Agro-potentiality of Paper Mill Effluent on the characteristics of *Trigonella foenum-graecum* L. (Fenugreek).

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Abstract: The present study was conducted to determine the agronomical characteristics of *Trigonella foenum-graecum* irrigated with different concentrations of Paper mill effluent such as 5%, 10%, 25%, 50%, 75% and 100% along with control (Borewell water). The study revealed that the effluent is rich in some plant nutrients and affected the agronomical characteristics of *T. foenum-graecum* (Pusa early bunching) and physico-chemical characteristics of the soil as well. On irrigation of soil with different effluents up to 90 days of harvesting, it was observed that there was a significant effect on WHC, EC, Na^+, PO_4^{3-} and SO_4^{2-} ($P<0.05$), Cl^-, K^+ and Ca^{2+} ($P<0.01$) and NO_3^{2-} ($P<0.001$) and insignificant effect on pH, moisture content and bulk density ($P>0.05$).There was no significant change in the soil texture of the soil. Among various concentrations of effluent irrigation, the irrigation with 100% effluent concentration decreased moisture content (14.69%), WHC (18.10%) and bulk density (5.92%), pH (7.60%) and increased EC (119.41%) , soil nutrients like Cl^- (57.39%), K^+ (13.59%) and Ca^{2+} (18.68%) Na^+ (38.80%), NO_3^{2-} (36.43%), PO_4^{3-} (63.29%) and SO_4^{2-} (25.62%) of the soil. The agronomical parameters such as seed germination, shoot length, root length, number of roots, root nodule, number of leaves, flowers, pods, pod length, dry weight, chlorophyll content and crop yield of *T. foenum-graecum* were recorded to be in increasing order at low concentration of the effluent i.e. from 5% to 25% and in decreasing order at higher effluent concentration i.e. from 50% to100% as compared to control. Stimulation was observed in seed emergence period and shoot length, root length, number of leaves and biomass with the increase in effluent concentration in early seedling growth period. [New York Science Journal 2010;3(5):68-77]. (ISSN: 1554-0200).

Keywords: Paper mill effluent, *Trigonella foenum-graecum*, Irrigation, Agronomical characteristics

1. INTRODUCTION

With increasing global population, the gap between the supply and demand for water is widening and is reaching such alarming levels that in some parts of the world, it is posing a threat to human existence. Growing scarcity of high quality freshwater as well as stringent regulatory standards is compelling these units to explore appropriate water management options. This scarcity of water directly affects the developmental processes including agricultural output. Scientists around the globe are working on new ways of conserving water. The reuse of effluent by irrigation can make a significant contribution to the integrated management of our water resources. It can play prominent role to maintain the crop yield as the nation is looking for second green revolution for their food security. Therefore this could release clean water for use in other sectors that need fresh water and provide water to sectors that can utilize wastewater e.g., for irrigation and other ecosystem services (Kretschmer *et al.*, 2000). It is an opportune time, to refocus on one of the ways to recycle water through the reuse of wastewater, for irrigation and other purposes and to understand the specific relationship of crops and industrial waste effluent. Pulp and paper mills in India are one of the most polluting industries; in addition, they are high consumers of raw water and discharge huge quantity of effluent. The pulp and paper industry is one of the core industrial sectors in India with ranks 15th among the paper producing countries in the world, generating more than 0.3 million direct and around 1 million indirect employments through agricultural activities. At present, there are 666 pulp and paper mills in India, of which 632 units are agro-residue and recycled fiber based units with manufacturing capacity of 7.6 million tons. The Indian pulp and paper industry is highly water intensive, consuming 100-250 m^3 freshwater/ton paper and also generate the corresponding wastewater 75-225 m^3 wastewater/ton paper (Thompson, 2001 and Tewari *et al.*, 2009).

The disposal of wastewater is a major problem faced by industries, due to generation of high volume of effluent and with limited space for land based treatment and disposal. On the other hand, wastewater is also a resource that can be applied for productive uses since wastewater contains nutrients that have the potential for use in agriculture, aquaculture, and other activities (Hussain *et al.*, 2001). The utilization of industrial waste as soil amendment has generated interest in recent times. Most crops give higher potential yields with wastewater irrigation; reduce the need for chemical fertilizers, resulting in net cost savings to farmers. So it is an important aspect to understand the specificity of crop-effluent relationship for their proper application in irrigation practices. The *Trigonella foenum-graecum* (Fenugreek) is an annual herb of the leguminoseae family. Its seeds are used a spice and its leaves are used as leafy vegetables which is rich in vitamins and minerals. 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 cattle fodder. Keeping in view the reuse of waste water effluent and the economic importance of *T. foenum-graecum*, the present investigation was undertaken to use the paper mill effluents as a source of fertilizer for more productivity of this crop.

