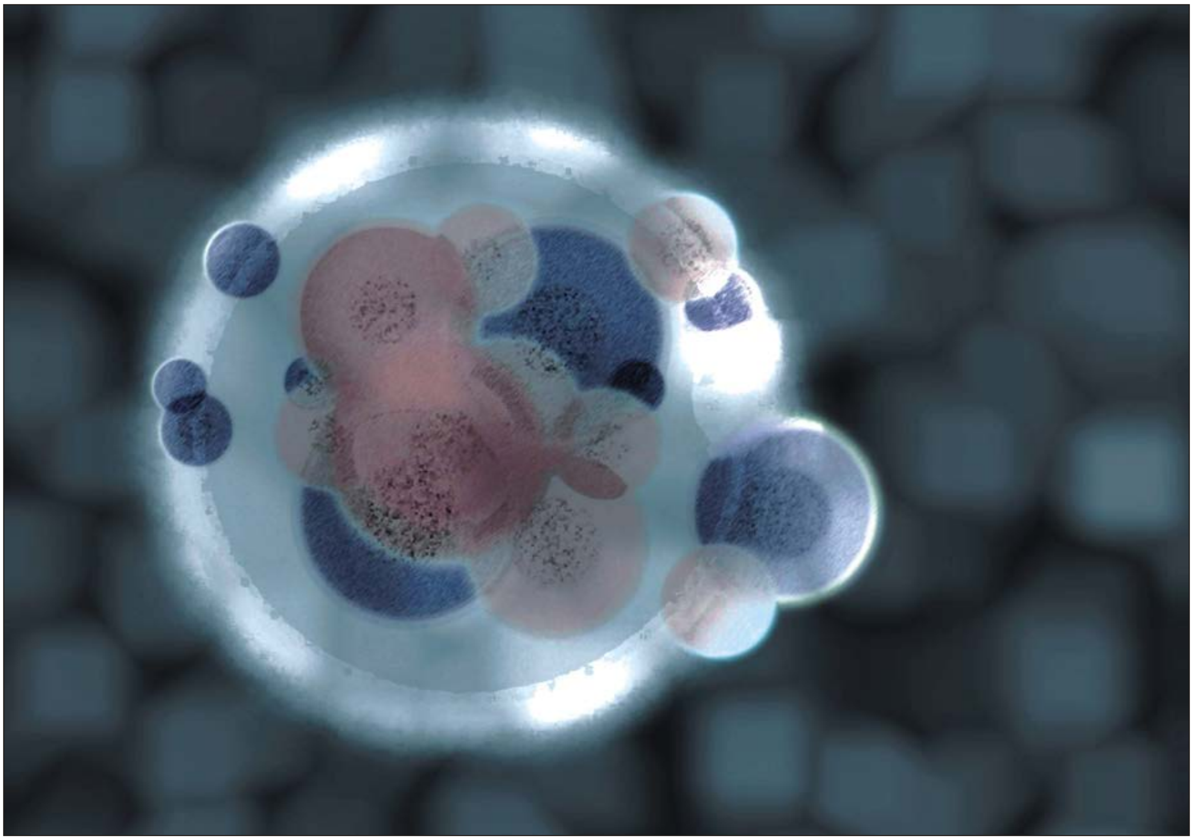

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Effects of Treated Municipal Wastewater on Growth Parameters of Corn in Different Irrigation Conditions

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Abstract: In order to calculate the effects of using treated municipal wastewater on quantity of yield in Corn, this study was conducted in 2003, at experimental farm in south treatment plant in Isfahan. The experimental was randomized complete block design with five treatments and tree replications were used. Treatment were: Furrow irrigation with drinking water network (T_1), surface drip irrigation with wastewater (T_2), subsurface drip irrigation with wastewater in 15 cm depth (T_3), subsurface drip irrigation with wastewater in 30 cm depth (T_4) and furrow irrigation with wastewater (T_5). Results indicated that, subsurface drip irrigation with wastewater in 30 cm depth as compared to other treatments had higher growth parameters and had seen significant difference. Thus, drip irrigation with wastewater and furrow irrigation with wastewater, had lower growth parameters as compared to another treatments. In T_4, plants absorb water and essential elements, better than other treatments because irrigation source is near the root zone.

