American Journal of Earth and Environmental Sciences
2018; 1(1): 34-40
http://www.aascit.org/journal/ees

American Association for Science and Technology

Sugar Mill Effluent Induced Changes in Growth and Yield of African Marigold (*Tagetes erecta* L.)

Thanapal Vaithiyanathan[1], Anbazhagan Kathirvel Murugan[2], Perumal Sundaramoorthy[2, *]

[1]PG Research Department of Botany, Vivekanandha College of Arts and Sciences for Women, Tamil Nadu, India
[2]Department of Botany, Annamalai University, Tamil Nadu, India

Email address

vaithiyanathant@yahoo.in (T. Vaithiyanathan), ppsmoorthy@yahoo.com (P. Sundaramoorthy)
[*]Corresponding author

Citation

Thanapal Vaithiyanathan, Anbazhagan Kathirvel Murugan, Perumal Sundaramoorthy. Sugar Mill Effluent Induced Changes in Growth and Yield of African Marigold (*Tagetes erecta* L.). *American Journal of Earth and Environmental Sciences.* Vol. 1, No. 1, 2018, pp. 34-40.

Received: January 23, 2018; **Accepted**: February 26, 2018; **Published**: March 23, 2018

Abstract: Sugar mills play a major role in creating environmental pollution. It releases a larger amount of wastewater as effluent into the nearby water bodies which create serious problem in the aquatic ecosystem. Due to water scarcity, the farmers are started to use these polluted water for agricultural irrigation. In the present study, the impact of different concentrations (10, 25, 50, 75 and 100%) of sugar mill effluent on growth and yield of African marigold (*Tagetes erecta* L.) was reported. The morphological growth parameters such as root length, shoot length, total leaf area, fresh weight and dry weigh were recorded at 30, 60 and 90 DAS respectively. The yield parameters like number of flowers per plant, diameter of flower, fresh weight and dry weight of flower were recorded at harvest stage. The highest growth and yield was recorded in the plant irrigated with lower concentration (10%) of sugar mill effluent. These parameters were found to be gradually decreased with increase of effluent concentrations. From this study, it is suggested that the lower concentration (10%) of sugar mill effluent can be used for irrigation.

Keywords: Agriculture, Pollution, Sugar Mill Effluent, *Tagetes erecta* and Yield

1. Introduction

The sugar mill is one of the agro-based industries in India. It plays a major role in rural economy of our country. It works only for four to six months per year due to availability of sugarcane, an important raw material for sugar production. During the manufacture of sugar, a large amount of wastewater released into nearby water bodies. The effluent contains high Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), suspended solids and dissolved solids [1]. The higher amount of organic and inorganic compounds was reported to be present in the sugar mill effluent. It alters the physico-chemical properties of the receiving water bodies and adversely affects the aquatic flora and fauna [2], the soil and biological systems [3]. It has also rich plant nutrients which are very much essential for plant growth. The farmers are utilizing this wastewater to grow their agricultural crops [4]. If the farmers used this effluent continuously for irrigation, the soil properties of agricultural land determined by accumulating the heavy metals deposited in the soil [5]. The uptake of the heavy metal from polluted soil might cause the reduction in plant growth and yield [6]. The effluent irrigation not only affects the yield of crop and also affects the health of the consumers [7].

Since the waste water irrigation affects the soil fertility, plant growth, yield and consumers. It is planned to cultivate the ornamental plants under effluent irrigation. The plant marigold was selected because their wild cultivation and economic importance. This practice not only reduces the pollution load and but also reduce the water scarcity for irrigation. Thus, the present research work was carried to find out the effect of different concentrations of sugar mill effluent on growth and yield of the African marigold.

2. Materials and Methods

2.1. Effluent Collection and Analyses

The effluent sample was collected in the plastic container from the outlet of the N.P.K.R. Ramaswamy Co-operative sugar mill in Thalainayar, Mayiladuthurai Taluk, Nagapattinam District, Tamil Nadu, India. The effluent was brought to the Ecology Laboratory, Department of Botany and stored in a refrigerator at 4°C for analysis purpose.

The collected sugar mill effluent sample was analysed for their various physico-chemical properties in Ecology Laboratory, Department of Botany, Annamalai University as per the routine Standard methods mentioned in [8].The collected effluent sample was treated as 100 per cent raw effluent. Different concentrations (10, 25, 50, 75 and 100%) of effluent were prepared freshly by using tap water whenever necessary and they were used for field experiments.

