both plants irrigated with secondary treated wastewater and treated wastewater from the epuvalisation system were less vigorous and produced significantly less flowers of lower quality than flowers produced from plants irrigated with freshwater with the addition of fertilizer. Results on the effects of fertilizer and water quality on flower weight of gerbera plants indicate that high salt concentration in wastewater can be a limiting factor for the production of sensitive plants such as *Gerbera jasmesonii*. Mixing of wastewater with freshwater could give good results by lowering the salt concentration of the water and also providing some nutrients to the plants.

Key words: Wastewater, irrigation, water reuse, green pepper, eggplants, sudax, nitrogen, *Gerbera jasmesonii, Limonium perezii,* Antirrhinum.

INTRODUCTION

In Cyprus and in most Mediterranean countries, the scarcity of water together with the high cost associated with collecting and using the limited surface rainwater for irrigation, have become real constrains for our irrigated agriculture. Because of this, particular emphasis is placed on the water use efficiency and the cultivation of crops with high return per square meter and volume of water i.e. flowers and vegetables (Chimonidou, 2002 and 2003).

The irrigated agriculture in semi arid countries like Cyprus demands large amounts of water and faces the serious challenge to increase or at least sustain agricultural production while coping with less and/or lower quality water. Over the years, the severe shortage of water, primarily in the arid and semi-arid regions, has promoted the search for extra sources currently not intensively exploited. Treated wastewater is now being considered and used in many countries throughout the world, as a new additional, renewable and reliable source of water, which can be used for agricultural production. By releasing freshwater sources of potable water supply and other priority uses, treated wastewater reuse makes a contribution to water conservation and expansion of irrigated agriculture, taking on an economic dimension. It also solves disposal problems aimed at protecting the environment and public health and prevents surface water pollution by the direct discharge of pollutants into inland and coastal waters (Papadopoulos and Savvides, 2002, Papadopoulos et.al. 2005).

The benefits, potential health risks and environmental impacts resulting from wastewater use for irrigation and the management measures aimed at using wastewater within acceptable levels of risk to the public health and the environment are well documented (WHO, 1973 and 1989, Hespanhol, 1990; Hespanhol and Prost, 1994; FAO, 1992, Jenkins *et al*., 1994, Asano and Levine,1995, Angelakis *et al*.,1997). Properly planned use of wastewater can reduce environmental and health related hazards, which have been observed with traditional wastewater disposal.

Statistical analysis of rainfall in Cyprus reveals a decreasing trend of rainfall amounts in the last decades. The wastewater generated by the main cities, about 25Mm^3/year, is collected and used for irrigation after tertiary treatment. About 10 Mm^3/year is conservatively estimated to be available for agricultural irrigation in the near future allowing irrigated agriculture to be expanded by 8-10% while conserving an equivalent amount of water for other sectors (Papadopoulos 1995).

In addition to water benefit to the irrigated land, treated municipal wastewater can provide significant amounts of plant nutrients, especially nitrogen and phosphorous, which can improve the fertility of soils, benefit plant growth, improve crop production and reduce the total requirements of commercial fertilizers needed to be applied, increasing the total economic return to the farmers. However with the treated effluent as an irrigation source, the additional fertilizer N may create conditions of NO_3 percolation and pollute groundwater (Papadopoulos and Stylianou, 1987, 1988a,b).

The aim of the first study is to present yield results obtained from sudax, eggplant and sweet pepper, irrigated with wastewater and freshwater with the addition of N fertilizer and of the second study, is the effect of water quality and fertilization on flower production of Gerbera jasmesonii (in soil) and *Limonium perezii* and Antirrhinum (in Hydroponic culture).

MATERIALS AND METHODS

Experiments of Sudax, Eggplant and Sweet pepper

Three separate experiments were carried out from 1998-2001, on sudax (hybrid “Trudan”), eggplants (*Solanum melongena*) of the variety “Bonica“, and sweet pepper (*Capsicum annuum*) of the variety “Gedeon“.