2. MATERIALS AND METHODS

2.1. Experimental design

A field study was conducted in the Experimental garden of the Department of Zoology and Environmental Sciences, Faculty of Life Sciences, Gurukula Kangri University Haridwar($29^o55'10.81''$ N and $78^o07'08.12''$ E) during the period November,2007-February, 2008 to study the effect of paper mill effluent on *Trigonella foenum-graecum.* Polythene bags (dia.30 cm) were used for growing the *T. foenum-graecum* plant. The experiment was conducted under completely randomized designed and replicated by four times. The number of polythene bags (28) having soil were used for the cultivation of *T. foenum-graecum*. Proper 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 crop. Each polythene bag was made porous for aeration and it was labeled for the various treatments viz.0, 5, 10, 25, 50, 75 and 100%.

2.2. Effluent collection and analysis

Shamli Paper Mill, Shamli Muzaffarnagar (Uttar Pradesh) producing paper/paper board as its main product from agro-residue at the rate of 50000 MT/annum was selected for the collection of its effluent sample. The samples of effluents were collected in the plastic containers from a settling tank installed by the paper mill used to reduce the BOD and solids of the factory and were brought to the laboratory. These samples were analyzed for various physico-chemical parameters (temperature, color, odor, turbidity, EC, TS, DS, SS , pH, DO, BOD, COD, Cl^-, hardness, alkalinity, NO_3^{2-}, PO_4^{3-}, SO_4^{2-}) and microbiological parameters (SPC and MPN) following standard methods (APHA, 2005) and were used as fertigant in different concentrations viz.5, 10, 25, 50, 75 and 100% for cultivation of *T. foenum-graecum*.

2.3. Soil preparation, filling of polythenebags, sampling and analysis

The soil used was collected from the experimental garden of the Environmental Science Department at a depth of 0 – 15 cm. Each polythene bag (30x30cm) was filled with this 5 kg well prepared soil, earlier air-dried and sieved to remove debris and mixed with equal quantity of farmyard manure. Five Kg of soil in each of the twenty eight of poly bags were irrigated twice in a week with 500 mL of paper mill effluent in six concentrations 5%, 10%, 25%, 50%, 75% and 100% along with bore well water (control). The soil was analyzed before sowing and after harvesting the crop for the physico-chemical parameters following standard methods (Buurman *et al.*, 1996 for soil temperature, moisture content and EC), (Bouyoucos, 1962 for soil texture), (Carter, 1993 for bulk density, and WHC). The soil pH was determined at soil: water ratio of 1:1 using glass electrode pH meter; and Cl^-, Na^+, K^+ and Ca^{2+}, NO_3^{2-}, PO_4^{3-} and SO_4^{2-} were determined as per standard methods (APHA, 2005).

2.4. Sowing of seeds, irrigation pattern and collection of crop parameters data

In each case, the paper mill effluent with volume of 500 ml was applied with its dilutions of 0, 5, 10, 25, 50, 75 and 100% concentration per 5 kg soil and then left for 2 weeks to allow for mineralization and further irrigation of the crop plant. The seeds of *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. Fifteen seeds were initially sown in each polythene bag at equal distance between plant to plant (5 cm) in the last week of November, 2007. Ten plants out of the fifteen were maintained in each polythene bag and each set was replicated four times. Thus, forty plants were grown for each treatment as well for the control group. Each group of crop plant received the effluent as fertigant doses twice in a week with concentrations of 5, 10, 25, 50, 75 and 100% of effluent separately along with control (Bore well water) and no drainage was allowed. The various agronomical parameters of *T. foenum-graecum* from germination to maturity (0-90 days)

Table: 1. Physico-chemical and microbiological characteristics of control (Bore well water) and paper mill effluent.
Mean ± of three values; BW - Borewell water; BIS- Bureau of Indian standard

Parameters	Control (BW)	Effluent	BIS for Drinking water	BIS for irrigation water
Temperature (^oC)	15.60 ±0.20	18.36 ±0.66	-	-
Colour (Hazen units, Max)	colourless	blackish	5	25
Odour (TON)	none	pungent smell	agreeable	-
Turbidity (NTU)	4.46±0.31	11±0.87	4	10
EC (dS m^{-1})	1.10±0.08	1.63±0.15	-	-
TS (mg L^{-1})	324±4.00	610±10.00	600	1900
DS (mg L^{-1})	302.66±1.15	195±5.00	500	2100
SS (mg L^{-1})	21.33±3.05	415±5.00	100	200
pH	7.60±0.20	6.56±0.21	6.5-8.5	5.5-9.0
DO (mg L^{-1})	6.87±0.11	1.46±0.30	6-8	-
BOD_5(at 20 ^oC) (mg L^{-1})	4.86±0.30	371.67±10.40	4.0	100
COD(mg L^{-1})	18.68±0.27	1115±5.00	150-200	250
Cl^- (mg L^{-1})	245.80±2.90	346.33±7.09	250	500
Hardness (mg L^{-1})	312.20±4.30	671±3.60	300	600
Alkalinity (mg L^{-1})	168.42±0.43	295±15.00	200	600
NO_3^{2-} (mg L^{-1})	16.16±0.35	73.27±3.16	45	100
PO_4^{3-} (mg L^{-1})	0.11±0.02	30.73±2.00	-	-
SO_4^{2-} (mg L^{-1})	198.63±0.25	219±1.00	200	1000
SPC (SPC ml^{-1})	63±6.20	2324.33±23.11	-	-
MPN (MPN100 ml^{-1})	-	28.46x10^5±1000	50	5000

were determined following standard methods (Chandrashekher, 1998 for seed emergence, seed germination, shoot length root length, no. of leaves, biomass, no. of flowers no. of secondary roots, root nodules, no. of pods, pod length and crop yield); (Milner and Hughes, 1968 for biomass) and (Arnon, 1949, revised by Porra, 2002 for chlorophyll content).