Key words: Corn, municipal wastewater, subsurface drip irrigation, wastewater reuse

INTRODUCTION

The unconventional growth of the world population especially in the third world countries has brought about a serious food shortage. This food shortage has set researchers in different branches of agriculture to take action to increase productivity to compensate for that (Emam and Niknejad, 1994). This shortage and repeated droughts in recent years resulted in a high consumption of surface fresh water resources in most countries located in the dry region belt leading to too much pressure on water resources (Arvandi and Kamyab-Moghadas, 2001). For a number of countries where current fresh water reserves are or will be in the near future at critical limit, recycled water is the only significant low-cast alternative resource for agriculture industrial and urban non potable purposes (Lazarova and Bahri, 2005). IRAN is among the Middle East countries, which experienced 20-25% drop in annual rainfall comparing to average annual rainfall between 1961-1990 in the year of 2000 (Abedi and Najafi, 2001). These days the use of wastewater for fertilizing agricultural lands and wet land farming is common. The study has shown that the best way for usage of wastewater after treatment is in the agriculture (Pescode, 1992). Having access to wastewater as a reliable and permanent source and nutrients can satisfy the need of agricultural products for water and manure during critical periods. This also provides suitable sources of water and manure for the plant during their growth period. On the other hand, the amount of wastewater salts in some cases is lower than that of the underground water used in agriculture and since the high amount of salts result in lower products, the use of wastewater with lower amount of salts and sufficient nutrients leads to higher yield in many plants (Siahi and Jebeli, 2002).

Since the use of wastewater is an uncommon source of water, its application in agriculture requires especial management to take satisfactory advantage of it and prevent its environmental and sanitary dangers in soil, plant and in surface and underground water (Abedi and Najafi, 2001). Pascode studied the advantage and disadvantages of the application of different methods of irrigation in the exploitation of wastewater and reached to this conclusion that the trickle irrigation is the only method that can remove especial problems resulting form the use of wastewater.

Oron *et al.* (1992) used wastewater in experiment fields in the Palestine and concluded that the contamination of soil and plant surfaces is the lowest when drip irrigation system is used, but when sprinkling irrigation is applied the contamination rate was at its maximum level. Erfani *et al.* (2001) showed that the application of home-purified wastewater enhanced tomato functioning compared with conventional irrigation of this product by well water. In addition to that, in relation to the effect of the application of wastewater in irrigation of corn, Oron *et al.* (1999) realized that the functioning of corn in subsurface drip irrigation is better than that in

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surface drip irrigation system. The aim of this study was to examine important physiological index fluctuations during Corn vegetative growth including leaf area and net assimilation rate which are the constituents of product growth rate. This study also considered the evaluation of the effect of irrigation method on these rates and the trend of the total dry matter accumulation.

Najafi (2006), showed that the subsurface drip irrigation in the depth of 15 cm, in the case of design and implementation of ET-HS model for measuring of crop water requirement, the best condition is achieved for tomatoes when using the municipal wastewater for irrigation. That research indicates that estimating the effects of using treated municipal wastewater and subsurface drip irrigation in the same condition of this research will be offered on the others agriculture crops for further investigation. Also Asgari *et al*. (2007) in the same condition of this research on sunflower reported same results. In addition finding the relationship between soil texture, root zone area and microbiological pollution on soil surface and crops will be suggested for future study.

The aim of this research is assessing of effects of treated municipal wastewater on growth parameters of Corn in the different irrigation treatment specially subsurface drip irrigation.

MATERIALS AND METHODS

South municipal wastewater plant of Isfahan, Iran, was treated about 3 m^3 sec^{-1} of domestic wastewater by activated sludge process. Near of this plant, an experiment was carried out to study the effects of urban treated wastewater in different treatment irrigation conditions on the quantity specification of Corn plant. The experiments were performed in 2003 in random complete blocks in five treatments with three repetitions. The treatments were: Furrow irrigation with Drinking water network (T_1), surface drip irrigation with wastewater (T_2), subsurface drip irrigation with wastewater in 15 cm depth (T_3), subsurface drip irrigation with wastewater in 30 cm depth (T_4) and furrow irrigation with wastewater (T_5). In all of the drip irrigation treatments, in line emitters were selected with 4 L h^{-1} discharge (Table 1). Irrigation schedule was based on ET-HS model (Najafi and Tabatabaei, 2007). This study was done from Jun to Oct, 2003. Only for T_1, to enrich the soil and provide the required elements for the sunflower plant 150 kg of ammonium phosphate was employed before plowing and was evenly distributed over the land based on soil testing. In addition, 50 kg of urea was used before sowing for T_1. Sowing was performed by the use of four-row seeder machine in 75 cm intervals and shrub rows of 18 cm and was irrigated immediately. In the three-to-four-leaf stage, with regard to the space between the shrubs on each row and in order to obtain a desirable accumulation, thinning was performed. On T_1, within this period, 5 kg of urea in each hectare was added to each plot.