The treatments included two sources of irrigation water, (borehole and secondary treated wastewater) with four levels of nitrogen, 0, 50, 100 and 150ppm. The field experimental layout for all three experimental plots was a split plot design with four replications with the two sources of water assigned to the main plots and N levels to the subplots.

In the sudax experiment each plot consisted of 3 rows 30 m long, spaced 60cm apart and irrigated with 10L drippers spaced 30cm apart on the irrigation line. In the sweet pepper experiment, each plot consisted of three rows 1m apart with 42 plants in each row, having each plant planted 60 cm apart whereas in the eggplant experiment the rows were 80cm apart. Plants of eggplant and sweet pepper were watered by drip irrigation using 10L drippers and in all experiments the amount of water applied was based on Epan evaporation.

The field studies were conducted on a calcaric cambisol soil with 20% $CaCO_3$. The secondary treated wastewater used in this experiment is a product of an activated sludge treatment plant from a residential community with no industrial inputs. The quality of the treated wastewater was monitored every week during the investigation period. The analysis included electrical conductivity (EC_w), pH, Ca, Mg, Na, K, HCO_3, Cl, SO_4, NO_3-N and B. Nitrate-N was determined by using a specific NO_3-N electrode (Kent, EIL model 8006.2). All other analyses were performed according to standard procedures. The average chemical composition of the treated wastewater and borehole freshwater during the irrigation season is given in *Table 1*. The mean biological oxygen demand (BOD_5), the chemical oxygen demand (COD) and the suspended solids (SS) of the treated wastewater were during the irrigation season 76, 45 and 38 mg/lt respectively.

Table 1. Chemical composition (ppm) of freshwater and wastewater used for irrigation.

	EC_w	pH	Ca	Mg	Na	K	HCO_3	SO_4	NO_3	Cl	B
Borehole	2.9 mmhos/cm	7.5	36	71	570	9	415	387	75	629	1.2
Wastewater	3.0 mmhos/cm	7.3	60	52	540	31	482	375	10	560	0.8

Experiment of *Gerbera jasmesonii* on soil

The experiment on the cultivation of *Gerbera jasmesonii* was carried out in 2001-2002 using Gerbera of the red variety "testarosa" as the experimental plant, in order to evaluate the effect of four different sources of water with (treatments F1-F5) and without fertilization (treatments W1-W5) on flower production and quality. The sources of water were: a) Secondary treated wastewater, b) Treated wastewater from the epuvalisation system c) Borehole water and d) Fresh water. Analysis of the sources is given in *Table 2*.

Fertilization (treatments F1-F5) consisted of 150ppm N (Ammonium Nitrate), 40ppm P (Urea Phosphate) and 180ppm K (Potassium Nitrate). Once a month 5gr/plant of Fe chelate was applied to all treatments as Gerbera plants are sensitive to iron deficiencies.

The plants were grown under 70% shading on ridges 30 cm wide and 40 cm high. The experimental plots were irrigated by drip irrigation using 10L drippers. Water was pumped from the storage tanks near the epuvalisation system with ½ hp electric pumps generated by an electric generator.

The experimental design was factorial with six replications. Each replication consisted of 10 randomized plots, each plot being a 6m long row (ridge) with 13 plants 50cm apart. The distance between rows was 120 cm with a central 120 cm wide corridor separating the three replications.

Table 2. Chemical analysis of the four sources of water used in the experiment.