2.5. Statistical analysis

Data were analyzed for one way analysis of variance (ANOVA) for determining the difference between soil parameters before and after effluent irrigation, crop parameters and effluent concentration, standard deviation, coefficient of correlation for soil, crop parameter and effluent concentration were also calculated with the help of MS Excel, SPSS12.0 and Sigma plot, 2000.

3. RESULTS AND DISCUSSION

3.1. Effluent characteristics

The mean±SD values of physico-chemical and microbiological parameters of paper mill effluent (Black liquor) are given in Table 1.

Table 2. Physico-chemical characteristics of soil before and after irrigation with paper mill effluent i.e. after crop harvesting of 90 days.

Parameters	Before effluent irrigation	After effluent irrigation – Effluent concentration (%): 0 (BW)	5	10	25	50	75	100	r - value	F-Critical	CD
Soil temperature (^{o}C)	15.76 ±0.25	16.50 ±0.05	16.47 ±0.11 (-0.18)	16.50 ±0.06 (0)	16.50 ±0.06 (0)	16.47 ±0.09 (-0.18)	16.48 ±0.05 (-0.12)	16.46 ±0.12 (-0.24)	-0.57	0.15	0.10
Soil moisture (%)	48.67 ±3.06	45.33 ±8.08	43.67 ±4.93 (-3.66)	42.00 ±6.00 (-7.34)	41.33 ±4.51 (-8.82)	39.67 ±4.51 (-12.48)	39.00 ±5.20 (-13.96)	38.67 ±6.66 (-14.69)	-0.91	0.82	7.22
Soil texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	-	-	-
WHC (%)	42.73 ±4.10	42.20 ±2.41	41.07 ±2.92 (-2.67)	40.68 ±3.13 (-3.60)	39.61 ±4.24 (-6.13)	36.04[a] ±2.69 (-14.59)	35.76[a] ±3.58 (-15.26)	34.56[a] ±4.66 (-18.10)	-0.97	3.46*	4.29
BD (gm cm^{-3})	1.53 ±0.08	1.52 ±0.09	1.50 ±0.08 (-1.13)	1.50 ±0.09 (-1.13)	1.46 ±0.13 (-3.94)	1.45 ±0.06 (-4.60)	1.43 ±0.13 (-5.92)	1.43 ±0.09 (-5.92)	-0.93	0.61 NS	0.12
EC (dS m^{-1})	1.10 ±0.02	1.03 ±0.27	1.48 ±0.34 (+43.68)	1.49 ±0.46 (+44.66)	1.53 ±0.60 (+48.54)	1.88[a] ±0.54 (+82.52)	1.91[a] ±0.58 (+85.43)	2.26[a] ±0.18 (+119.41)	+0.93	3.45*	0.56
pH	8.19 ±0.14	8.02 ±0.19	8.10 ±0.30 (+0.99)	8.14 ±0.25 (+1.49)	8.12 ±0.24 (+1.24)	7.96 ±0.09 (-0.74)	7.74 ±0.60 (-3.49)	7.41 ±0.59 (-7.60)	-0.92	2.73 NS	0.44
Cl^- (mg Kg^{-1})	34.67 ±4.20	32.32 ±4.00	36.35 ±6.04 (+12.46)	36.63 ±6.12 (+13.33)	41.48[a] ±5.45 (+28.34)	46.33[a] ±6.67 (+43.34)	48.19[a] ±6.41 (+49.10)	50.87[a] ±2.50 (+57.39)	+0.96	7.20**	6.81
Na^+ (mg Kg^{-1})	46.15 ±9.71	42.86 ±10.28	45.59 ±8.99 (+6.36)	46.75 ±10.03 (+9.07)	49.47 ±4.66 (+15.42)	52.72[a] ±4.11 (+23.00)	55.30[a] ±0.71 (+29.02)	59.49[a] ±5.77 (+38.80)	+0.99	3.01*	8.87
K^+(mg Kg^{-1})	134.37 ±10.35	129.26 ±5.04	136.03 ±7.29 (+5.23)	138.23[a] ±4.76 (+6.93)	140.66[a] ±2.82 (+8.81)	143.01[a] ±7.87 (+10.63)	145.37[a] ±1.40 (+12.46)	146.83[a] ±8.96 (+13.59)	+0.89	4.54**	7.45
Ca^{2+} (mg Kg^{-1})	56.00 ±6.93	51.05 ±4.13	51.15 ±2.82 (+0.19)	53.97 ±1.71 (+5.71)	55.29[a] ±3.05 (+8.30)	57.31[a] ±4.05 (+12.26)	59.62[a] ±1.14 (+16.78)	60.59[a] ±4.93 (+18.68)	+0.97	5.77**	4.17
NO_3^{2-} (mg Kg^{-1})	32.65 ±5.53	31.01 ±1.84	32.20 ±2.87 (+3.83)	32.31 ±1.76 (+4.19)	33.41 ±3.64 (+7.73)	38.56[a] ±3.69 (+24.34)	41.18[a] ±3.04 (+32.79)	42.31[a] ±3.17 (+36.43)	+0.98	11.48***	3.65
PO_4^{3-} (mg Kg^{-1})	13.20 ±1.80	11.96 ±1.53	13.50 ±2.56 (+12.87)	13.74 ±1.01 (+14.88)	15.00 ±4.27 (+25.41)	16.04 ±4.99 (+34.11)	17.50[a] ±1.51 (+46.32)	19.53[a] ±1.91 (+63.29)	+0.98	3.58*	3.60
SO_4^{2-} (mg Kg^{-1})	43.01 ±3.60	41.41 ±5.99	43.99 ±4.72 (+6.23)	44.33 ±5.27 (+7.02)	45.47 ±3.51 (+9.80)	47.56 ±1.01 (+14.85)	49.81 ±2.11 (+20.28)	52.02 ±2.33 (+25.62)	+0.98	3.90*	4.89

