EC AGRICULTURE
Research Article

Agronomical Response of High Yield Cultivar of Fenugreek (*Trigonella foenum-graecum L.*) After Irrigation with Treated Sugar Mill Effluent Under Nursery Polybags Trials

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Received: June 06, 2016; **Published:** August 30, 2016

Abstract

Nursery polybags cultivation experiments were conducted to determine the agronomical characteristics of fenugreek (*Trigonella foenum-graecum*) irrigated with different concentrations of treated sugar mill effluent such as 10%, 20%, 40%, 60%, 80% and 100% along with control (Ground water). The results showed that the sugar mill effluent was varied in characteristics and significantly rich in some plant nutrients and heavy metals. The sugar mill effluent irrigation showed significant ($P < 0.05$/ $P < 0.01$/ $P < 0.001$) effect on EC, pH, OC, Na^+, K^+, Ca^{2+}, Mg^{2+}, TKN, PO_4^{3-}, Fe, Cu, Mn, Zn of the soil used for the cultivation of T. foenum-graecum. Moreover, the soil parameters viz., EC (r = +0.93), OC (r = + 0.98), Na+ (r = + 0.96), K+ (r = + 0.94), Ca^{2+} (r = +0.88), Mg^{2+} (r = +0.90), TKN (r = +0.96), PO_4^{3-} (r = + 0.98), Fe (r = + 0.89), Cu (r = +0.92), Mn (r = +0.72) and Zn (r = + 0.74) were recorded to be significantly ($P < 0.05$) and positively correlated with different concentrations (10% to 100%) of sugar mill effluent. The agronomical parameters such as plant height, root length, chlorophyll content, LAI, number of flowers, number of pods, crop yield and biochemical components like total carbohydrates, total fat and total protein of fenugreek (*T. foenum-graecum*) were progressively increased at low concentration of the sugar mill effluent i.e. from 10% to 60% and decreased at higher concentrations of the effluent i.e. from 80% to 100% in comparison to the ground water irrigated plants of fenugreek (*T. foenum-graecum*) (Control). Therefore, treated sugar mill effluent can be used to increase the soil fertility and achieve the maximum crop attributes of fenugreek (*T. foenum-graecum*) after appropriate dilution up to 60%.

Keywords: *Agronomical response; Growth and yield attributes; Irrigation; Sugar mill effluent; Trigonella foenum-graecum*

Introduction

The green leafy vegetable fenugreek (*Trigonella foenum-graecum*) is an annual herb belongs from the *Leguminoseae* family [1]. It is widely used in Indian cuisine. Its leaves are used as leafy vegetables and packed in vitamins and minerals and its seeds are used a spice and [2,3]. The seeds are protein rich. Fenugreek seeds are used as spice and have medicinal values in the treatment of dyspepsia, rheumatism, asthma and constipation. It is also an important source of Diosgenin. It is also a good source of green fodder for the cattle [1-3].

Industrialization contributes economic development, most precious natural resources like water and soil are generally polluted due to generation of huge volume of wastewater and with by products, waste materials and non-utilized chemicals [4-6]. Sugar industry is one of the most significant agro based industries in India and is greatly accountable for creating major impact on rural economy in particular and countries economy in general. India is the largest producer of sugar in the world [5,7-9]. Among the effluent discharging industries, sugar mills plays a major role in polluting the land and aquatic resources [5,10-13]. Varied sugar industry effluents disposed of in land and aquatic environment cause major pollution problems. The sugar industry plays an important role in the economic development of India, but the effluents discharged produce a high degree of organic pollution in both aquatic and terrestrial ecosystems [8,14-16].

Additionally, the sugar mill contain higher total dissolved solids (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), sodium, potassium, magnesium, total nitrogen and phosphate. Besides the certain heavy metals like iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn) are also reported in the sugar mill effluent due the widespread application chemical fertilizers and pesticides in the cultivation of sugarcane crop [3,8,17,18]. Therefore discharge untreated or partially treated sugar mill effluent alters the physico-chemical characteristics, and flora and fauna of receiving aquatic bodies. Additionally, sugar mill effluents discharged in the environment poses a serious health hazard to the aquatic and terrestrial environment [8,10,19-22].