	FRESH WATER	BOREHOLE WATER	EPUVALISATION SYSTEM (CHANNEL A)	SECODARY TREATED WASTEWATER
pH	7.38	7.53	8.0	8,2
Conductivity	0.92 mmhos/cm	3.03 mmhos/cm	2.8 mmhos/cm	2,6 mmhos/cm
Boron	0.37 ppm	1.15 ppm	0.8 ppm	0.8 ppm
Calcium	50 ppm	36 ppm	60 ppm	60 ppm
Magnesium	52 ppm	71 ppm	52 ppm	52 ppm
Sodium	103 ppm	570 ppm	540 ppm	540 ppm
Potassium	2.6 ppm	9 ppm	31 ppm	31 ppm
Bicarbonate	275 ppm	415 ppm	482 ppm	482 ppm
Sulphate	160 ppm	387 ppm	375 ppm	375 ppm
Chloride	124 ppm	629 ppm	560 ppm	560 ppm
Nitrate	10 ppm	10 ppm	90 ppm	100 ppm
SS			27 mg/lt	31 mg/lt
COD			45 mg/lt	45 mg/lt
BOD_5			80 mg/lt	85 mg/lt

Greenhouse experiment with flower plants using hydroponics

Two flower plants *Limonium perezii* and Antirrhinum were planted in a new hydroponic system made from Polygal´s plant beds. The plant beds are manufactured from double walled polypropylene sheets and have a drainage system at the base of the channel, which provide better drainage and aeration. Perlite was used as a substrate in the plant beds and plants were irrigated using 4L drippers. The experimental design was factorial with six replications and each replication consisted of four plant beds 2.4m long placed 60cm apart in two rows. In each plant bed six plants from each variety were planted.

Both plants were irrigated with: a) untreated secondary treated wastewater, b) treated wastewater from the epualization system c) fresh water with additional fertilizer of 60 ppm N and d) fresh water with additional fertilizer of 120 ppm N.

The aim of the experiment was to investigate whether untreated and treated wastewater could be used in hydroponics for flower production without the addition of extra nutrients.

RESULTS AND DISCUSSION

From the results of yield of eggplant and sweet pepper (Figs 1 and 2) it is demonstrated that wastewater gave better yield and fruit number than freshwater at all nitrogen concentrations and without N application. Without application of N in water, yield increased by 99% in the case of sudax, 65% and 82% in the case of eggplant and sweet pepper irrigated with wastewater compared with treatments irrigated with borehole water. In all cases, application of N in wastewater had no significant effect on yield, and fruit number at all concentrations.