Mean ± of three values; Significant F -***P - 0.01%, **P -0.1% level,*P- 0.05% level, r-Coefficient of correlation; % Increase or decrease to control given in parenthesis; a - significantly different to the control; NS - Not Significant; BW - Borewell water; CD -Critical difference.

The characterization of the effluent revealed that it is blackish in color, having pungent odour, temperature, 18.36±0.66 ^{o}C, turbidity, 11±0.87 NTU, EC, 1.63±0.15 dS m^{-1}, and higher TS, 610±10.00 mg L^{-1}, TDS, 195±5.00 mg L^{-1}, TSS, 415±5.00 mg L^{-1}, alkalinity 295±15.00 mg $L^{-1}$and hardness 671±3.60 mg L^{-1}. The pH of the effluent was found acidic in nature having pH, 6.56±0.21. The effluent had poor DO, 1.46±0.30 mg L^{-1}, higher BOD, 371.67±10.40 mg $L^{-1}$and COD, 1115±5.00 mg L^{-1}. The higher concentration of BOD and COD indicated the higher concentration of organic and inorganic substances in the effluent. The major plant nutrients like Cl^-, 346.33±7.09 mg L^{-1}, NO_3^{2-}, 73.27±3.16 mg L^{-1}, PO_4^{3-}

, 30.73±2.00 mg L^{-1}, SO_4^{2-}, 219±1.00 mg L^{-1}were also recorded in the effluent. The microbiological parameters of the effluent such as SPC, 2324.33±23.11 and MPN, 28.46x10^5±1000 indicated that the effluent contained higher bacterial load.

Table 3. Agronomical characteristics of *Trigonella foenum-graecum* at different days after irrigation with paper mill effluent.

Effluent Conc.	Agronomical parameters								
	Germination stage (0-10 days)		Vegetative and Flowering and Fruiting stage (60 days)			Maturity stage(90 days)			
	Seed emergence (days)	Seed germination (%)	No. of flowers/ plant	No. of pods/ plant	Chlorophyll content (mg/g)	No. of secondary roots / plant	No. of root nodules /plant	Pod length (cm.)	Crop yield /plant (gm)
0(BW)	4.67 ±0.58	72.50 ±0.96	6.75 ±0.96	5.00 ±0.82	0.46 ±0.04	10.0 ±0.82	7.25 ±0.96	5.95 ±0.66	1.53 ±0.15
5	4.67 ±0.58	82.50[a] ±1.71	7.25 ±0.96	5.75 ±0.96	0.47 ±0.2	11.0 ±0.82	8.25 ±0.96	5.98 ±0.17	1.73 ±0.22
10	4.33 ±0.58	82.50[a] ±0.96	8.0 ±0.82	6.0 ±0.82	0.55[a] ±0.02	11.25 ±0.96	8.75 ±0.50	7.90[a] ±0.26	2.12[a] ±0.16
25	4.00 ±0.00	95.00[a] ±0.58	9.75[a] ±0.25	7.50[a] ±1.29	0.67[a] ±0.2	13.50[a] ±1.29	12.25[a] ±2.06	9.98[a] ±0.48	2.71[a] ±.07
50	3.67[a] ±0.58	92.50[a] ±0.50	8.25[a] ±0.96	7.25[a] ±0.96	0.58[a] ±0.03	12.25[a] ±2.06	9.50[a] ±1.29	8.00[a] ±0.39	1.95[a] ±.16
75	3.33[a] ±0.57	85.0[a] ±0.58	7.75 ±1.26	6.75[a] ±0.95	0.48 ±0.03	12.25[a] ±0.96	8.75[a] ±0.96	6.70[a] ±1.00	1.55 ±0.09
100	3.33[a] ±0.58	87.50[a] ±0.50	7.50 ±1.73	6.25 ±0.96	0.40 ±0.05	11.0 ±0.82	6.75 ±1.71	5.50 ±0.62	1.25 ±0.17
r-Value	-0.95	+0.38	+0.06	+0.42	-0.34	+0.23	-0.21	-0.23	-0.46
F-calculated	4.28**	2.61*	3.1*	3.22*	35.85***	5.36**	7.61***	30.52***	39.81***
CD	0.86	1.35	1.6	1.44	0.05	1.49	1.91	0.84	0.23

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

3.2. Soil characteristics

The mean±SD of various physico-chemical parameters of the soil before and after effluent irrigation at different concentrations viz.5%, 10%, 25%, 50%, 75% and 100% along with control (Borewell water) for 90 days are given in Table 2.

