Journal of Sustainable Bioenergy Systems, 2012, 2, 43-48
http://dx.doi.org/10.4236/jsbs.2012.23007 Published Online September 2012 (http://www.SciRP.org/journal/jsbs)

Impact of Sugar Industrial Treated Effluent on the Growth Factor in Sugarcane—Cuddalore, India

Usha Damodharan, M. Vikram Reddy*
Department of Ecology and Environmental Sciences, Pondicherry Central University, Pondicherry, India
Email: *Venkateshsrinivas1@gmail.com, *prof.mvikramreddy@yahoo.com, ushadamodhar@gmail.com

Received May 7, 2012; revised June 10, 2012; accepted June 17, 2012

ABSTRACT

The present study focused on evaluating the impact of application of sugar industry treated wastewater effluent on Sugarcane growth comparing at two experimental farms, one irrigated with the effluent and the other with bore well water, over a period of 11 months (March 2010 to January 2011).The result indicated a significant increase in growth pattern, plant height, shoot diameter, number of leaves and nodes, and biomass of the saplings that was irrigated with the effluents compared to that irrigated with bore well water. The growth parameters showed close relationship with the nutrient contents of treated industrial effluent and bore well water, the former being characterized by relatively higher pH, electrical conductivity (µs/cm), total suspended solids (TSS), sulphate, biochemical oxygen demand, chemical oxygen demand, nitrate and phosphate, and heavy metals—Cu, Pb, Cd, Zn and Mn (mg/l) compared to that of bore well water, indicating profound influence of nutrient rich sugar industry effluent on the plant growth. Higher biomass in sugarcane saplings resulted with irrigation of the effluents compared to that irrigated with the bore well water.

Keywords: Industrial Effluent Irrigation; Bore Well Water Irrigation; Sugarcane; Growth Pattern; Biomass

1. Introduction

Emerging trends of agricultural automation, and reclaimed and treated industrial effluent irrigation over stresses the agricultural land resources through their excessive micro element contamination [1]. Rising trends of using the waste water (industrial effluents) for irrigation has the advantage of pollution removal where the pollutants are partly taken up by the plants and partly transformed in the soil without causing any damage. In many parts of the world, treated effluents have been successfully used for irrigation, and researchers have recognized its benefits [2]. In the Mediterranean countries, treated wastewater is increasingly used in the areas with water scarcity, and its application in agriculture is becoming important to water supplies. The potential for adverse health impacts of irrigation with wastewater has been addressed in a number of earlier studies. Effective and appropriate wastewater treatment processes can reduce the health hazards associated with wastewater use. However, [3] the treated effluent coming through stabilization ponds or conventional treatment plants followed by maturation ponds or sand filtration may be free of pathogens. In India as referred by [4], the significant positive correlation between the growth of the saplings *Casuarina equisetifolia* and the nutrient quality of municipal sewage has been reported. In Greece, the possibility of wastewater reuse for irrigation of vegetables has been studied by Kalavrouziotis [5]. Several earlier studies have shown the advantages and disadvantages of using wastewater for irrigation of various crops. The reuse of treated wastewater is a good option for increasing water supplies to agriculture. One of its benefits is the plant's use of the water's nutrients and therefore, a reduction in the pollution load that wastewater contributes to the water and land resources [6]. However, depending upon its sources and treatments, industrial wastewater may contain high concentrations of nutrients and toxic heavy metals and the reclaimed industrial wastewater application may create undesirable effects in soils, which may lead to bio-accumulation in plants and pose a health risk for human beings.