2.2. Seed Collection

Tagetes erecta (L.) seeds were procured from Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu, India. The healthy and uniform size seeds were selected and used for field experiments.

2.3. Experimental Site

Field experiments were conducted in the village Kali, nearby factory, Mayiladuthurai Taluk, Nagapattinam District, Tamil Nadu. It was carried out to assess the effect of different concentrations (10, 25, 50, 75 and 100%) of sugar mill effluent on morphological growth and yield response of African marigold.

2.4. Irrigation Schedule

The experimental plots were irrigated with tap water was treated as control. The quality of tap water did not vary during the experimental periods as per the standards prescribed by Indian Standard Institution for irrigation water. First irrigation was done to all plots with good tap water two days before sowing. African marigold seeds were sown with a spacing of 20 X 20 cm. Equal volumes of the different concentrations (10, 25, 50, 75 and 100%) of sugar mill effluent were irrigated at weekly twice up to harvest stage. Equal volume of tap water irrigated plot was treated as control.

2.5. Parameters Studied

Five plant samples were randomly collected from each treatment plot at various stages (30, 60, and 90 DAS) of its growth and used for recording morphometri observations. The root length, shoot length, total leaf area, fresh weight, dry weight, and yield parameters such as number of flowers per plant, diameter of flower, fresh weight of flower and dry weight of flower of African marigold plants were recorded at the time of harvest stage.

2.6. Soil Analyses

The soil samples were collected at 20 cm increments to a depth of 60 cm from each plot before the experiment started and after harvesting. The samples were kept in polythene bags and labeled separately. The collected samples were air dried, crushed and sieved to pass through a 2-mm sieve. They were analysed for their physico-chemical properties such as pH, Electrical Conductivity (EC), moisture content, available nitrogen [9], available phosphorus, available potassium and available magnesium [10], available calcium [11], available zinc, available copper, available iron and available manganese [12].

3. Results and Discussion

3.1. Physico–chemical Characteristics of Effluent

The physico-chemical analysis of sugar mill effluent was presented in Table 1. The pH is a very important factor for ecosystems that serve as an index for pollution. The pH value showed that the effluent is acidic in nature caused by the use of phosphoric acid and sulphuric acid during clarification of sugarcane juice [2]. This effluent was dull white in colour and decaying molasses smell. Various sulphides and nitrates used in sugar industry decomposed under an anaerobic condition to give the colour and decaying molasses smell of the effluent. This effluent contains the high value of EC (4745 Mm-homs) that is affecting the ecosystem. The effluent has considerable amounts of suspended solids (180 mg/l), chloride (314 mg/l), fluoride (1.88 mg/l) and calcium (124.8 mg/l). It also contains a high amount of total dissolved solids (3725mg/l) and total solids (3905mg/l). The total solids are composed of carbonates, bicarbonates, chlorides, sulphates, nitrates, Ca, Mg, Mn, organic matter, silts and other particles which caused for pollution of water bodies which are also affected the intensity of light into the water bodies [13]. The analysis of effluent noticed that the values of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were 3480 mg/l and 7880 mg/l that exceeded the Tamil Nadu Pollution Control Board (TNPCB) tolerance limit. The BOD is one of the important parameters for the indicator of the pollution strength of the water which caused by oxidation of organic substances. The BOD and COD tests are the indication of toxic conditions and the presence of biologically resistance substances [14]. The sugar mill effluent contain high amount of magnesium (286 mg/l), sulphate (290.88 mg/l), nitrogen (1250 mg/l), oil & grease (19 mg/l) and the toxic heavy metals such as zinc (0.89 mg/l), iron (16 mg/l), copper (0.420 mg/l), lead (0.52 mg/l) and manganese (0.068 mg/l). The pollution load of the effluent depends on the nature of raw materials, chemicals used, the processes involved in the factory and also the methods of treatments given to the effluent before they discharged from the factory [4].