Furthermore, sugar mill effluent that has not been treated properly has an unpleasant odour when released into the environment. Farmers using these effluents for irrigation to reduce water demand have found that plant growth and crop yield were reduced and soil health was compromised [9,23-25]. Because sugar industry effluents are commonly used for irrigation, it is essential to determine how crops respond when exposed to industrial effluents. In this regard, efforts have been made to determine the effect of industrial effluents on seed germination of various crops such as maize, rice, wheat, pine, green gram and catechu. Seed germination is a critical stage that ensures reproduction and controls the dynamics of plant populations, so it is a critical test of probable crop productivity [18,26,27].

Moreover, all the sugar industries consume huge quantity of water and generate a large volume of effluent which contains highly toxic materials in dissolved or suspended state [12,28-31]. The sugar industry requires nearly about 1200 to 1400 m^3 M.T. of water is released as wastewater during the cane crushing [15,32-34]. Therefore, if this sugar mill wastewater is properly used or it is purified to recycled, a part of water shortage will surely be solved.

Therefore, the sugar industry is contributing an important role in the economic development of the Indian sub-continent, but the effluents released produce a high degree of organic pollution in both aquatic and terrestrial ecosystems [28,30,35]. Scientists are continuously working on the application of sugar mill effluent in the cultivation of different agricultural crops and vegetables. In the recent past various studies have been conducted on the use of sugar mill effluent in the cultivation of green leafy vegetables but a few reports are available in this context [1,3,22,31]. Thus, keeping in view the reuse of waste effluent and the economic importance of fenugreek (*T. foenum-graecum*), the present investigation was undertaken to use the sugar mill effluents as a source of fertilizer for more productivity of this crop.

Materials and Methods

Experimental design

Nursery polybags cultivation experiments were carried out in the Experimental garden of the Department of Zoology and Environmental Sciences, Faculty of Life Sciences, Gurukula Kangri University Haridwar (29°55'10.81'' N and 78°07'08.12'' E) during November, 2015 to February, 2016 to study the effect of sugar mill effluent on fenugreek (*T. foenum-graecum*). Nursery polybags (diameter 60 cm) were used for growing the fenugreek (*T. foenum-graecum*) plants. The experiments were performed under completely randomized designed and replicated by six times. The number of nursery polybags (42) having soil were used for the cultivation of fenugreek (*T. foenum-graecum*). Adequate distance was maintained between each replicate (30 cm), between each treatment (60 cm) and plant to plant (5 cm) for the maximum performance of the fenugreek (*T. foenum-graecum*) plants. Each polybag was made porous to provide aeration to the plants and it was labeled with different treatments *viz*., 10%, 20%, 40%, 60%, 80% and 100% of the sugar mill effluent.

Effluent sampling and analysis

Shamli Sugar Mill, Shamli (Uttar Pradesh) was selected for the collection of its effluent sample. The samples of treated effluents were collected in the plastic containers from the outlet of the effluent treatment plant located in the premises of the sugar mill. The effluent samples were brought to the laboratory and immediately analyzed for various physico-chemical parameters *viz*., EC, TDS, pH, BOD_5, COD, Na^+, K^+, Ca2$^+$, Mg^{2+}, TKN and PO_4^{3}-), microbiological parameters (SPC and MPN) and heavy metals (Fe, Cu, Mn and Zn) following standard methods [36] and were used for irrigation of fenugreek (*T. foenum-graecum*) in different concentrations *viz*., 10%, 20%, 40%, 60%, 80% and 100%.