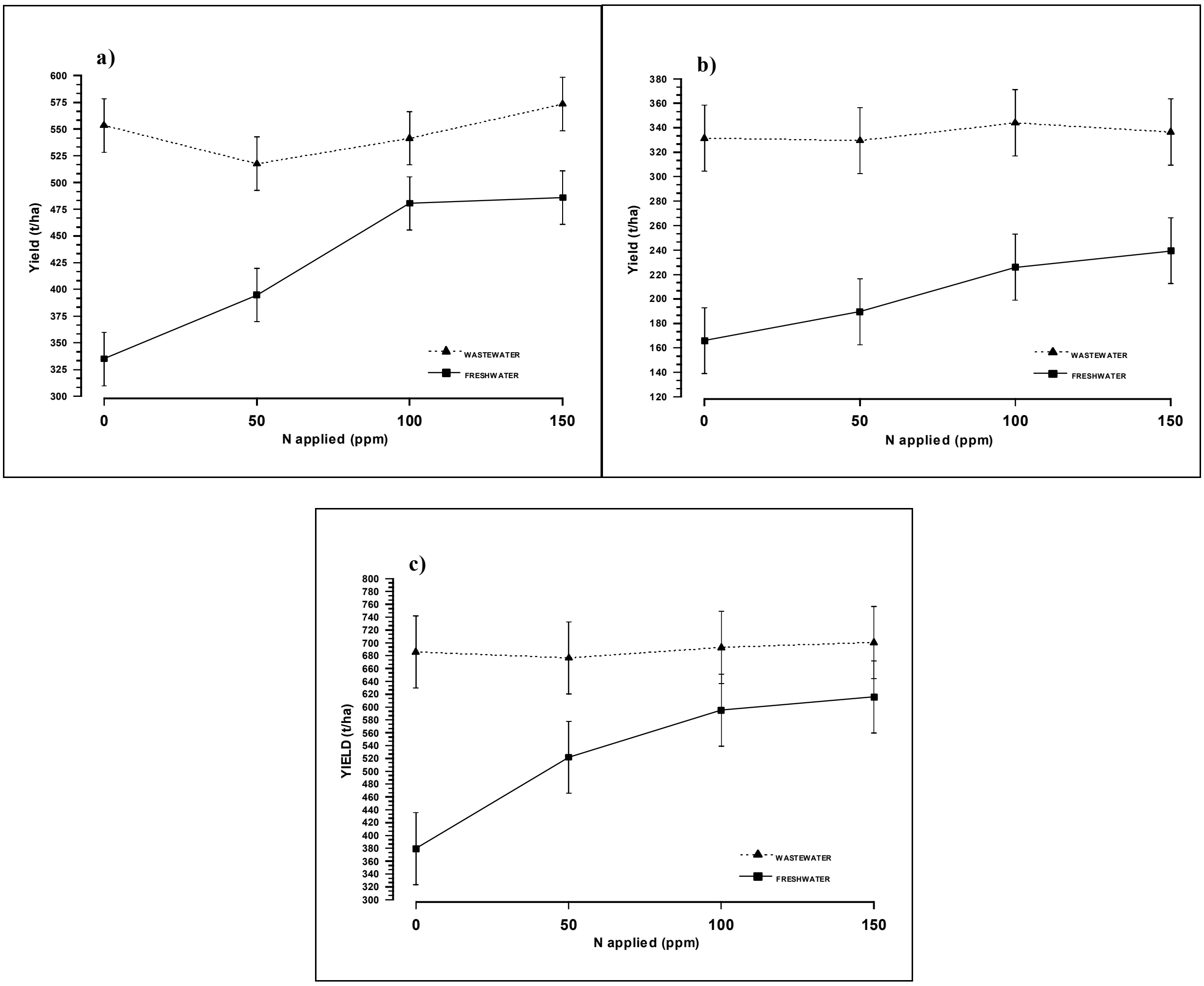
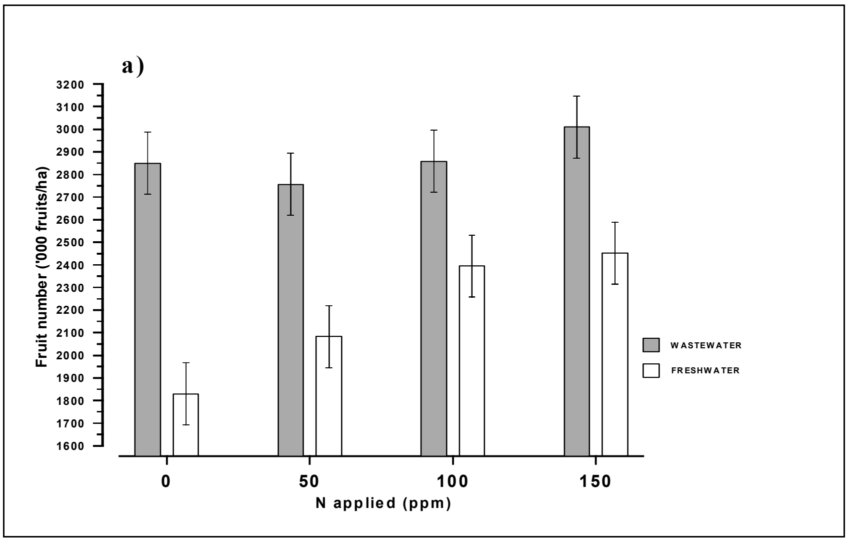


Fig. 1. Average yield of a) eggplant, b) sweet pepper and c) sudax as influenced by N applied and water quality.