Table 1. *Physico – chemical analysis of sugar mill effluent with its tolerance limits for agricultural irrigation.*

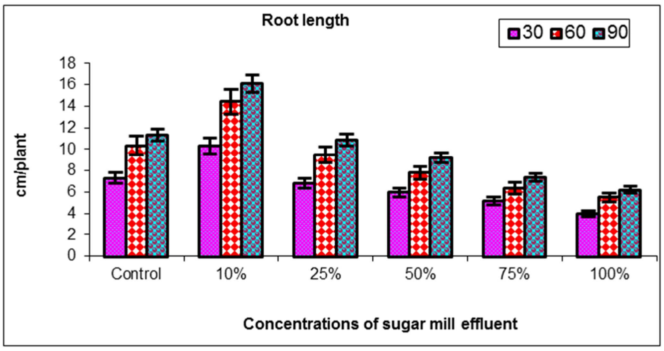
S. No.	Properties	Raw effluent	Tolerants limits for Agricultural irrigation suggested by TNPCB
1	Colour	Dull white	Colourless
2	Odour	Decaying molasses smell	-
3	pH	4.04	5.5-9.0
4	Electrical Conductivity (EC)	4745 Mm- homs	-
5	Temperature (°C)	36.0	40.0
6	Acidity	1350.0	-
7	Suspended solids	180.0	200
8	Total dissolved solids	3725.0	200
9	Total solids	3905.0	2100
10	BOD	3480.0	30
11	COD	7880.0	250
12	Chloride	314.0	600
13	Sulphate	290.88	12
14	Magnesium	286.0	100
15	Phosphorous	7.2	10
16	Nitrogen	1250	600
17	Fluoride	1.88	1.0
18	Silica	99.0	-
19	Calcium	124.8	200
20	Zinc	0.89	0.01
21	Iron	16.00	1.00
22	Copper	0.420	0.01
23	Lead	0.52	0.05
24	Manganese	0.068	0.01
25	Oil & grease	19	10

All parameters except colour, odour, pH, EC and temperature are expressed in mg/l.
TNPCB - Tamil Nadu Pollution Control Board.

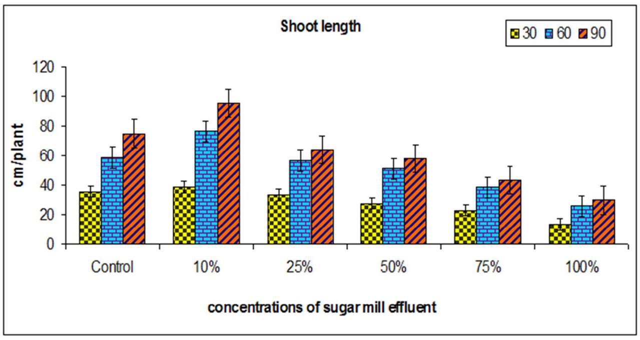
3.2. Morphological Growth Parameters

The influence of the various concentration of sugar mill effluent on root length, shoot length, total leaf area, fresh weight and dry weight of African marigold at various stages of its growth was given in Figure 1. The highest root length (10.30, 14.43 and 16.13 cm/plant), shoot length (38.59, 76.50 and 95.16 cm/plant) total leaf area (952.14, 1650.65 and 1812.36 cm^2/plant), fresh weight (16.06, 39.63 and 47.10 g/plant) and dry weight (3.16, 9.86 and 13.10 g/plant) are recorded in plants irrigated with 10% concentration of sugar mill effluent at 30, 60 and 90 DAS respectively. The lower concentrations of effluent increased the plant growth and it may be due to the presence of required amount of plant nutrients present in the effluent [15]. The plant may absorb the maximum nutrients such as nitrogen, phosphorus and potassium which improved the plant growth and biomass by the process of sugar translocation and turgor pressure in the plant [16]. Production of assimilates may be increased in the leaves during lower concentration of sugar mill effluent irrigation. It is translocated to the storage organs. photoassimilates induced the ameliorating effects in the plant that results increase in leaf turgidity, which could possibly lead to the accumulation of excessive water, thus resulting consequently in an increase in fresh mass and dry mass of plant [17].