Soil sampling and analysis

The soil used in the cultivation of fenugreek (*T. foenum-graecum*) was collected from the experimental garden of the Environmental Science Department at a depth of 0-15 cm. Each nursery polybag (60 × 60 cm) was filled with this 10 kg well prepared soil, earlier air-dried and sieved to remove debris and mixed with farmyard manure @ the rate of 1 Kg per 10 Kg of soil. Ten Kg of soil in each of the forty-two poly bags were irrigated twice in a week with 1000 mL of sugar mill effluent in six concentrations 10%, 20%, 40%, 60%, 80% and 100% along with ground water (control). The soil was analyzed before sowing and after harvesting the crop for various physico-chemical parameters viz., soil pH, EC, OC, Na^+, K^+, Ca^{2+}, Mg^{2+}, TKN, PO_4^{3-}, Fe, Cu, Mn and Zn following standard methods cited by Chaturvedi and Sankar [37].

Cultivation practices and determination of crop parameters

The seeds of fenugreek (*T. foenum-graecum*) (var. Pusa early bunching) were procured from ICAR, Pusa, New Delhi and sterilized with 0.01 mercuric chloride and was soaked for 12 hrs. Twenty seeds of fenugreek (*T. foenum-graecum*) were initially sown in each polybag at equal distance between plant to plant (5 cm) in the last week of November, 2015. Ten plants were maintained in each polybag. The plants of fenugreek (*T. foenum-graecum*) were irrigated twice in a week with concentrations of 10%, 20%, 40%, 60%, 80% and 100% of sugar mill effluent separately along with control (ground water) and no drainage was allowed. The various agronomical parameters of fenugreek (*T. foenum-graecum*) *viz.,* seed germination, plant height, root length, leaf area index (LAI), chlorophyll content, number of flowers, pods, crop yield, total carbohydrates, total fat and total protein were determined following standard methods [37,38].

Statistical analysis

The collected data were statistically analyzed for one way analysis of variance (ANOVA) to determine the significant difference between soil and fenugreek (*T. foenum-graecum*) parameters before and after sugar mill effluent irrigation. Mean, standard deviation, coefficient of correlation for soil and fenugreek (*T. foenum-graecum*) parameters and effluent concentrations were also calculated with the help of MS Excel 2013, SPSS 20.0 and Sigma plot, 13.0.

Results and Discussion

Characteristics of sugar mill effluent

During the present study, the sugar mill effluent was recorded to be varied in characteristic and loaded with higher contents of EC, TDS, pH, BOD_5, COD, $Na^{+,}$ K^+, Ca^2, Mg^{2+}, TKN, PO_4^{3-}, Fe, Cu, Mn, Zn, SPC and MPN (Table 1). The values of BOD_5, COD, Ca^{2+}, Fe, Cu, Zn, SPC and MPN in the sugar mill effluent were observed beyond the effluent discharge guidelines prescribed by BIS [39]. Here, it is noticeable that these parameters of the sugar mill effluent are directly or indirectly associated with different inorganic and organic nutrients required for the plant growth. In the present study, the higher values of TDS and EC indicated the presence of more ionic species (Na^+, K^+, Ca^{2+}, Mg^{2+}, PO_4^{3-}) in the sugar mill effluent. The higher values of BOD5 and COD are in the conformity of more biodegradable and organic pollution load of the sugar mill effluent. More values of SPC and MPN in the sugar mill effluent were also in the agreement with higher organic nature of the sugar mill effluent. Therefore, sugar mill effluent was considerably rich in different macro and micro nutrients required for the growth of agricultural plants. Kumar and Chopra [10] also reported the higher values of TDS, BOD, COD, TKN, P, Fe, Zn, SPC and MPN in the sugar mill effluent. Srivastava., *et al.* [6] also reported higher values of heavy metals Cd, Cu, Fe, Ni and Zn in the sugar mill effluent.