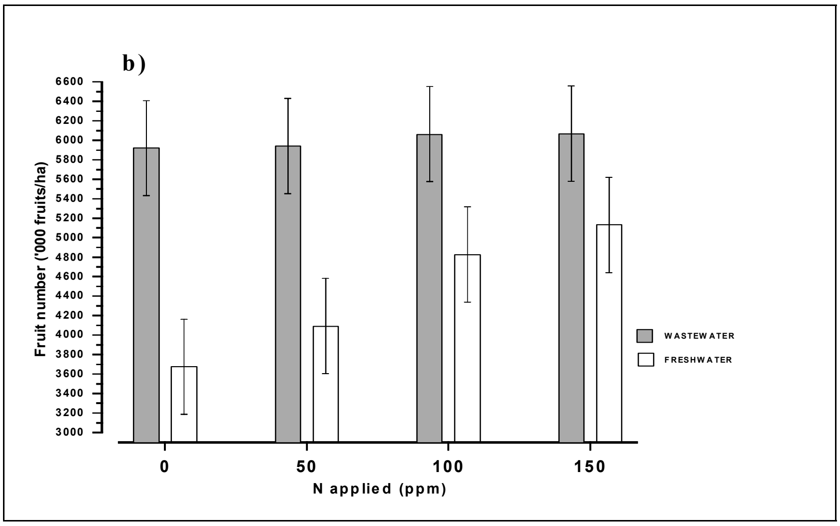


Fig. 2. Average fruit number of a) eggplant and b) sweet pepper as affected by N applied and water quality.

The increase of average yield of sweet pepper from the wastewater-irrigated plots was by 63 % higher compared to the borehole water, 29% for eggplant and by 30% in the case of sudax.

In the case of irrigation with borehole water there was no significant difference in yield at N applications above 50ppm in the case of sudax and above 100ppm in the case of sweet pepper.

With all crops, higher yield was obtained with the treated wastewater than with the borehole water indicating the superiority of the treated wastewater and the possibility of producing high yields without additional N fertilizers (Papadopoulos and Stylianou, 1987,1988a, 1988b, 1991). It is therefore, imperative that recommendations to the farmers concerning fertilisation should be different for the effluent and fresh water, in order to improve the efficient use of water and of nutrients present in wastewater. This will also minimise the risk of pollution, especially in cases where water table is shallow and pollution by nitrate-N could easily happen (Papadopoulos and Stylianou, 1987, 1988a,b). Properly planned use of wastewater can be of economic importance to crop production as it could substitute for fertilizer application and, therefore, reduce cost of production, which can be an important factor to the agricultural economy of developing countries where fertilizer cost is a major constrain to improve production.

On the contrary, results of the productivity of *Gerbera jasmesonii* (flower production per plant) showed that freshwater produced significantly more flowers per plant than the other water qualities.

During the course of the experiment mentha in the epuvalisation system was not fully established from the beginning of the experiment and as it is shown in Table2, of the average water analysis of the four sources of water used in the experiment, there was no significant differences between the secondary treated wastewater and the treated wastewater from the epuvalisation channel A. Therefore there was no significant difference in the flower production and quality between the two treatments (Figs 3 and 4).

Fertilization had a significant effect on flower production in the case of freshwater irrigated plants, but no significant effect on wastewater irrigated plants. Plants irrigated with borehole water had a reduction on flower production especially with the addition of fertilizer, when compared with plants irrigated with wastewater. Reduced flower production and quality could be due to the high electrical conductivity and chloride concentration of the borehole water and wastewater as Gerbera plants are sensitive to high salt concentrations (*Table2*).

Results on the effects of fertilizer and water quality on flower weight of gerbera plants indicate that high salt concentration in wastewater can be a limiting factor for the production of sensitive plants such as *Gerbera jasmesonii* probably due to the slower uptake of water and fertilizer by the plant. Mixing of wastewater with freshwater could give good results by lowering the salt concentration of the water and also providing some nutrients to the plants.