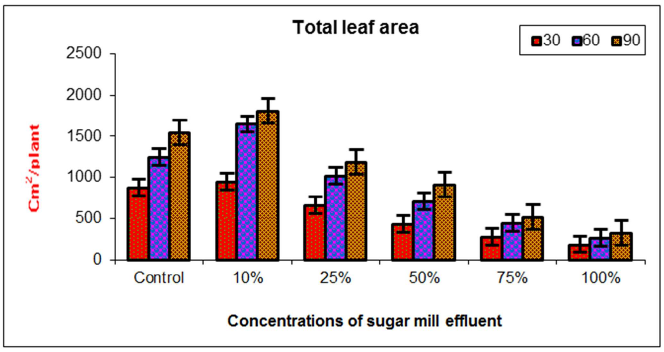
Similarly, the lowest root length (3.97, 5.50 and 6.23 cm/plant), shoot length (13.32, 25. 75 and 29.73 cm/plant), total leaf area (186.75, 264.13 and 328.45 cm^2/plant) fresh weight (5.23, 9.50 and 13.53 g/plant) and dry weight (0.44, 2.16 and 3.36 g/plant) are recorded in the plants irrigated with 100% concentration of sugar mill effluent at 30, 60 and 90 DAS respectively. The excess amount of nutrients present in the higher concentrations of effluent which is dangerous to the plants [2]. The high amount of elements may be negatively influenced cell turgidity and cell enlargement. The excess mount of elements in higher concentrations showed toxic effects on plant growth and inhibited plant hormones such as auxin and gibberline which are mainly required for plant growth and development [18]. The interference of heavy metals decreased the root and shoot length of the plant might be due to affect the physiological processes of plant and it also involved in inhibition of the enzyme activities, affected the nutrition, water imbalance, alternation of hormonal status and changed in membrane permeability [19]. The high amount of salts might be inhibited rubisco activity and CO_2 in chloroplast that reduced the photosynthesis of leaves which responsible of the plant development [20]. The untreated wastewater contained various metallic ions. The metal ions alter the plant activity such as reduction in stomatal openings and resulted in the CO_2 concentrations decreased internal of the leaves which reduced synthesized of carbohydrates [21]. The fresh and dry biomass of plant reduced due to the high saline condition caused by inhibition of plant growth. The availability of water reduction in plant and inhibition of hydrolysis of reserved foods and it's translocation to the growing shoots during the high salt concentrations [22].