In effluent-fed agriculture, nutrients flow from wastewater into the plants accelerates and improves the crop production, and eventually it may lead to the reclamation of effluent water as an added advantage. Many economically important vegetables and flowering plants can utilize the major nutrients (NO_3-N, NH_4-N and H_2PO_4/HPO_4-P) for their growth from the nutrient—rich waste water upon proper management or suitable amendments [7]. This concept may be applied as a method for eco-

*Corresponding author.

logical treatment of wastewater but there is also a risk of accumulation of the heavy metals within the edible parts of the plant that can create metal toxicity in the human body when they are consumed. This accumulation depends directly upon the concentration of heavy metal in wastewater, so the feasibility of implementing this eco-tech for wastewater reclamation massively must be cautioned of heavy-metal accumulation in leaf and crops. Several drawbacks in using waste water for agriculture was determined [6]. They reported the problem of soil salinity, interaction of chemical constituents of the wastes with the uptake of nutrients and changes in soil property and micro flora in the agricultural field irrigated with the wastewater. This necessitates a detailed study before any specific waste can be used for irrigation for a particular crop with a particular soil and climate. The objective of this research work was to study the effects of sugar industry treated effluent reuse for the irrigation of sugarcane crop, comparing two sources of irrigated water and evaluating their effects on plant growth. Since, crop plants are increasingly being irrigated with the effluents, an attempt has been made to study the comparative effects of sugar industry treated effluents and bore well water on growth and biomass in sugarcane.

2. Materials and Methods

2.1. Sampling Location

The experimental sites were located in Cuddalore and Panruti both from Cuddalore district, Tamil Nadu. The first experimental plot was located at Nesanur in Cuddalore, where the treated wastewater used and the second experimental plot was located at L.N.Puram in Panruti where the bore well water was used for irrigating sugarcane. Sampling at Nesanur farm and Panruti farm was undertaken across 5 plots each measures approximately 50m × 200 m and sugarcanes of these plots were measured every month for their length, shoot diameter, number of leaves and nodes (**Figure 1**).

2.2. Irrigation and Fertilization

Flood irrigation method was followed for irrigating both the sugarcane fields. Effluent Irrigation was scheduled at two months interval and the bore well water irrigation was scheduled at six or ten days interval. The actual irrigation application rate may be altered in response to rainfall, soil moisture, and other related factors. An average of 128 kg/ha N, 63 kg/ha P_2O_5 and 7 kg/ha K_2O fertilizers were applied in both the fields.

2.3. Physico-Chemical and Heavy-Metal Analysis

The physico-chemical characteristics—pH, electrical conductivity (µs/cm), total suspended solids, 5-days biochemical oxygen demand, chemical oxygen demand, nitrate nitrogen, sulfate, phosphate (mg/l) and heavy metals—Cu, Pb, Cd, Zn and Mn (mg/l) of sugar industry treated effluent and bore well water were analyzed using following standard methods cited in **Table 1** [8]. Water analysis was done taking three replicates.

2.4. Plant Growth Measurement

The heights, diameter of shoots and number of nodes and leaves, of each sugarcane sapling in each replicate plot were recorded every month, and the biomass of each of the saplings was measured at the end (12 months) of the experiment (**Table 1**).