Table 1: The irrigation water quality of treatments

Parameters	Unit	Drinking water	Wastewater
EC	dS m^{-1}	0.5	1.5
SAR_{adj}	-	1.8	8.0
N	mg L^{-1}	-	34.0
P	mg L^{-1}	-	66.1
K	mg L^{-1}	-	23.0
pH	-	7.4	7.5

To determine the indices of plant growth, sampling was done 15 days after the sprouting of the plant and this practice was repeated for every 15 days until the harvest. With the deletion of the two side rows with an area of one square meter, the samples were harvested and transferred to the laboratory immediately. The area of the leaf was determined by graph paper. After being separated into different parts, samples were dried in a ventilated oven for 72 h at 70°C and were then weighed.

Then the leaf area index rate fluctuations, the trend of total accumulation of dry matter net assimilation rate and growth speed were determined. The required statistical calculations were carried out by Mstat-C and Stat Graph and graph plotting was performed by Excel software. Duncan's multiple range tests was employed to compare the means.

RESULTS AND DISCUSSION

Leaf area index: Leaf Area Index (LAI) fluctuation trend of the treatments revealed that about 30 days after sprouting, a slow growth in the leaf area index was observed. Probably it resulted from meristematic cells and small leaf area. Then with a fast and linear growth until 90 days after planting, it reached the maximum growth and until the end of the growth, it had a declining trend due to the fall of the leaves. Of course, slight differences were observed among different treatments when they reached their maximum leaf area during the season (Fig. 1).

The leaf area index fluctuation trend for different treatments during the growing season suggests that T_4 treatment has produced more leaf area index compared to other treatments during the growing season (Fig. 1). That is T_4 gained more significant leaf area index compared to other treatments when leaf area index reached it maximum point (Fig. 2). The results suggest that in T_4 treatment, more water has been absorbed and larger leaf area formed due to the nearness of rhizosphere to water and nutrient and made an appropriate moist bulb, up to 60 cm deep. In his research, Tvakoli (1997) has claimed that more water

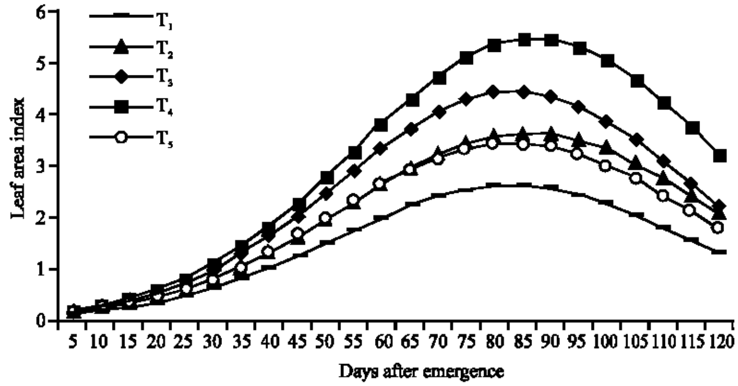

Fig. 1: The comparison of time fluctuation trend for leaf area index in different treatments

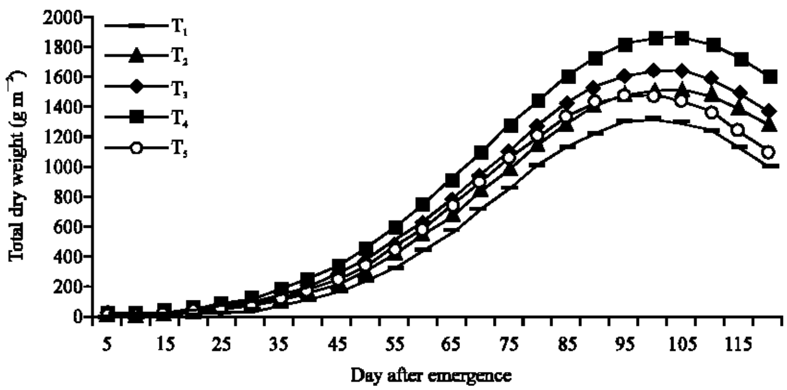

Fig. 2: Total dry weight fluctuation trend of aerial organs in different treatments

absorption by the plant resulted in an increase in the leaf area index. He also added that high concentration of nitrogen in the wastewater compared with common water and its nearness to rhizosphere for absorption by the plant in T_4 treatment resulted in an increase in the leaf area index. Stoskopf (1985) reported that the higher level of nitrogen absorption by the plant increases the leaf area expansion. Asgari *et al.* (2007) in the same condition of this research on sunflower reported that sunflower under the same irrigation condition has same LAI index.