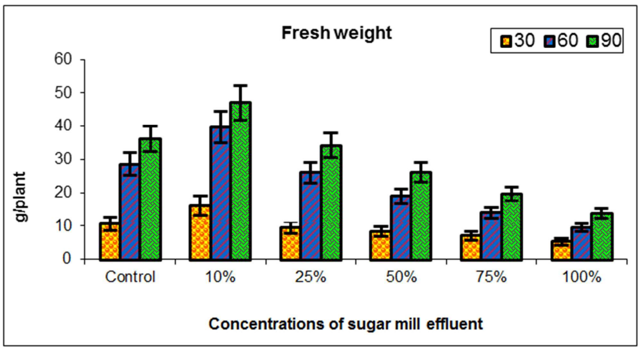
a. Root length



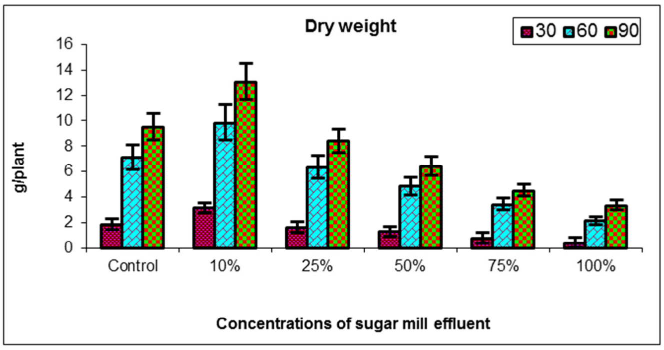
b. Shoot length



c. Total leaf area



d. Fresh weight



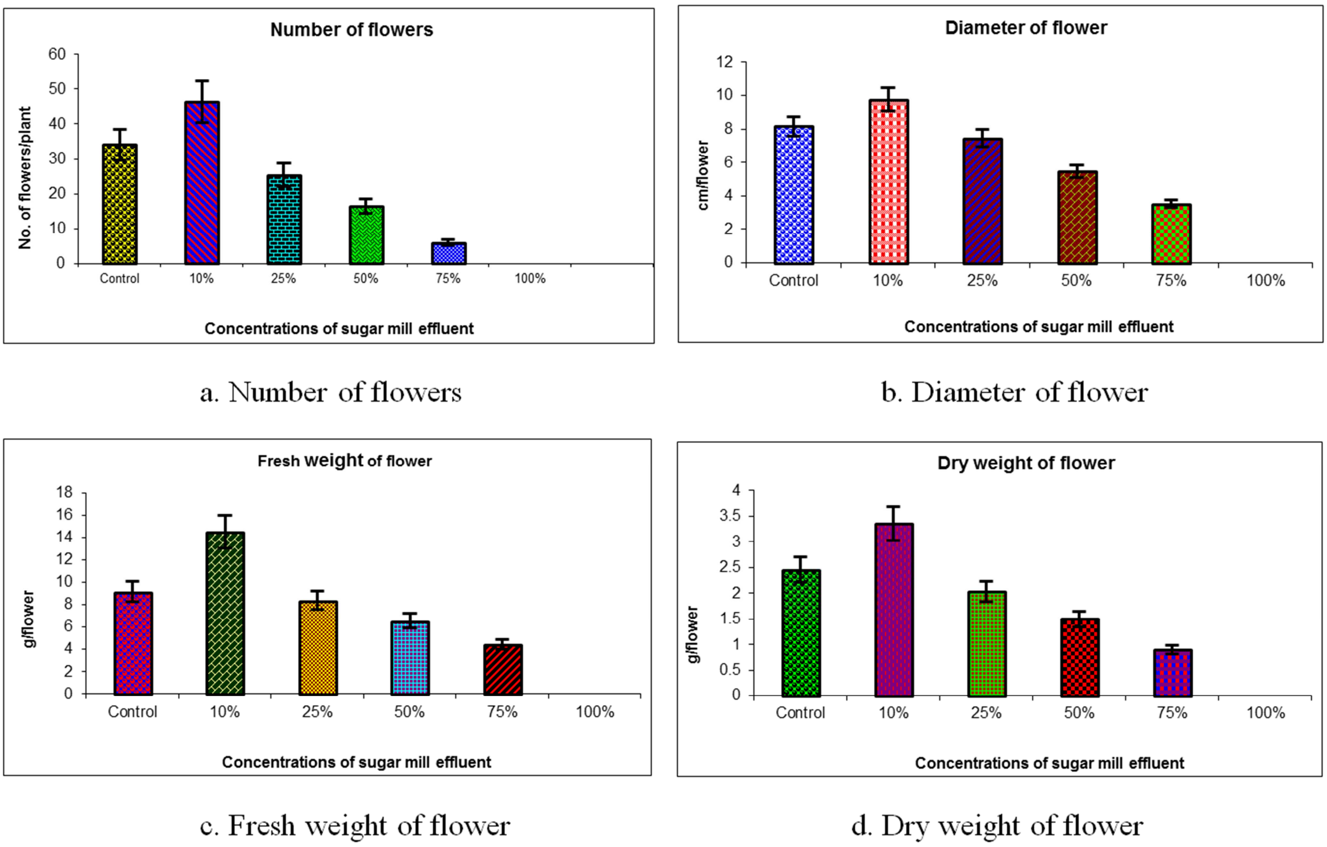
e. Dry weight

Figure 1. *The effect of different concentrations of sugar mill effluent on morphological parameters of Tagetes erecta (L.) at various stages of its growth.*

3.3. Yield Attributes

The effect of various concentrations of sugar mill effluent on yield parameters of African marigold is given in Figure 2. The highest number of flowers (46.33/plant), diameter (9.76 cm/flower), fresh weight (14.50 g/flower) and dry weight (3.36 g/flower) of flower are recorded in the plant irrigated with 10% concentration of sugar mill effluent at the time of harvest. Nitrogen and phosphorus are important for vegetative growth, maturity and flower formation of the plant. The lower (10%) concentration of effluent contains sufficient nitrogen and phosphorus which are needed for the better growth of the plant [23]. The flowering yield increased at the lower concentration of wastewater because of increasing in total leaf area which may be contributed to yield by enhancing the duration of photosynthates supply to plants and flowers. Plants uptake nutrients such as K^+, Fe^{3+}, Mg^{2+}, and Mn^{2+} with lower concentrations of sugar mill effluent which help to improve the synthesis of chlorophyll and photosynthesis in the leaves of plant and it give additional energy to the plant cells that lead to increasing the formation of flowers in the plants [24]. The plants inhibited uptake of nutrients due to higher concentrations of effluent irrigation that reduced plant growth and yield [25].