Parameters	Control (GW)	Effluent	BIS for irrigation water
EC (dS m^{-1})	1.34 ± 0.19	4.76 ± 0.44	--
TDS (mg L^{-1})	198.50 ± 10.75	1268.00 ± 12.65	2100
pH	7.50 ± 0.24	7.78 ± 10	5.5-9.0
BOD_5 (mg L^{-1})	3.83 ± 0.59	824.70 ± 3.43	100

COD (mg L^{-1})	5.88 ± 1.37	1134.25 ± 7.93	250
Na^+ (mg L^{-1})	9.65 ± 1.25	203.67 ± 8.97	500
K^+ (mg L^{-1})	5.54 ± 2.25	259.83 ± 3.39	--
Ca^{2+} (mg L^{-1})	23.46 ± 4.16	650.35 ± 1.56	200
Mg^{2+} (mg L^{-1})	12.15 ± 1.50	136.53 ± 3.47	--
TKN (mg L^{-1})	24.27 ± 5.08	107.66 ± 4.61	100
PO_4^{3-} (mg L^{-1})	0.04 ± 0.00	144.37 ± 3.77	--
Fe (mg L^{-1})	1.28 ± 0.04	18.84 ± 2.07	1.0
Cu (mg L^{-1})	0.86 ± 0.02	9.72 ± 0.42	3.00
Mn (mg L^{-1})	0.22 ± 0.01	1.45 ± 0.14	--
Zn (mg L^{-1})	1.36 ± 0.1	7.17 ± 0.81	15
SPC (SPC ml^{-1})	2.56×10^1 ± 2.0	7.42×10^5 ± 15	10000
MPN (MPN100 ml^{-1})	5.65×10^1 ± 1.0	4.85×10^7 ± 20	5000

Table 1: *Physico-chemical and microbiological characteristics of control (Ground water) and sugar mill effluent.*
Mean ± of six values; GW - Ground water; BIS- Bureau of Indian standard

Effects on soil characteristics after sugar mill effluent irrigation

In the present study, different concentrations (10%, 20%, 40%, 60%, 80% and 100%) of the sugar mill effluent significantly ($P < 0.05$/ $P < 0.01$/ $P < 0.001$) affected the contents of EC, pH, OC, Na^+, K^+, Ca^{2+}, Mg^{2+}, TKN, PO_4^{3-}, Fe, Cu, Mn, Zn in the soil used for the cultivation of T. foenum-graecum in comparison to the ground water irrigated soil.

The contents of EC (r = +0.93), OC (r = + 0.98), Na^+ (r = + 0.96), K^+ (r = + 0.94), Ca^{2+} (r = +0.88), Mg^{2+} (r = +0.90), TKN (r = +0.96), PO_4^{3-} (r = + 0.98), Fe (r = + 0.89), Cu (r = +0.92), Mn (r = +0.72) and Zn (r = + 0.74) of the sugar mill effluent irrigated soil were recorded to be significantly ($P<0.05$) and positively correlated with different concentrations (10% to 100%) of the sugar mill effluent. The pH (r = -0.92) of the soil was recorded to be negatively correlated with different concentrations of the sugar mill effluent. Therefore, the progressive increase of EC, OC, Na^+, K^+, Ca^{2+}, Mg^{2+}, TKN, PO_4^{3-}, Fe, Cu, Mn, Zn in the soil is in the conformity of the presence of these chemicals or nutrients in the sugar mill effluent which is required for the cultivation of agricultural crops like fenugreek (*T. foenum-graecum*). Roy., *et al.* [14] also reported higher contents of different physico-chemical parameters EC, OC, nitrogen, phosphorus and heavy metals like iron, manganese and zinc of the soil after sugar mill effluent irrigation.

Effects on *T. foenum-graecum* after sugar mill effluent irrigation

The agronomical attributes of fenugreek (*T. foenum-graecum*) after irrigation with sugar mill effluent are presented in table 3. The results showed that the seed germination of fenugreek (*T. foenum-graecum*) was progressively decreased when the concentration of the sugar mill effluent was increased. The most seed germination (95.33%) of fenugreek (*T. foenum-graecum*) was recorded with control (ground water) while the least seed germination (82.33%) of fenugreek (*T. foenum-graecum*) was observed with 100% concentration of the sugar mill effluent. This gradual reduction in the seed germination of fenugreek (*T. foenum-graecum*) is might be due to the presence of more salts and heavy metals in the sugar mill effluent which might sometimes be inhibited seed germination. Therefore, the seed germination of fenugreek (*T. foenum-graecum*) was found to be significantly ($P > 0.05$) but negatively correlated (r = - 0.84) with different concentrations (10% to 100%) of the sugar mill effluent. Here it is interesting to note that although the most seed germination of fenu-