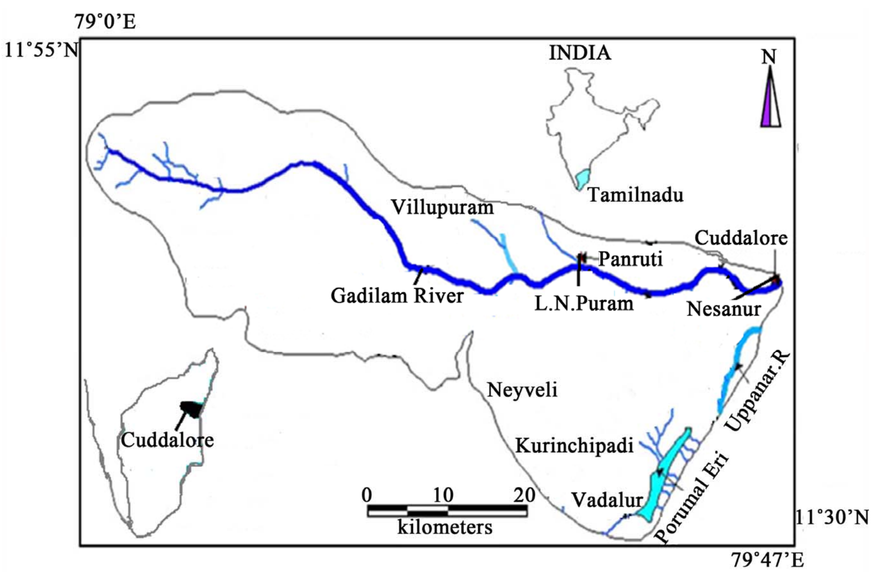

Figure 1. Sampling locations.

Table 1. Methods for measuring different parameters used in this study.

Parameters	Methods
Stem length and diameter	Simple scale measuring method
Number of nodes and leaves	Visual counting method
Biomass	Wet weight measuring method
Sulfate	Spectrophotometric method (APHA, 1995)
PO_4-P	Stannous chloride method (APHA, 1995)
NO_3-N	Spectrophotometric screening method (APHA, 1995)
Temperature	Partial immersion method (APHA, 1995)
pH	Electrometric method (APHA, 1995)
Chemical oxygen demand	Closed reflux titrimetric method (APHA, 1995)
Biological oxygen demand 5-day dilution	BOD test method (APHA, 1995)
Total suspended solid (TSS)	Filtration and thermal evaporation method (APHA, 1995)
Digestion of heavy metals (Cd, Cu, Pb, Zn and Mn)	Di-acid digestion method (APHA, 1995)
Estimation of heavy metals (Cd, Cu, Pb, Zn and Mn)	Spectrophotometric method (APHA, 1995)

2.5. Statistical Analysis

ANOVA analysis of the data on height of the saplings, diameter of shoots, number of nodes and leaves of plants that were grown in industry treated effluent and bore well water over the 11 month period was computed. Multiple correlation analyses were computed between the nutrients of the irrigated water and the plant growth.

3. Results

3.1. Water-Quality Parameters

Analyses of water quality parameters such as pH, electrical conductivity, suspended solids (TSS), Biochemical Oxygen Demand-5, Chemical oxygen demand, nitrate nitrogen, sulfate, phosphate (mg/l) and heavy metals (Cu, Pb, Cd, Zn and Mn) of sugar industry treated effluent and bore well water used for irrigation of sugarcane saplings showed that the average concentrations of each of the above water quality parameters of treated effluent were higher than those of the bore well water (**Table 1**). The average temperature in the treated effluent and bore well water were 28.1˚C and 27.0˚C, respectively. The average pH and that of electrical conductivity and nitrates (mg/l) in treated effluent were higher than those of the bore well water. The average TSS, BOD, phosphates, nitrates and sulfates in treated effluent were 108, 3100, 35, 7 and 23 folds higher than that of the bore well water, respectively (**Table 2**). The COD of treated effluent water was higher (19,860 ± 247.85 mg/l) while its concentration was below the detection limit in bore well water indicating its cleanliness. Heavy metals like Cu, Pb, Zn and Mn (mg/l) in treated effluent were 150, 48, 352 and 83 folds higher than the bore well water, respectively (**Table 2**).

3.2. Sugarcane Sapling Growth

One of the ways to reduce the pollution of the receiving water bodies due to the industrial effluent is its optimum reuse in irrigation of crops and tree plantations. Our study revealed that the height of sugarcane during the first month of the irrigation with treated effluent and bore well water were 14.25 ± 2.45 and 9.12 ± 1.54 cm, respectively. After four months of irrigation, the height of the saplings increased 41.4 ± 12.68 and 38.5 ± 18.37 cm, respectively, whereas after eight months the height of the saplings increased to 148.12 ± 37.17 and 92.18 ± 14.68 cm in treated effluent and bore well water irrigation, respectively; after eleven months of irrigation and at the time of harvesting the height of the saplings recorded were 185.15 ± 34.12 and 135.12 ± 21.15 cm, respectively in the two corresponding sites (**Figure 2**). ANOVA results of the plant height grown across the treatments of treated