The lowest number of flowers (6.0/plant), flower diameter (3.53 cm/flower), fresh (4.43 g/flower) and dry weight (0.90 g/flower) of flower are recorded in the plant irrigated with 75% concentration of sugar mill effluent at harvest stage. Similar result in yield attribute of *Spinacea oleracea* irrigated with sugar mill effluents is observed [26]. The higher concentrations of the effluent induced a high amount of ABA in leaves which affect the stomatal movement and stimulated the senescence in leaves. It may decrease photosynthetic activity which inhibited the plant growth and yield [27]. The high amount of salts presented in higher concentrations of effluent which shows lethal effects on plant growth and formation of flowers which reduced the marketable quality of flowers. Furthermore, these concentrations of effluent reduced moisture content and aeration of the soil which caused the inhibition in the yield of plant [28]. The excess amount of metals reduced the area of conductive canals (mainly phloem) during vegetative growth. So, it reduced the translocation of assimilates towards the developed grains have occurred [29]. The plants irrigated with 100 percent concentration of sugar mill effluent have not emerged flowers at harvest stage. The reduction in shoot and root growth were the main factors for nonappearance of flower formation in the marigold plant due to raw effluent irrigation.



a. Number of flowers

b. Diameter of flower

c. Fresh weight of flower

d. Dry weight of flower

Figure 2. *The effect of different concentrations of sugar mill effluent on yield parameters of Tagetes erecta (L.) at harvest stage.*

3.4. Effect of the Effluent on Soil Properties

The physico-chemical analyses of sugar mill effluent irrigated soil (before sowing and after harvesting) such as pH, EC, moisture content, nitrogen, phosphorus, potassium, calcium, magnesium, copper, zinc, iron and manganese were analyzed and recorded. The highest amount of nutrients and heavy metals were recorded in the soil irrigated with higher concentration (100%) of sugar mill effluent. The lowest amount of mineral content was recorded in control soil. The minerals content in the soil is gradually increased with increase of effluent concentrations. The increase in nutrients and heavy metals in the effluent irrigated soil depend upon the nature of effluent concentrations and their contents. The higher level of pollution load affects the aeration of the soil [30]. The effluent is capable of altering soil fertility and such alteration plays injurious effect on the growth and yield [31]. The control soil as well as the lower concentration (10%) of effluent irrigated soil was suitable for crop production. It is generally believed that continuous use of industrial wastewater for irrigation may deteriorate the soil properties which make the soil unfit for crop production.

Table 2. *Physico-chemical analysis of soil irrigated with different concentrations of sugar mill effluent (before sowing and after harvesting).*

Soil properties	Before sowing	Sugar mill effluent concentration in percentage					
		After harvesting					
		control	10%	25%	50%	75%	100%
pH	6.83	6.92	6.86	6.34	6.18	6.06	5.92
EC (dS m^{-1})	0.42	0.49	0.52	0.69	0.84	0.96	1.17
Moisture content	19.42	17.60	19.28	17.23	15.52	14.06	12.47
Available N (kg/ha)	182.62	175.78	180.40	198.65	218.94	232.63	247.35
Available P (kg/ha)	21.80	19.92	22.46	26.25	29.98	34.08	39.42

Soil properties	Before sowing	Sugar mill effluent concentration in percentage					
		After harvesting					
		control	10%	25%	50%	75%	100%
Available K (kg/ha)	220.00	208.52	224.09	246.78	268.75	282.46	305.50
Available Ca (mg/kg)	19.65	14.87	23.56	27.42	31.20	36.14	40.52
Available Mg (mg/kg)	10.20	10.36	10.68	10.86	11.08	11.32	11.86
Available Zn (ppm)	3.20	2.80	3.18	3.98	4.42	5.06	5.82
Available Cu (ppm)	1.85	1.70	1.83	1.92	2.13	2.42	2.63
Available Fe (ppm)	14.18	12.96	14.52	15.28	15.42	15.89	16.10
Available Mn (ppm)	4.20	4.03	4.68	5.25	5.76	6.28	6.82

4. Conclusion

From these results it can be concluded that the lower concentration (10%) of sugar mill effluent promoted the growth and yield of the African marigold. So, it is suggested that the lower concentration of sugar mill effluent can be used for irrigation to get higher yield. It can be used after proper treatment and appropriate dilution to save an environment.