Parameters	Before effluent irrigation	After effluent irrigation							r - alue
		Effluent concentration (%)							
		0 (GW)	10	20	40	60	80	100	
EC (dS m^{-1})	2.18 ± 0.14	2.28 ± 0.11	2.50* ± 0.12	2.79* ± 0.17	2.94** ± 0.15	3.18** ± 0.17	3.33*** ± 0.16	3.43*** ± 0.19	+0.93
pH	7.45 ± 0.01	7.50ns ± 0.02	7.57ns ± 0.04	7.69ns ± 0.07	7.78ns ± 0.06	8.05ns ± 0.03	8.11ns ± 0.02	8.23ns ± 0.09	-0.92
OC (mg Kg^{-1})	0.42 ± 11	0.46 ± 0.08	1.58* ± 0.34	3.00* ± 0.55	4.22** ± 0.11	5.16** ± 0.08	7.66*** ± 0.05	9.98*** ± 0.79	+0.98
Na^+ (mg Kg^{-1})	18.82 ± 5.31	20.06 ± 4.30	24.72* ± 3.91	26.84* ± 3.73	29.00** ± 3.96	31.58** ± 5.61	33.12** ± 4.68	37.41** ± 2.66	+0.96
K^+ (mg Kg^{-1})	141.51 ± 5.30	156.59 ± 4.53	164.54* ± 1.82	173.59* ± 3.07	187.11** ± 3.08	212.45** ± 1.59	220.28** ± 1.61	228.47** ± 2.97	+0.94
Ca^{2+} (mg Kg^{-1})	14.23 ± 3.86	16.61 ± 2.73	37.09* ± 2.38	45* ± 2.99	75.60** ±1.41	106.23** ± 3.71	134.58*** ± 4.22	151.49*** ± 4.61	+0.88
Mg^{2+} (mg Kg^{-1})	1.42 ± 0.04	1.73 ± 0.53	3.85* ± 16	5.03* ± 0.35	9.88** ± 0.78	12.19** ± 1.28	15.43*** ± 2.28	22.25*** ± 3.94	+0.90
TKN (mg Kg^{-1})	25.91 ± 2.18	33.46 ± 3.23	55.83* ± 2.17	64.19* ± 0.84	123.84** ± 4.70	179.77** ± 3.86	246.82*** ± 1.63	286.96*** ± 6.13	+0.96
PO_4^{3-} (mg Kg^{-1})	38.04 ± 3.87	54.25 ± 4.79	67.40* ± 2.67	73.87* ± 3.67	95.44** ± 4.66	108.22** ± 1.49	117.61*** ± 3.49	125.09*** ± 2.77	+0.98
Fe (mg Kg^{-1})	2.18 ± 0.38	2.68 ± 0.77	3.26* ± 0.08	4.49* ± 0.29	5.13** ± 0.5	6.31** ± 0.07	7.63** ± 0.16	8.79** ± 0.57	+0.89
Cu (mg Kg^{-1})	1.75 ± 0.32	2.03 ± 0.30	2.77* ± 0.18	2.96* ± 0.38	3.21** ± 0.24	3.71** ± 0.42	4.12*** ± 0.17	5.71*** ± 0.97	+0.92
Mn (mg Kg^{-1})	1.05 ± 0.10	1.16 ± 0.11	1.58* ± 0.12	1.65* ± 0.08	1.80** ± 0.09	1.89** ± 0.07	1.95*** ± 0.09	2.13*** ± 0.15	+0.72
Zn (mg Kg^{-1})	1.12 ± 0.03	1.85 ± 0.05	2.92* ± 0.08	3.26* ± 0.06	3.88** ± 0.11	4.55** ± 0.14	5.62*** ± 0.17	6.79*** ± 0.29	+0.74