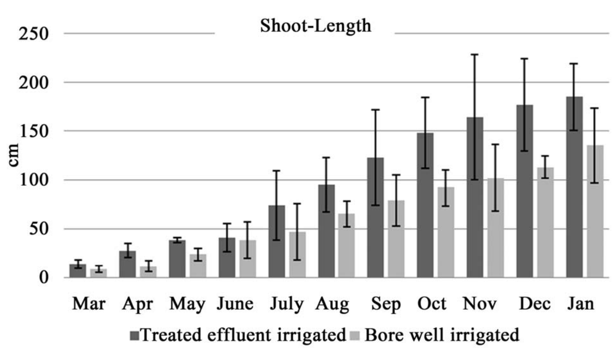

Figure 2. Variation in the shoot-length of the sugarcane across the two different treatments.

Table 2. Mean concentration of physico-chemical parameters, and heavy metal concentration of treated effluent in relation that of bore well water used for irrigation.

Physico-chemical parameters	Treated effluent	Bore well water
Temp (˚C)	28.1	27
pH	8.5	6.5
EC (µs/cm)	1076	164
TSS (mg/l)	432	4
COD (mg/l)	19,860	BDL
BOD (mg/l)	9300	3
Nitrate (mg/l)	36.7	5
Phosphate (mg/l)	14	0.39
Sulfate (mg/l)	107	4.53
Heavy metal concentration		
Cu (mg/l)	3.12	0.02
Pb (mg/l)	1.46	0.03
Cd (mg/l)	2.37	BDL
Zn (mg/l)	14.11	0.04
Mn (mg/l)	5.03	0.06

effluent and bore well water being recorded highest in the former and lowest in the later showed significant difference in the height of the saplings between and within the two sites (**Table 3**). There was significant positive correlation between the height of the saplings and the quality of treated effluent in the present study (R2 = 0.74, $p < 0.01$). Shoot length increased with the increase of strength of effluent. The lower height in the saplings irrigated with bore well water were most probably due to its relatively low nutrient contents.

Our present result showed that shoot diameter during the first month of irrigation with the treated effluent and bore well water were 5.13 ± 1.1 and 2.14 ± 0.056 cm, respectively. After fourth month of irrigation, it increased to 11.23 ± 2.11 and 7.09 ± 3.45 cm, respectively. After eight months of irrigation with the treated effluent and bore well water the diameter of the shoot increased to 15.26 ± 4.13 and 9.38 ± 1.54 cm, respectively and at the time of harvesting it was 22.34 ± 9.75 and 11.66 ± 3.48 cm, respectively (**Figure 3**). In order to compare the variation in the numbers of leaves and nodes that indicate the physiological age of sugarcane plants irrigated with treated effluent and bore well water, were counted. ANOVA Analysis showed that the variations in their count between the two sites were significantly different (**Table 3**). The number of nodes of plants irrigated with the treated effluent ranged from (2 - 23), whereas in the bore well water irrigated field it ranged from (2 - 17). The node number was directly proportional to the strength of the effluent and it was declined in the bore well water irrigation (**Figure 4**). The number of leaf was more with the increasing strength of wastewater and the variances in number in relation to different strengths of effluent were statistically distinct (one way ANOVA, $p < 0.05$). The range of leaves of sugarcane irrigated with treated effluent were (2 - 36), and in the bore well irrigated field it ranged from (2 - 22) (**Figure 5**). Similarly, the average wet biomass of each sapling after 11 months of irrigation of treated effluent and bore well water were 4.3 and 2.85 kg per sapling, respectively (**Figure 6**).