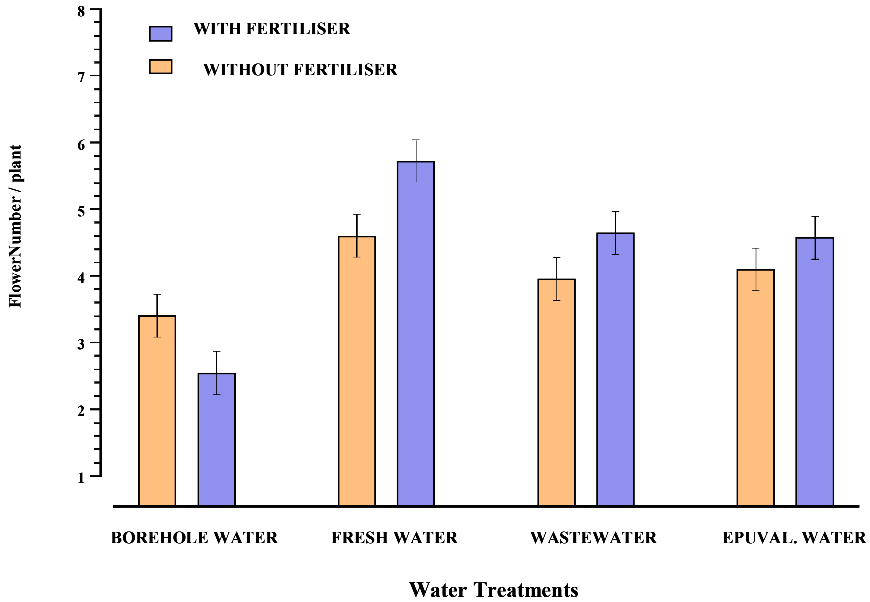


Fig. 3. Effect of water quality and fertilizer on flower production of Gerbera plants