Total dry matter: The total dry weight fluctuation trend shows that the dry matter seasonal fluctuations in shoots can be divided into three stages. The first stage which starts from the sprouting until about 30 days after planting, the growth is slow. After this stage, the fast growth starts and continues until 95 days after sprout. After this stage, the trend of total dry weight is stable. The cause of this reduction is the start of defoliation and petiole falling. In all treatments, the maximum accumulation of dry matter takes place within the time span between stages of flower initiation (R_5) and end of flowering (R_6).

The dry weight fluctuation trend under study for total treatments during the growing season also shows that T_4 treatment compared with other treatments during the growing season, has produced more total dry weight. This same T_4 treatment has meaningfully produced more total dry weight during the final harvest compared with other treatments. This fact shows the proper use of moisture by the plant resulting from this treatment in deeper depth of soil and better absorption of nutrients by the root (Fig. 2). The study of the total dry matter in the maximum leaf area stage showed a positive and meaningful correlation with the leaf dry weight ($r = 0.965^{**}$). This shows the effect of the photosynthetic area in the increase of the total dry matter. The same is true for the plant Ear dry weight, so that with T_4 treatment with 545.8 g m^{-2}, there will be the most functioning and shows a meaningful difference at 5% level with other treatments Fig. 3.

The results indicate that in (T_3 and T_4) subsurface Drip irrigation treatments, less weed grew to compete with the plant and less water evaporated from the soil surface with more dry weight were due to the nearness of irrigation water source and nutrients nitrogen present in

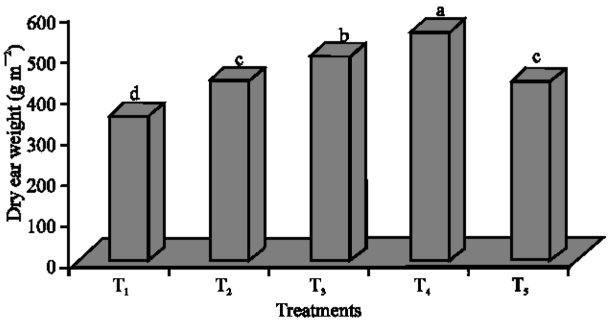

Fig. 3: The mean for dry ear weight in the treatments under study

the wastewater around he rhizosphere to be absorbed. With an increase in root depth during the growing season in T_4 treatment, due to the formation of moisture around bulb with a more depth compared to T_5 treatment, more absorption of water and nutrients like nitrogen was done.

This resulted in a meaningful increase in the total dry matter functioning of T_4 treatment compared with T_3 treatments. Therefore, more absorption of water and nutrients resulted in an increase in photosynthetic activity and ultimately into more production of dry matter in T_4 treatment. Kamprath *et al.* (1982) reported that more water and Nitrate absorption by Corn resulted in an increase in the total dry matter. Christopher *et al.* (2000) also reported that more absorption of nitrogen by the plant leads to an increase in the functioning of total dry matter.

Net Assimilation Rate (NAR): The fluctuation trend of the net assimilation rate during the growing season shows that the T_4 treatment in its initial growth has a higher absorption rate compared to other treatments (Fig. 4). However, by lapse of time and in the middle of the growth, the absorption rate becomes less than that of other treatments. It shows that in this treatment, more leaf area is formed in the initial growth and the net assimilation rate has increased, but during the middle of the growth, due to more leaf area, a large number of ventral leaves of the shrub hid within the upper leaves and change into consumers. This brings about a reduction in the net assimilation rate in unit area. The above trend after T_4 treatment is also observed in T_3. T_2 and T_5 treatments have rather the same absorption rate.

T_1 treatment is an index for less leaf area formation in the initial growth, so it has a lower absorption rate in this stage, but in the middle of the growth, due to less leaf area, the present lower leaves compared with T_4 treatment receive more sunlight resulting in an increase in net assimilation rate in T_1 treatment compared with other treatments. During the end of the growth period, T_4 treatment shows more net assimilation rate compared to other treatments, because in this period, we have great abscission and with regard to more head area in T_4 treatment, its net assimilation rate is higher (Soleymani *et al.*, 2003). Asgari *et al.* (2007) in the same condition of this research on sunflower reported that sunflower that irrigated with subsurface drip irrigation system has higher NAR compared to Furrow irrigation.

Crop growth rate: The growth rate of the product in T_4 treatment reaches its highest level about 65 days after sprouting, which coincided with pollination (Fig. 5), but after that, the growth rate of the product in all treatments became less and at the time of harvest, the lowest growth rate of the product is observed in T_4 treatment.

The product growth rate fluctuations are more harmonious with leaf area index fluctuations but it enjoys less harmony with net assimilation rate fluctuations. Therefore, the leaf area index has the main role in the determination of the product growth rate.