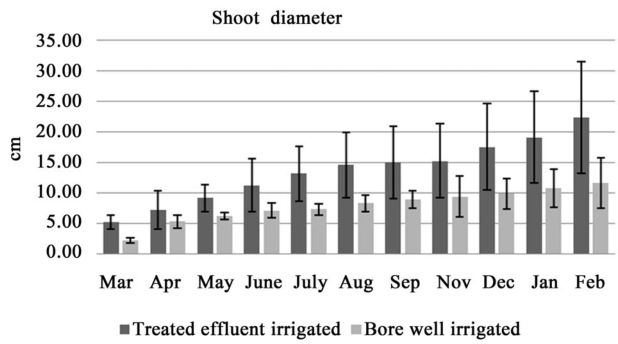

Figure 3. Variation in the shoot diameter of the sugarcane across the two different treatments.

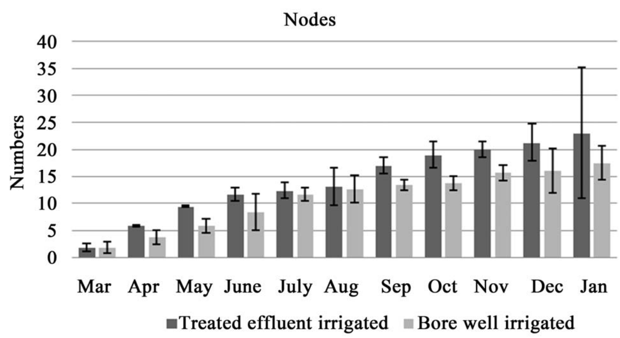

Figure 4. Variation in the number of the nodes of sugarcane across the two different treatments.

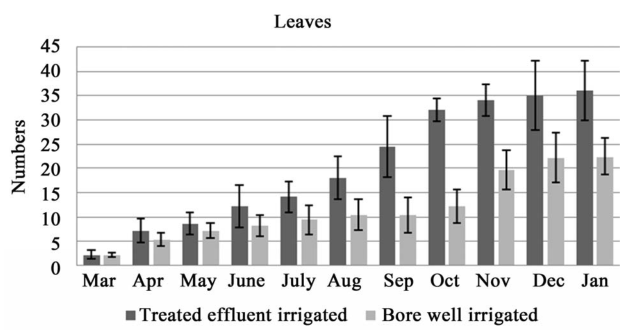

Figure 5. Variation in the number of leaves of the sugarcane across the two different treatments.

Table 3. ANOVA analysis of growth of the plants (sugarcane) across two different irrigation treatments.

Source of variation	SS	df	MS	F	p-value	F crit
Height of the plants	3599.522	11	3599.522	4.662467	0.033824*	3.960352
Diameter of the plants	179.9512	11	179.9512	10.52694	0.004061*	4.351243
Number of nodes	3309.183	13	1103.061	11.428797	2.74E – 14**	2.718785
Number of leaves	404.6328	13	404.6328	4.921508	0.048642*	4.351243

*$p < 0.05$, **$p < 0.01$.

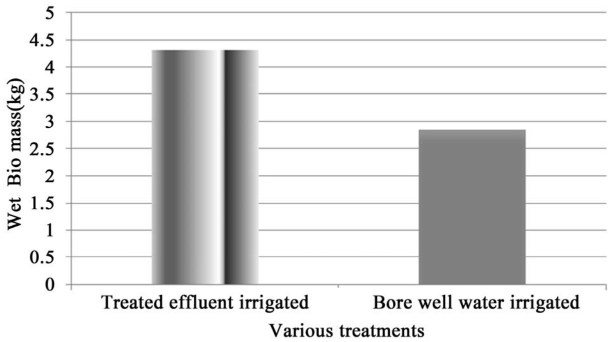

Figure 6. Variation of the wet biomass (kg) of the sugarcane across different treatments.