Acknowledgements

One of the authors, (T. Vaithiyanathan) is very much thankful to the University Grants Commission, New Delhi, India for providing financial support in the form of UGC-BSR research fellowship (F.25-1/2013-2014(BSR)/ 7-11/2007(BSR)). The authors are also thankful to Dr. V. Venkatesalu, Professor and Head, Department of Botany, Annamalai University for providing laboratory facilities to carry out this research work.

Statistical Analysis

The statistical analysis of experimental results was carried out by using SPSS version 16.0 and the data were analyzed for one way analysis of variance (ANOVA). All the data were given as mean of 3 assays and their standard error was calculated by using Duncan's multiple range test ($P<0.05$) and Preparation of graphs by MS- Excel (2003).

References

[1] Arminder Kaur, Siddharth Vats, Sumit Rekhi, Anki Bhardwaj, Jharna Goel, Ranjeet S. Tanwarand Komal K. Gaur (2010). Physico-chemical analysis of the industrial effluents and their impact on the soil microflora. Procedia Environmental Sciences, 2: 595-599.

[2] Ayyasamy, P. M., Yasodha, R., Raja Kumar, S., Lakshmanaperumalsamy, P., Rahman, P. K. S. M. and Lee, S.(2008). Impact of sugar factory effluent on the growth and biochemical characteristics of terrestrial and aquatic plants. Bull. Environ. Contam. Toxicol., 81: 449-454.

[3] Kumar, V. and Chopra, A. K. (2010). Influence of sugar mill effluent on physico – chemical characteristics of soil at Haridwar (Uttarakhand), India. J. Appl. & Sci., 2 (2): 269-279.

[4] Kumar, V. and Chopra, A. K. (2014). Pearl millet (*Pennisetum glaucum* L.) response after ferti-irrigation with sugar mill effluent in two seasons. Int. J. Recycl. Org. Waste Agricult., 3 (67): 1-13. doi: 10.1007/s40093-014-0067-x.

[5] Guo, L. B. and Sims (2003). Soil response to *Eucalyptus* tree planting and meat works effluent irrigation in a short rotation forest regime in New Zealand. Bioresour. Technol., 87: 341-347.

[6] Sharma, R. K., Agrawal, M. and Agrawal, S. D. (2008). Interactive effects of Cd and Zn on Carrots: growth and biomass accumulation. J. Plant Nutr., 31: 1-17.

[7] Garg, V. K. and Kaushik, P. (2007). Influence of textile mill wastewater irrigation to the growth of *Sorghum* cultivars. Appl. Ecol. Environ. Res., 6: 1-12.

[8] APHA (2005). Standard methods for the examination of water and wastewater. American Public Health Association, 21st ed., Washington, DC.

[9] Subbiah, B. V. and Asija, G. L. (1976). A rapid procedure for estimation of available nitrogen on soil. Curr. Sci., 11: 259-260.

[10] Jackson, M. L. (1958). Soil chemical analysis, Prentice Hall of India Private Limited, New Delhi, pp. 22-31.

[11] Yoshida, S., D. Fordo, J. Cork and Gomez, K. (1972). Laboratory manual for Physiological studies of rice 3rd Ed., The International Rice Research Institute, Philippines, pp. 11-23.

[12] Piper, C. (1966). Soil and Plant analysis. Asian Hans Publishers, Bombay, pp. 11-36.

[13] Kumar, V. and Chopra, A. K. (2012). Fertigation effect of distillery effluent on agronomical practices of *Trigonella foenum-graecum* L. (Fenugreek). Environ. Monit Assess., 184 (3): 1207–1219. doi: 10. 1007/s10661-011-2033-7.

[14] Singh, G. and Bhati, M. (2005). Growth of *Dalbergia sissoo* in desert regions of Western India using municipal effluent and the subsequent changes in soil and plant chemistry. Biores. Tech., 96: 1019-1028. doi: 10.1016/j.bior tech.2004.09.011.

[15] Heaton, R. J., Sims, R. E. H. and Tungcul, R. O. (2002). The root growth of *Salix viminalis* and *Eucalyptus nitens* in response to dairy farm pond effluent irrigation. Biores. Technol., 81: 1-6.