After 90 days of *T. foenum-graecum* crop-harvesting, the soil particle size depicted that the soil was sandy loam and no drastic change in soil texture occurred with the application of all the concentrations of paper mill effluent throughout the period of the trial. The temperature was recorded to be higher after 90 days of crop harvesting but it appears to be environmentally regulated. Moisture content ($r = -0.91$) and bulk density ($r = -0.93$) were insignificantly but negatively correlated with the increase in effluent concentrations. WHC was negatively and significantly correlated ($r = -0.97$) with effluent concentrations. As the concentrations of effluents increased, WHC was decreased with in effluent concentrations from 5% to 100%. It was quite interesting to note that among various concentrations, the concentrations such as 50%, 75% and 100% showed significant ($P<0.05$) decrease on WHC as compared to control. The irrigation with 100% effluent concentration decreased the moisture content (38.67±6.66,14.69%), WHC (34.56±4.66, 18.10%) and bulk density (1.43±0.09, 5.92%), pH (7.41±0.59, 7.60%) and increased EC (2.26±0.18, 119.41%), Cl^- (50.87±2.50, 57.39%), K^+ (146.83±8.96, 13.59%) and Ca^{2+} (60.59±4.93, 18.68%) Na^+ (59.49±5.77, 38.80%), NO_3^{2-} (42.31±3.17, 36.43%), PO_4^{3-} (19.53±1.91, 63.29%) and SO_4^{2-} (52.02±2.33, 25.62%) of the soil.

The pH is an important parameter as many nutrients are available only upon a particular range of pH for plant uptake. A pH value at 6.0 – 8.2 pH provides predominating bacterial activity and is favourable for maximum yield of crops. A shift in pH outside that range renders the nutrients less available, even though they remain in the soil. Under acidic conditions, elements such as iron, aluminium, manganese and the heavy metals (zinc, copper, and chromium) become highly soluble and may create problems for vegetation (Charman *et al.*, 2000). During present study, the soil pH was not significantly affected by effluent concentrations. It was recorded to be significantly and negatively correlated (r = -0.92) with effluent concentrations and slightly basic in nature at 100% effluent. However, EC(r=+0.93),Cl^- (r = +0.96), Na^+ (r = +0.99), K^+ (r = +0.89), Ca^{2+} (r = +0.97), NO_3^{2-} (r = +0.98), PO_4^{3-} (r = +0.98) and SO_4^{2-} (r = +0.98) were significantly and positively correlated with all the effluent concentrations.

The soil characteristics have been found to change on irrigation with pulp and paper mill effluent. The higher concentration of Na in soil after effluent irrigation is associated with presence of higher concentration of carbonate, bicarbonate in the effluent (Thompson *et al.*, 2001). Higher concentration of Na causes the decrease the bulk density as well as water holding capacity by deceasing the porosity in clay soil due to deflocculating of clay particles in presence of high Na content as it affects the cation exchange capacity in the soil and it is adversely affect the seed germination and plant growth. Calcium and potassium are also an essential fertilizers element. They are essential for photosynthesis for protein synthesis, for starch formation and for the translocation of sugars. It is important for grain formation and is absolutely necessary for tuber development. Effluent irrigation generally adds significant quantities of salts to the soil environment, such as sulphates, phosphates, bicarbonates, chlorides of the cations sodium, calcium, potassium and magnesium they stimulate the growth at lower concentration but inhibit at higher concentration (Patterson, 2008).

Nitrate is the most essential and available form of nitrogen to plants because plant roots take up nitrogen in the form of NO_3^{2-} and $NH4^+$. Plants respond quickly to application of nitrogen and it encourages the vegetative growth and gives a deep green colour to the leaves. The overall increase in nitrogen is due to the use of wastewater, which contains higher amount of nitrogen. Kannan and Oblisami (1990) reported that paper mill effluent irrigation significantly increased the nitrogen in soil. The phosphorus is a part of every living cell in a plant and many activities of plant such as growth, respiration and reproduction depends upon phosphorus levels. Yadav *et al.* (2002) reported that soil irrigated with sewage water contains higher amount of available phosphorus which plays significant role in plant growth and strengthen the root system.

During present study ANOVA analysis on the data showed that different concentrations of effluent affected differently on various nutrients. The effluent concentrations of 50%, 75% and 100% of paper mill effluents had a significant (P<0.05) difference on EC, sodium, phosphate and sulphate as compared to control whereas the chlorides, potassium and calcium were recorded to be more significantly (P<0.01) different at 25%, 50%, 75% and 100% effluent treatments. Among these, potassium was recorded significantly different at 10% concentration also. Nitrate was recorded significantly (P<0.001) different with effluent concentrations like 50%, 75% and 100%.