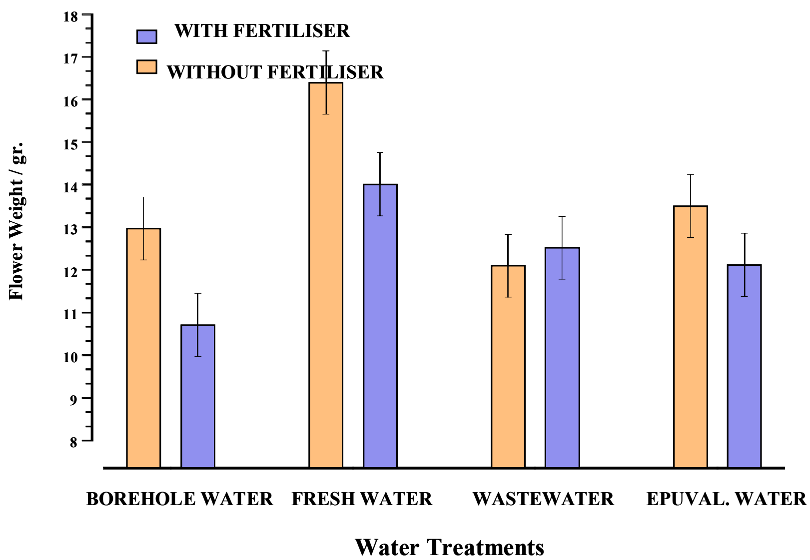


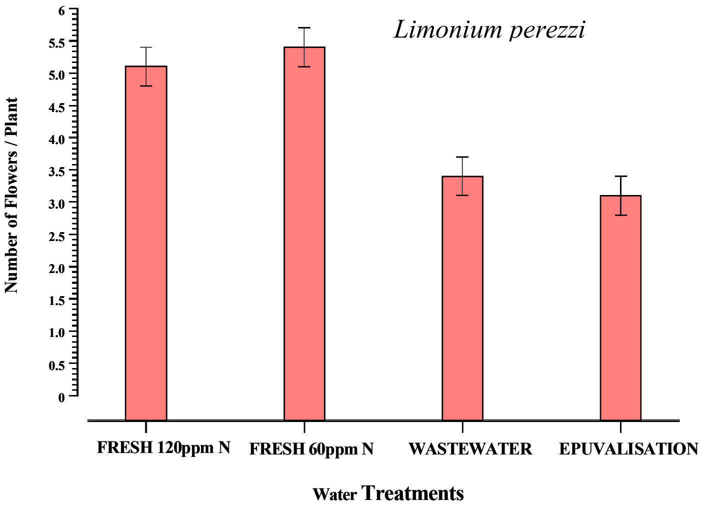
Fig. 4. Effect of water quality and fertilizer on stem weight of Gerbera plants

Results of the effect of fertilizer and water quality on flower production of *Limonium perezii* and Antirrhinum plants showed that both plants irrigated with secondary treated wastewater and treated wastewater from the epuvalisation system were less vigorous and produced significantly less flowers of lower quality than flowers produced from plants irrigated with freshwater with the addition of fertilizer (Figs 5 and 6).

Limonium perezii produced significantly higher number of flowers when irrigated with fresh water with the addition of 120 ppm N than when irrigated with fresh water with the addition of 60ppm N, wastewater or treated wastewater from the epuvalisation channel. Antirrhinum on the other hand, produced significantly more flowers when irrigated with fresh water with the addition of 120 or 60 ppm N, than when irrigated with wastewater or treated wastewater from the epuvalisation system (Fig. 5).

The quality of the produced flowers in both plants (most pronounced effect on Antirrhinum) followed the same trend with significantly higher stem weight (fresh weight) in the cases of fresh water with the lower level of fertilization 60ppm N (Fig. 6).

Plants irrigated with wastewater and treated wastewater from the epuvalisation system showed nitrogen deficiency symptoms indicating that the low flower production was most probably due to the low nitrogen levels in the wastewater during that period (35ppm N in wastewater and 23 ppm N in wastewater treated in the epuvalisation system). Addition of N fertiliser in treated wastewater might be essential when used for irrigation depending on the plant used and level of treatment of effluent.



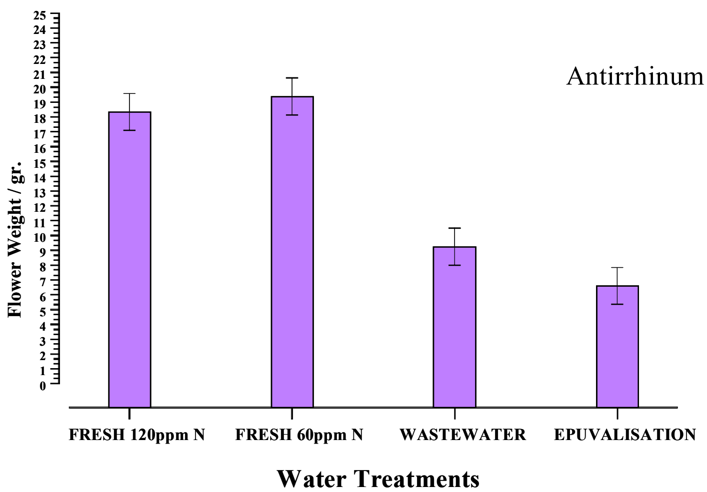
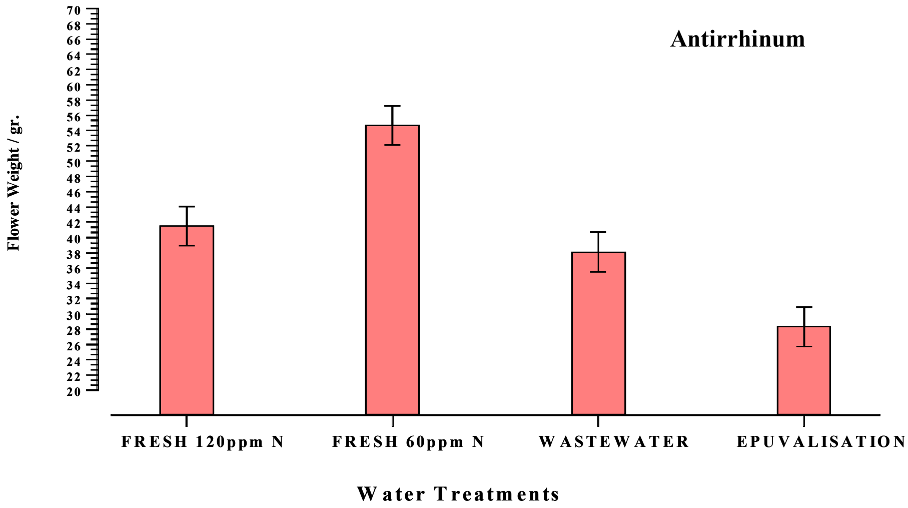