[16] Al-Tahir, A., Osman, Y. A., Al-Nabulsi and Helalia, A. M. (1997). Effects of water quality and frequency of irrigation on growth and yield of barley (*Hordeum vulgare* L.). Agriculture Water Management, 34: 17-24.

[17] Singh, S., Sinha, S., Saxena, R., Pandey, K. and Bhatt, K. (2004). Translocation of metals and its effects in the tomato plants grown on various amendments of tannery waste: Evidence for involvement of antioxidants. Chemos. Phere., 57 (2): 91-99. doi: 10.1016/j.chemosphere.2004.04.041.

[18] Subramani, A., Sundaramoorthy, P. and Lakshmanchary, A. S. (1995). Effect of distillery effluent on growth, yield and productivity of *Vigna radiata.* Poll. Res., 14 (4): 477-482.

[19] Sharma, P. and Dubey, R. S., 2005. Lead Toxicity in Plants. Braz. J. Plant. Physiol., 17 (1): 35-52.

[20] Dehshiri, A., Modarres-Sanavy, S. A. M. and Mahdavi, B. (2015). Amelioration of salinity on photosynthesis and some characteristics of three rapeseed (*Brassica napus*) cultivars under increased concentrations of carbon dioxide. Archives of Agronomy and Soil Science, 61 (10): 1423–1438. doi: 10.1080/03650340.2014.1002777.

[21] Ali, B., Hasan, S. A., Hayat, S., Yadav, Q., Fariduddin, Q. and Ahmad, A. (2008). A role for brassinosteroids in the amelioration of aluminum stress through antioxidant system in mung bean (*Vigna radiata* L. Wilczek). Environ. Exp. Bot., 62: 153-159.

[22] Sayyed, A., Gul, H., Hamayun, M., Nangyal, H. and Fazal, I. (2014). Influence of sodium chloride on growth and chemical composition of *Tagetes erecta*. S. Asian J. Life Sci., 2 (2): 29-32.

[23] Singandhupe, R. B., Bankar, M. C., Anand, P. S. B. and Patil, N. G. (2008). Management of drip irrigated sugarcane in Western India. Archives of Agronomy and Soil Science, 54 (6): 629-649.

[24] Kumar, V. and Chopra, A. K. (2012). Effect of paper mill effluent irrigation on agronomical characteristics of *Vigna radiata* (L.) in two different seasons. Communication in Soil Science and Plant Analysis, 43 (16): 2142-2166. doi: 10.1080/00103624.2012.697236.

[25] Naeem, M., Iqbal, J. and Maaha, B. (2006). Comparative study of inorganic fertilizers and organic manures on yield and yield components of Mung bean (*Vigna radiata* L.). J. Agr. Soc. Sci., 2 (4): 227-229.

[26] Chopra, A. K. and Pathak, C. (2013). Enrichment and translocation of heavy metals in soil and *Spinacea oleracea* grown in sugar mill effluent irrigated soil. Sugar. Tech., 15 (1): 77-83. doi: 10.1007/s12355-012-0194-5.

[27] Geissler, N., Hussin, S. and Koyro, H. W. (2009). Elevated atmospheric CO_2 concentration ameliorates effects of NaCl salinity on photosynthesis and leaf structure of *Astertripolium* L. J. Exp. Bot., 60: 137-151.

[28] Luis, A., Valdez-Aguilar, Catherine M. Grieve and James Poss (2009). Salinity and alkaline pH in irrigation water affect marigold plants. Hort. science, 44 (6): 1719-1725.

[29] Bharagava, R. N., Chandra, R. and Rai, V. (2008). Phytoextraction of trace elements and physiological changes in Indian mustard plants (*Brassica nigra* L.) grown in Post Methanated Distillery Effluent (PMDE) irrigated soil. Bioresour. Technol., 99: 8316-8324. doi: 10.1016/j.biortech. 2008.03.002.

[30] Kumar, V. and Chopra, A. K. (2014). Fertigational effects of sugar mill effluent on agronomical characteristics of high yield cultivar of sugarcane (*Saccharum officinarum* L.) in two seasons. Acta Advances in Agricultural Sciences, 2 (09): 17-39.

[31] Kumar, A. and K. Arindam (2000). Reclamation of soil polluted by industrial effluents using herbaceous flora. Adv. Plant Sci., 13 (2): 427-430.