4. Discussion

During the present investigation, a pattern of pH and temperature alteration was noticed in both the treated effluent and bore well water; the maximum value of pH, indicated the alkaline nature of water, and it is attributed to high temperature that reduces the solubility of CO_2. Due to the higher concentration of phosphates, sulfates, nitrates and other organic matters in the treated effluent showed a highest average value of total suspended solids, when compared to that of bore well water. In consistence to the present findings, [9] reported an increased physico-chemical concentration in treated wastewater than that of ground water used for irrigation in Egypt. Similarly, [10] reported increased average values of the water-quality parameters—TSS, TDS, BOD, COD, pH, NH_3, phosphates, temperature (˚C) in treated effluents than that of river water in Kuwait.

Increased growth of sugarcanes irrigated with treated effluent is associated with the availability of increased organic matter, and both macro and micronutrients, especially total and available N in the treated effluent [11]. In consistence to the present findings, [12], also reported increased growth density and shoot length in Navel Orange trees irrigated with sewage in Egypt. Similarly, increase in water and nutrient availability through effluent application influenced the growth of *Acacia nilotica* [13]. [14] reported that nitrate in waste water is usually beneficial in increasing yields and quality. However, he also concluded that highest concentration of nitrate also can reduce the sugar content of crops, which may affect flavor and quality. Similar findings were also reported by [15], in green leafy vegetables. Delayed growth reported during the primary stage of the sugarcane sapling was agreed in the previous studies [16]. [17] reported that higher concentration of effluent causes delayed shoot growth, seedling growth and chlorophyll content in sunflower (*Helianthus annuus*) and it could be safely used for irrigation purpose at low concentration. However, presence of higher concentration of heavy metals in irrigated water has been reported to cause adverse effects in plants [18]. Maximum number of nodes and leaves reported in effluent irrigated sugarcane is probably due to the higher concentration of phosphate in effluent water, which is absorbed by the plant and stored for its metabolic process. [19] reported the significant increase in the sapling height in the treatment irrigated with municipal raw sewage in the species of *Casuarina glauca*, *Eucalyptus camaldulensis* and *Tamarix aphylla*. The availability of water and nutrients probably had positive effects on shoot growth [13]. Maximum biomass resulted in sugarcane saplings irrigated with treated effluent may be due to its response to the nutritive elements, constant supply and continuous replenishments of nutrients like nitrogen and phosphorous from irrigated water and improved soil structure. [13] reported higher growth and biomass in seedling of acacia and eucalyptus respectively, which they attributed to the effects of available nutrients, particularly N in the effluent facilitating leaf initiation that converted more solar energy enhancing CO_2 fixation and photosynthetic level leading to higher growth and biomass production. The irrigation with effluent on landscape and agricultural fields has the risk of modified soil chemical and physical properties [11].

5. Conclusion

The findings from this study suggest that the irrigation with the treated sugar industry effluent characterized by high nutritive value can improve the overall growth of the sugarcane compared to the bore well water. Furthermore, irrigation with treated effluent minimizes the use of mixed compound chemical fertilizers, increases the soil organic matter, improves soil physical and chemical properties, upgrade soil fertility, and it is helpful for building good soil ecosystem and sustainable sugarcane production. These findings conclude that the future perspective of treated effluent in agriculture is favorable due to its effect on increased crop yield and growth, but there is also a possible accumulation of various nutrients and heavy metals in soil and in the ground water that may cause potential problems after long-term reclaimed wastewater irrigation. Nevertheless, it is suggested that risk assessment should be conducted prior to effluent irrigation to keep the safe application of wastewater for landscape and agriculture and make its reuse safer.

6. Acknowledgements

Mrs. Usha is very grateful to Ecology and Environmental Science Department of Pondicherry Central University for providing the laboratory facilities to carry out the necessary analysis, and to Pondicherry University for providing the university fellowship. This paper is a part of the primary author (Mrs. Usha)'s PhD research work.

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