3.3. Agronomical characteristics

3.3.1. Germination and seedling growth stage

The seed emergence period of *T. foenum-graecum* at different concentration viz.5%, 10%, 25%, 50%, 75% and 100% along with control is shown in Table 3.

In present study ANOVA analysis on data showed that effluent concentrations 50%, 75% and 100% significantly (P<0.01) affected emergence period as compared to control. The seed emergence of *T. foenum-graecum* was negatively correlated (r = -0.95) i.e. it decreased with increase in the effluent concentrations. Among different concentrations, seed emergence was much better on irrigation of the crop with 100% effluent treatment. It may be due to that in the emergence period the mineralization and nutrients accumulation occurs slower as per the low frequency of effluent irrigation and it catalyzes the physiological activities as per the effluent concentration of seed emergence and germination. The germination behaviour of *T. foenum-graecum* was also affected significantly (P<0.05) at different concentrations of 5% to100% effluent concentrations. As the concentrations of effluent increased, the germination percent decreased. The maximum seed germination of *T. foenum-graecum* was recorded at 25%. This type of germination pattern is likely due to the presence of toxicants in the paper mill effluent which may inhibit the germination at higher concentrations.

Salts are usually most damaging to young plants but not necessarily at the time of germination, although high salt concentration can slow seed germination by several days or completely inhibit it. Because soluble salts move readily with water, evaporation moves salts to the soil surface where they accumulate and make the soil surface harden as a result delay in germination. Sandeep *et al.* (2007) reported that germination percentage of wheat became lower than that of the control in effluent irrigated soil. The higher concentration of Na in effluent treated soil affected the seed germination. Many foreign substances in the soil environment such as diverse acids, alkali, salts of metals, phenolics, fluorides, and so on from polluted water influenced germination. In present study the emergence period of *T. foenum-graecum* was found in decreasing order i.e. minimum emergence period was noted at cent percent effluent concentration. It is likely due to the low salt accumulation in the soil because of the low frequency of effluent irrigation and low evaporation in the winter season.

Seedling stage parameters such as shoot length, root length, number of leaves and biomass of *T. foenum-graecum* at 21and 30 days are shown in Table 4. It is evident from the table and ANOVA analysis on the data that effluent concentrations affected the shoot length, root length and biomass of *T. foenum-graecum* at 21 days significantly ($P<0.001$) at 25%, 50%, 75% and 100% effluent concentration after 21 days of irrigation while shoot length, root length were also affected significantly at 10%; and 5% and 10% respectively. There was a significant change ($P<0.05$) in the number of leaves at 100% effluent concentration and it was positively correlated ($r = +0.93$). The change in shoot length of *T. foenum-graecum* was recorded to be significant ($P<0.05$) at 25%, 50%, 75% and 100% and that of root length ($P<0.01$) at 75% and 100% effluent concentrations as compared to control after 30 days of irrigation. The effluent concentration of 50% and above significantly ($P<0.001$) affected the number of leaves and biomass of *T. foenum-graecum*. In addition, the biomass was affected significantly at 10% and 25% effluent concentration also. It was quite interesting to note that at the stage of 21 to 30 days the maximum values of these parameters were recorded at 100% effluent concentration irrigation. The availability, uptake and leaching of nutrients is greatly influenced by the pH. In the acidic soil environment the availability of the basic cations like calcium, Ca^{2+}, magnesium, Mg^{2+}, potassium, K^+ and sodium Na^+ becomes lower due to leaching. In the seedling stage (21-30 days) the crop performance was observed to increase with increase in effluent concentrations. It may be likely due to competitive uptake of nutrients from the soil that may result in stimulation of the plant performance in the seedling stage.

3.3.2. Vegetative growth, flowering and fruiting stage

The parameters of vegetative growth, flowering and fruiting stage such as shoot length, root length, number of leaves and biomass of *T. foenum-graecum* at different concentration viz.5%, 10%, 25%, 50%, 75% and 100% along with control (Table4 and 5) and number of pods, number of flowers and number of pods/plants are given in Table3.

It has been observed that tannery effluent stimulates the synthesis of chlorophyll which was accelerated at low concentration of the effluent but certain toxicants inhibited the growth of Vigna (*Vigna unquiculata*), tomato (Lycopersicon *esculentum*), cotton (*Gossypium hirsutum*) and black gram (*Vigna mungo*) crop plants (Karunyal *et al.*, 1994). During the present study it was observed that there was a significant ($P<0.001$) change in shoot length, root length/plant ($P<0.01$) of *T. foenum-graecum* on irrigation of soil with 25%, and 50% effluent concentrations. The effect of effluent concentrations (10%, 25%, 50%) on number of leaves and their chlorophyll content while that of concentrations (10%, 25%, 50% and 75%) on biomass of *T. foenum-graecum* were highly significant ($P<0.001$). The change in the number of flowers at 25% and 50% effluent concentration and in the number of pods/plant of *T. foenum-graecum* at 25%, 50% and 75% concentration treatment were recorded to be significantly ($P<0.05$) higher. At vegetative growth, flowering and fruiting stage of *T. foenum-graecum*, the maximum values of shoot length, root length, number of leaves, chlorophyll content, biomass number of flowers and number of pods/plant of *T. foenum-graecum* were recorded at 25% effluent concentration (Table3). It is very important stage in the life span of crop plant as availability and uptake of nutrients directly affect the biomass, flowering and grain filling. The crop performance decreased with the increase in the effluent concentration. It may be likely due to that the alkaline nature of paper mill effluent made the calcium, $Ca2^+$, magnesium, Mg^{2+}, potassium, K^+ and sodium Na^+ cations much available to the crop plants by gradually neutralizing the acidic environment of the soil and turned it into alkaline.