Table 2: *Physico-chemical characteristics of soil before and after irrigation with sugar mill effluent.*

Mean ± of six values; Significant F -***P - 0.01%, **P -0.1% level, *P- 0.05% level, r-Coefficient of correlation; a - significantly different to the control;

NS - Not Significant; GW - Ground water; CD – Critical difference.

greek (*T. foenum-graecum*) was recorded with control but a stimulation was observed in the seed emergence and seedling growth and it is likely due to the mineralization of different nutrients in the effluent irrigated soil which stimulates the seed emergence and seedling growth as earlier reported by Kumar and Chopra [1]. The findings are in accordance with Kumar and Chopra [13] who also reported that the higher contents of salts present in the sugar mill effluent significantly inhibited the seed germination of mung bean (*Vigna radiata L.*) after sugar mill effluent irrigation.

During the present study, the maximum plant height, root length, chlorophyll content, LAI, number of flowers/plant, number of pods/plant and crop yield/plant of fenugreek (*T. foenum-graecum*) was recorded with 60% concentration of sugar mill effluent. The values of plant height, root length, chlorophyll content, LAI, number of flowers/plant, number of pods/plant and crop yield/plant of fenugreek (*T. foenum-graecum*) was gradually increased with the lower concentrations (10 % to 60%) of the sugar mill effluent. Moreover, plant height (r = + 0.89), root length (r = + 0.77), chlorophyll content (r = + 0.75), LAI (r = + 0.76), number of flowers/plant (r = + 0.68), number of pods/plant (r = + 0.56) and crop yield/plant (r = + 0.54) of fenugreek (*T. foenum-graecum*) was recorded to be positively correlated with different concentrations (10% to 100%) of the sugar mill effluent. The findings of the present study were in the conformity of the presence of various macro and micro nutrients in the sugar mill effluent concentration which is responsible for this type of growth pattern of fenugreek (*T. foenum-graecum*) due to sugar mill effluent irrigation. Srivastava et al. [6] also reported that the growth and crop yield parameters like shoot length, root length, dry weight, biomass, number of flowers and pods of cow pea (*Vigna unguiculata L*. Walp) was progressively increased at lower concentrations of the sugar mill effluent and clear decline was observed in these growth and crop yield parameters of cow pea at higher concentrations of the sugar mill effluent.

Accumulation of heavy metals in *T. foenum-graecum* after sugar mill effluent irrigation

The contents of different heavy metals Fe, Cu, Mn and Zn were determined in the whole plant of fenugreek (*T. foenum-graecum*) after sugar mill effluent irrigation.

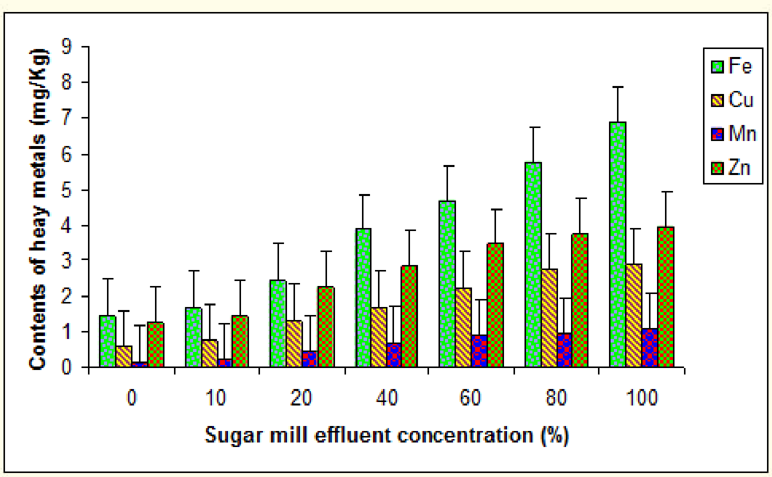

***Figure 1:** Contents of different heavy metals in T. foenum-graecum after irrigation with sugar mill effluent. Error bars are the standard error of the mean.*