Vanderhoek *et al.* (2002) consider the higher functioning of the sunflower in the same cultivation condition because of the high growth rate of its product. In another experiment, the same results were obtained for sugar beet and showed that the product growth rate of sugar beet is more related to the leaf area index compared with net assimilation rate. This trend conforms to Soleymani *et al.* (2003) conclusions. Asgari *et al.* (2007) in the same condition of this study on sunflower reported that sunflower under the same irrigation condition has same CGR.

This study also showed that the product growth rate was more dependent on leaf area index compared with net assimilation rate. The high product growth rate in T_4 treatment shows better enjoyment of the plant from waste resources and other environmental factors. In T_4 treatment, due to nearness of irrigation source and nutrition to rhizosphere, better absorption is performed compared with other treatments and these results in more increase in the product growth rate in this treatment. Ultimately, the higher product growth rate resulted in better functioning.

Suggestions: By studying the results of the product growth indices, it can be suggested that in the first place, the application of wastewater due to the presence of nutrients results in an increase in the product growth indices in ordinary situations (Asgari *et al.*, 2007; Meli *et al.*, 2002; Ramirez-Fuents *et al.*, 2002).

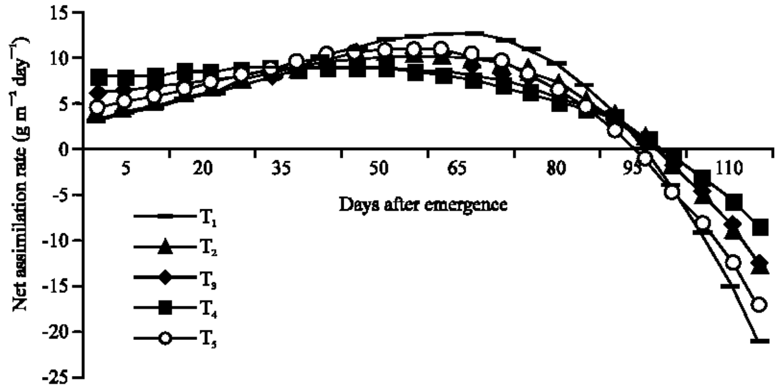

Fig. 4: Net assimilation rate seasonal fluctuations in different treatments

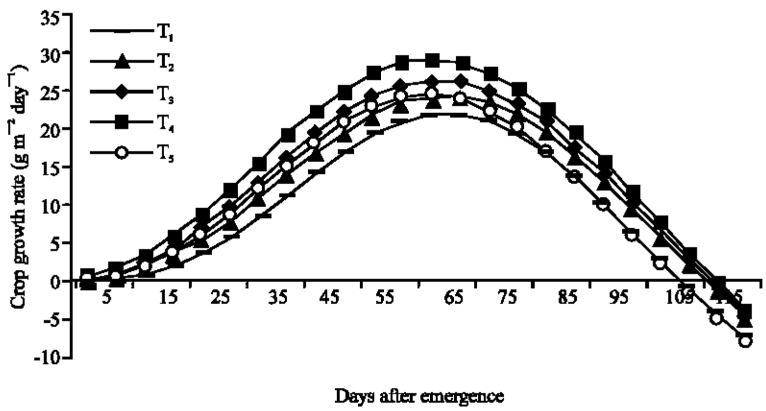

Fig. 5: The product growth rate fluctuations trend during the growing season in different treatments)

In the second place, among the treatments under study, the most dry matter rate and product functioning was observed to be performed by subsurface drip irrigation treatment at a depth of 30 cm (Asgari *et al.*, 2007). This shows the supply of moisture and nutrients in the rhizosphere development environment.

Third, when the surface evaporation rate in subsurface drip irrigation is reduced, the efficiency of water consumption in T_4 increases meaningfully.

As a general conclusion, irrigation with wastewater through drip method at a depth of 30 cm of soil is a suitable method for the irrigation of corn plant. Bryla *et al.* (2003) reported same result on faba bean. Due to the formation of moist bulb in suitable depth and reduction in soil surface evaporation leads to more access of the plant to water and nutrients Lamm and Trooien (2003) reported that a successful application of subsurface drip irrigation for 10 years in Kansas, USA, reduced the irrigation water-use for corn by 35-55% compared with traditional forms of irrigation. Also Fulton *et al.* (1991) reported same result on cotton.

In addition, less use of herbicides and reduction of the danger of environmental contamination, all result in a better control of weeds growing between the planting rows. Also, due to the dryness of the planting rows which provide suitable conditions for the movement of agricultural machinery in the best gain is attained.

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