Fig. 5. Effect of water quality and fertilizer in flower production and stem weight of *Limonium perezii* and Antirrhinum plants.



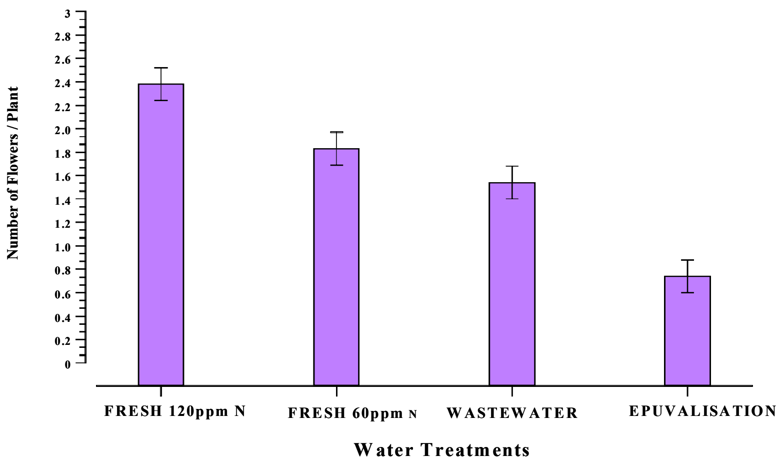


Fig. 6. Effect of water quality and fertilizer in flower production and stem weight of *Limonium perezii* and Antirrhinum plants.

CONCLUSION

The yield results of eggplant, sweet pepper and sudax, indicate the superiority of the treated wastewater and the possibility of producing high yields without additional N fertilizers. In this case yield might not be the highest but with no additional N, pollution problems are minimized. The plant nutrients load in the wastewater can be an important factor in saving costs of fertilizers needed for crop production. It is therefore advisable that recommendations to the farmers concerning fertilization be different for the effluent and freshwater. On the contrary, Gerbera plants irrigated with wastewater and borehole water, produced less flowers compared to the freshwater irrigated plants probably due to the high electrical conductivity and chloride concentration of both waters, as Gerbera plants are sensitive to high salt concentrations.

Plants of *Limonium perezii* and Antirrhinum irrigated with secondary treated wastewater and treated wastewater from the epuvalisation system, were less vigorous and produced significantly less flowers of lower quality than flowers produced from plants irrigated with freshwater with the addition of fertilizer. However, addition of fertilizer above 60ppm N had a negative effect on flower production. Plants irrigated with wastewater and treated wastewater from the epuvalisation system showed nitrogen deficiency symptoms indicating that the low flower production was most probably due to the low nitrogen levels in the wastewater during that period. Addition of N fertilizer in treated wastewater might be essential when used for irrigation depending on the plant used and level of treatment of effluent.

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