3.3.3. Maturity stage

The various parameters of maturity stage i.e. (at 90 days) such as number of secondary roots, root nodules, pod length and crop yield/plant of *T. foenum-graecum* at different concentration viz.5%, 10%, 25%, 50%, 75% and 100% along with control are given in (Table3).

The performance of different crop plants has been found to differ on irrigation with different types of waste effluents and also with their different concentrations. Saravanamoorthy and Ranjitha (2007) recorded that increased concentration of textile effluent in irrigation decreased the seed germination percentage of two species of *Arachis hypogaea* as TMV-10 and JL-24 showing the maximum germination percentage at 50% effluent concentration.

Table 4. Agronomical characteristics of *Trigonella foenum-graecum* at different days after irrigation with paper mill effluent.

Effluent conc.	Crop parameters (21-90 days)							
	Shoot length(cm.)				Root length(cm.)			
	Days				Days			
	21	30	60	90	21	30	60	90
0 (BW)	8.4 ±0.37	13.05 ±1.32	18.13 ±0.22	27.90 ±0.67	3.45 ±0.33	4.95 ±0.37	8.55 ±0.13	10.98 ±0.17
5	8.68 ±0.17	13.78 ±0.22	18.38 ±0.39	28.60 ±1.92	3.90[a] ±0.08	4.98 ±0.17	8.68 ±0.17	11.23 ±0.17
10	9.48[a] ±0.48	14.15 ±0.31	18.73 ±0.78	30.65[a] ±1.09	4.00[a] ±0.08	5.15 ±0.13	8.83 ±0.24	11.58[a] ±0.16
25	10.10[a] ±0.32	14.28[a] ±0.56	22.55[a] ±2.80	32.43[a] ±2.11	4.25[a] ±0.21	5.20 ±0.14	9.90[a] ±0.78	13.23[a] ±0.68
50	10.50[a] ±0.59	14.48[a] ±0.79	21.25[a] ±0.85	31.40[a] ±0.84	4.52[a] ±0.36	5.30 ±0.26	9.35[a] ±0.58	12.20[a] ±0.56
75	10.53[a] ±0.43	14. 73[a] ±0.25	19.98 ±0.95	30.50[a] ±0.22	4.65[a] ±0.31	5.43[a] ±0.13	9.13 ±0.51	11.80[a] ±0.22
100	10.88[a] ±0.30	15.10[a] ±1.14	19.25 ±0.62	30.13[a] ±0.13	5.13[a] ±0.22	5.53[a] ±0.15	8.88 ±0.46	11.63[a] ±0.26
r-value	+0.89	+0.89	+0.25	+0.33	+0.97	+0.97	+0.21	+0.19
F-calculated	23.23***	2.97*	7.00***	6.42***	19.28***	4.24**	3.97**	15.54***
CD	0.59	1.14	1.81	1.81	0.37	0.31	0.68	0.55

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

Table 5. Agronomical characteristics of *Trigonella foenum-graecum* at different days after irrigation with paper mill effluent.

Effluent conc.	Crop parameters(21-90 days)							
	Number of leaves				Biomass(mg/g.)			
	Days				Days			
	21	30	60	90	21	30	60	90
0 (BW)	5.50 ±0.58	7.50 ±0.58	13.25 ±1.50	17.50 ±1.29	0.31 ±0.03	0.34 ±0.05	1.07 ±0.03	1.67 ±0.24
5	5.57 ±0.50	7.75 ±1.26	14.0 ±0.82	18.50 ±1.28	0.31 ±0.01	0.35 ±0.01	1.09 ±0.08	1.71 ±0.24
10	6.00 ±0.00	8.00 ±0.82	16.25[a] ±1.26	20.75[a] ±0.96	0.33 ±0.03	0.42[a] ±0.02	1.23[a] ±0.16	1.91[a] ±0.05
25	6.00 ±1.41	9.25 ±1.89	18.75[a] ±0.96	25.75[a] ±1.71	0.40[a] ±0.02	0.53[a] ±0.05	1.67[a] ±0.01	2.37[a] ±0.10
50	6.25 ±0.50	9.50[a] ±1.29	16.50[a] ±0.58	23.00[a] ±1.41	0.45[a] ±0.02	0.57[a] ±0.02	1.60[a] ±0.06	2.20[a] ±0.05
75	6.50 ±0.58	10.50[a] ±1.29	14.25 ±0.96	18.00 ±1.83	0.60[a] ±0.02	0.63[a] ±0.02	1.22[a] ±0.02	1.80 ±0.04
100	7.75[a] ±1.26	12.75[a] ±0.96	12.50 ±1.00	16.00 ±1.41	0.67[a] ±0.01	0.71[a] ±0.01	1.01 ±0.02	1.59 ±0.10
r-value	+0.93	+0.98	-0.30	-0.30	+0.99	+0.96	-0.04	-0.16
F-calculated	3.19*	9.28***	17.48***	22.88***	177.9***	93.84***	52.79***	16.61***
CD	1.21	1.79	1.54	2.12	0.03	0.04	0.11	0.21