The results indicated that the most contents of Fe, Cu, Mn and Zn in fenugreek (*T. foenum-graecum*) was recorded with 100% concentration of the sugar mill effluent. The contents of Fe, Cu, Mn and Zn in fenugreek (*T. foenum-graecum*) was observed to be significantly ($P < 0.05$/ $P < 0.01$) different after sugar mill effluent irrigation in comparison to ground water irrigation (Control). The contents of Fe, Cu, Mn and Zn in fenugreek (*T. foenum-graecum*) were gradually increased as per the sugar mill effluent concentration. The contents of Fe (r = +

Effluent	Agronomical parameters							
Concentration	Seed germination (%)	Plant height (cm)	Root length (cm)	Chlorophyll content (mg/gfwt)	LAI	No. of flowers/plant	No. of pods/plant	Crop yield /plant (g)
0(GW)	95.33 ± 4.97	18.44 ± 2.49	10.38 ± 1.06	2.47 ± 0.38	2.17 ± 0.34	34.50 ± 2.66	18.33 ± 2.42	18.83 ± 2.93
10	93.83 ± 4.02	19.49 ± 4.22	11.10 ± 2.00	2.68 ± 0.38	2.99 ± 0.67	35.00 ± 2.28	19.00 ± 6.13	19.17 ± 5.34
20	92.50 ± 3.78	20.90 ± 3.85	13.47 ± 2.82	3.12 ± 0.42	3.39 ± 0.65	35.67 ± 4.46	19.50 ± 6.09	19.67 ± 5.72
40	92.33 ± 4.97	26.88 ± 3.84	14.92 ± 2.02	3.45 ± 0.61	3.66 ± 1.13	36.00 ± 7.32	21.70 ± 6.18	21.17 ± 5.19
60	86.00 ± 7.07	31.76 ± 3.82	17.29 ± 3.33	4.13 ± 1.29	3.99 ± 1.09	45.00 ± 4.86	28.67 ± 6.89	27.67 ± 2.34
80	84.50 ± 7.69	29.51 ± 3.29	13.60 ± 4.02	3.39 ± 0.89	3.86 ± 1.25	39.83 ± 5.88	23.83 ± 4.49	24.17 ± 3.37
100	82.33 ± 6.74	28.38 ± 4.82	12.64 ± 3.99	3.13 ± 0.84	3.70 ± 1.26	36.67 ± 7.20	19.83 ± 5.95	21.33 ± 4.08
r-Value	-0.82	+0.89	+0.77	+0.75	+0.76	+0.79	+0.41	+0.54
F-calculated	8.31	5.49	4.22	1.08	1.39	7.59	8.08	6.19
CD	4.73**	11.72***	3.70**	3.09*	2.55*	2.98*	2.57*	3.27*

Table 3: *Agronomical characteristics of T. foenum-graecum after irrigation with sugar mill effluent.*

*Mean ±SD of six values; Significant F -***P - 0.01%, **P -0.1% level, *P-0.05% level, r-Coefficient of correlation; a - significantly different to the control; GW - Ground water; CD- Critical difference.*

0.98), Cu (r = + 0.96), Mn (r = + 0.94) and Zn (r = + 0.98) in fenugreek (*T. foenum-graecum*) were observed to be positively correlated with different concentrations (10% to 100%) of the sugar mill effluent. The contents of Fe, Cu, Mn and Zn in fenugreek (*T. foenum-graecum*) after irrigation with sugar mill effluent was recorded within the permissible limit for Fe (80.00 mg Kg^{-1}), Cu (40.00 mg Kg^{-1}) and Zn (60.00 mg Kg^{-1}) prescribed by FAO/WHO [40]. Srivastava., *et al*. [6] also recorded significant and positive correlation of heavy metals accumulated in cow pea (*V. unguiculata*) after irrigation with different concentrations of the sugar mill effluent.