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

Total chlorophyll content has been found to decrease gradually with the increasing effluent concentration. The maximum value was recorded at 50% in JL-24 while at 75% in case of TMV-10. The number of pods was also recorded higher at 50% effluent concentration in both species. Maximum shoot and root length were found at 75% in both the varieties. (Osaigbovo *et al.,* 2006) reported maximum plant height and number of leaves and chlorophyll content at 25% of pharmaceutical effluent treatment on maize plant. (Orhue *et al.,* 2005) recorded maximum chlorophyll content in *Zea mays* at 25% brewery effluent concentration while plant height, biomass and leaf number at 100% concentration.

Legumes are capable of fixing atmospheric nitrogen through a symbiotic association with soil bacteria called *Rhizobium*. These bacteria form nodules on the roots of leguminous plants and enhance the nitrate level of the soil. Symbiotic nitrogen fixation is the result of a delicate balance between a higher plant and specific bacteria. It is important to understand properly the optimum conditions as low salinity for this fixation in order to provide full benefits to the plant (Mirza and Tariq, 1992 and Walsh, 1995) also reported that salinity decreased the number of nodules per plant but increased the size of nodules in *Sesbania sesbane.*

In present study, the ANOVA indicated that the difference in shoot length and root length was significant (P<0.001) at 10%, 25%, 50%, 75% and 100% as compared to their counterparts in control at maturity stage of *T. foenum-graecum* at 90 days. The effect of the concentrations of 10%, 25% and 50% effluent irrigation in the number of leaves and biomass of *T. foenum-graecum* was highly significant (P<0.001). The number of secondary roots (P<0.01) and root nodules/plant (P<0.001) were affected significantly with 25%, 50% and 75% effluent concentration treatment. The change in pod length/plant of *T. foenum-graecum* at 10%, 25%, 50% and 75% concentration while in crop yield/plant at 10%, 25% and 50% effluent concentration treatment was highly significant (P<0.001) as compared to control (Table3).At maturity stage of *T. foenum-graecum* at 90 days the values of parameters such as shoot length, root length, number of leaves, biomass, number of secondary roots, root nodules, pod length and crop yield/plant showed maximum performance at 25% effluent concentration. With further increase in the effluent concentration treatment, the reduction was noted in all these parameters. The major effect of a basic pH is to reduce the solubility of all micronutrients (except chlorine, boron and molybdenum), especially those of iron, zinc, copper and manganese. Also phosphate is often not readily available to some plants because of its precipitation in the soil solution. Although toxicity due to high concentration of sodium, chlorides or other ions can occur, salts usually affect plant growth because of the osmotic effect. High salt concentration increases the potential forces that hold water in the soil and makes it more difficult for uptake to plant roots. It is likely to occur due to the more and more accumulation of salts with the increase in concentrations of the effluent treatments. The more concentration and frequency of paper mill effluent treatment of soil may change its ion exchange capacity, pH due to higher accumulation of nutrients as well as toxicants, microbial activities and may make various nutrients like calcium, magnesium, sodium and potassium lesser available to the crop plants that might have ultimately resulted reduction in the growth performance of the crop *T. foenum-graecum*.

4. CONCLUSIONS

It was concluded from the present study that the Paper mill effluent of the Shamli Paper Mill, Shamli, Muzaffarnagar decreased the moisture content; WHC, bulk density and increased it pH. EC, Cl^-, Na^+, K^+, Ca^{2+}, NO_3^{2-} , PO_4^{3-} and SO_4^{2-} of the soil. Thus, irrigation improved the soil nutrient status. All effluent concentrations were better than the control in nutrient accumulation. The agronomical performance of the *T. foenum-graecum* plant was recorded in gradually increasing order at low effluent concentration i.e. from 5% to 25% while in decreasing order at higher effluent concentration i.e. from 50% to 100% as compared to control. Stimulation was observed in seed emergence period and shoot length, root length and biomass with the increase in effluent concentration in emergence and early seedling (0-30 days) growth period. The maximum growth performance of the plant was observed at 25% effluent concentration. It may be due to the low nutrients accumulation in the soil at this 25 % effluent concentration that might have stimulated the growth performance. However, more irrigation increased the accumulation of nutrients at higher effluent concentration i.e.50%, 75% and 100%, thus inhibited the overall performance of the crop plants. Thus, there is certain growth stimulating as well as inhibiting substances present in the paper mill effluent which are responsible for this growth pattern. The effluent has potentiality in the form of plant nutrients needed by *T. foenum-graecum* crop plant. Therefore, it can be used for irrigation purposes after proper dilution for the maximum yield of this crop and to maintain soil health.

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