Effects on biochemical of *T. foenum-graecum* after sugar mill effluent irrigation

The contents of biochemical components *viz*., total carbohydrates, total fat and total protein in fenugreek (T. foenum-graecum) were recorded to be significantly different with different concentrations of the sugar mill effluent.

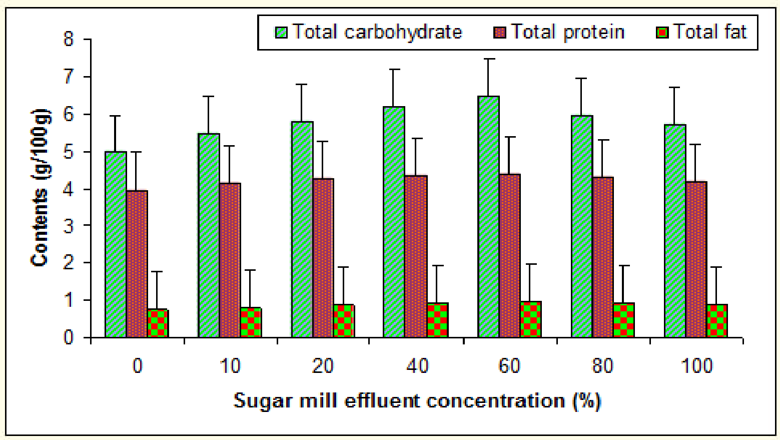

Figure 2: *Contents of different biochemical components in T. foenum-graecum after irrigation with sugar mill effluent. Error bars are the standard error of the mean.*

The most contents of total carbohydrates, total fat and total protein in fenugreek (*T. foenum-graecum*) were recorded with 60% concentration of the sugar mill effluent and it is like due the to maximum synthesis of these biochemical components and availability of most favourable nutrients at 60% concentration of the sugar mill effluent. The contents of total carbohydrates, total fat and total protein in fenugreek (*T. foenum-graecum*) were recorded were observed to be significantly ($P < 0.05$) and positively correlated with different concentrations (10% to 100%) of the sugar mill effluent. Kumar and Chopra [5,26] reported the most synthesis of total carbohydrates, crude protein, and dietary fiber in eggplant (*Solanum melongena L.*) 40% concentration of sugar mill effluent and sugarcane pressmud, respectively.

Conclusions

In conclusion, the sugar mill effluent was varied in characteristics and considerably loaded with EC, TDS, pH, BOD5, COD, Na^+, K^+, Ca^{2+}, Mg^{2+}, TKN, PO_4^{3-}, Fe, Cu, Mn, Zn, SPC and MPN. Different concentrations (10%, 20%, 40%, 60%, 80% and 100%) of the sugar mill effluent significantly ($P < 0.05$/ $P < 0.01$/ $P < 0.001$) affected the contents of EC, pH, OC, Na^+, K^+, Ca, Mg^{2+}, TKN, PO_4^{3-}, Fe, Cu, Mn, Zn in the soil used for the cultivation of T. foenum-graecum in comparison to control. the maximum plant height, root length, chlorophyll content, LAI, number of flowers/plant, number of pods/plant and crop yield/plant and biochemical components *viz*., total carbohydrates, total fat and total protein of fenugreek (*T. foenum-graecum*) was recorded with 60% concentration of sugar mill effluent. The most contents of Fe, Cu, Mn and Zn in fenugreek (*T. foenum-graecum*) was recorded with 100% concentration of the sugar mill effluent. Therefore, treated sugar mill effluent increased the soil fertility and crop yield of fenugreek (*T. foenum-graecum*) and it can be used for irrigation of vegetable crops after appropriate dilution. Further studies should be required on the effects of long term application of sugar mill effluent in irrigation of vegetable crops including soil characteristics and crop yield.

Acknowledgements

The University Grant Commission, New Delhi, India is acknowledged for providing the financial support in the form of UGC research fellowship (F.7-70/2007 BSR) to Mr. Vinod Kumar.

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