ISSN : 0974 - 7451 Volume 8 Issue 8

Environmental Science
An Indian Journal
Current Research Paper

ESAIJ, 8(8), 2013 [308-314]

The comparative impact of textile, tannery and sewage effluents on seed germination, biomass, leaf area, root development and chlorophyll contents in French bean (*Phaseolus vulgaris* L.)

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ABSTRACT

The use of industrial and sewage waste water for irrigation purpose has emerged as an important way of utilization of the presence of considerable quantities of essential elements and minimizing its pollution load. In view of such perspectives, an experiment was conducted to examine the comparative effect of textile, tannery and sewage effluents on seed germination, biomass, leaf area, chlorophyll content and root development in French bean (*Phaseolus vulgaris* L.) plants. Plants exhibited a marked reduction in seed germination and other physiological parameters when grown with higher concentrations (50 and 100 %) of all the three effluents. However, the effect was promotive when plants were raised with lower concentrations. The effect of tannery effluent was more deleterious on all parameters as compared with textile and sewage effluents. The overall impact of the three effluents was tannery > textile > sewage in descending order of their toxicity. It was suggested that the effluent released from industrial establishments i.e., textile and sewage in particular, may be used for raising crops after appropriate dilution. This may facilitate the availability of essential nutrients and irrigation water which are often in scarcity. However, this recommendation needs further extensive studies with different kinds of effluents and plant species. In addition, this phytoremedial approach may also contribute substantially towards eco-friendly disposal of industrial effluents, a cumbersome problem for the management and farmers as well.

KEYWORDS

Textile;
Tannery;
Sewage;
Effluent;
French bean.

INTRODUCTION

Rapid industrialization is a requisite for developing countries to meet the demand of their ever increasing population. However, the indiscriminate establishment of these industries without proper attention on pollution control measures has resulted into an adverse impact on the environment. These industries discharge their untreated or treated wastes directly into the natural environments (water, land, air) thereby polluting them[5,9,14,20,24,26,27]. The use of wastewaters (industrial effluents as well as municipal Sewage) for irrigation has emerged in the recent past as an important way of utilization of waste water taking the advantage of the presence of considerable quantities of nitrogen and phosphorus along with some other essential elements. Other advantage of waste water irrigation includes an important aspect of pollution removal. The pollutants are partly taken up by the plants and partly transformed in the soil without causing any damage. Nevertheless, the use of wastewaters for agriculture is marred by several constraints due to various problems like soil salinity, interaction of chemical constituents of the wastes with the uptake of nutrients and changes in soil property and micro flora[7,19,22]. This necessitates an extensive scientific study before any specific waste can be used for irrigation for particular crop with particular soil and climate. Since crop plants are increasingly being exposed to the effluent discharge from industries or sewage, it was thought worthwhile to study the comparative effects of theses three major effluents viz., textile, tannery and sewage on germination and some physiological and biochemical characteristics of French Bean (*Phaseolus vulgaris* L.). French bean (*Phaseolus vulgaris* L.) was selected as test crop as it is popularly grown in the area and consumed as vegetable as well as fodder for livestock.

MATERIALS AND METHOD

Petri dish culture experiment

The seeds of French Bean (*Phaseolus vulgaris* L.) were procured from local seed supplier in Arba Minch. The waste water (effluent) were collected from textile factory, Hawassa (SNNPR) and ELICO tannery, Addis Ababa. Sewage water was collected from disposal site at AMU campus. All effluents were stored at 4^{o}C to avoid any change in physico-chemical characteristics. 15 sterilized Petri dishes were collected and lined with filter papers moistened with 0, 10, 25, 50 and 100 % concentration of effluent. Seeds were disinfected with 1% sodium hypochlorite solution for 15 minutes and 10 seeds were kept in each Petri dish. Data for early growth and germination were recorded. The emergence of radicle was considered as criterion for germination.

Pot culture experiment

For pot culture, plastic pots (size: 15cm x 14cm) were filled with equal amount (2 Kg) of sandy loam soil (pH : 7.8, ECe : 2.8) of medium fertility and seeds of French bean (*Phaseolus vulgaris* L.) were sown in each pot after proper sterilization with 1% NaOCl. The pots were provided with ½ strength Hoagland solution (Hewitt, 1966) along with different concentrations of effluents (0, 10, 25, 50 and 100%). Each pot was provided with 100 ml effluent followed by 50 ml of nutrient Solution. A control set irrigated with distilled water (without effluent but having nutrient solution) was also maintained for comparison. Each treatment and control had three replications.

Analysis and determinations

Physico-chemical characteristics of effluents

The samples of waste water collected from different sources i.e., textile, tannery and sewage were analyzed for various physico-chemical characteristics[1].

Germination

Germination percentage of seed from each treatment was calculated on the basis of radicle emergence from seeds.

Biomass

Plant samples were taken from each treatment and divided into root and shoot parts. Plants were dried in a hot air oven at 60 ^{o}C for 48 hours and dry weights were estimated.

Root development

Plants were uprooted from each treatment carefully separated into root and shoot, slightly rinsed for same time in each case and blotted dry. The number and lengths of root were studied with the aid of Ax10 magnifying glass, of these primary, secondary, tertiary branches were counted. The root length was measured by ruler and various parameters of root development were calculated.

Mean extension rate (MER) and Relative multiplication rate (RMR)

The length of root/plant, number of root branches/ plant was measured at two time intervals and MER and RMR were calculated according to a formulae devised by Hunt.

MER = $(l_2-l_1)/(n_2-n_1)$ x $(\log_e n_2 - \log_e n_1)/ t_2-t_1$

RMR = $(\log_e n_2 - \log_e n_1)/ t_2-t_1$

Where, l_1 = root length per plant at first period ; l_2 = root length per plant at second period; n_1 = number of root branches per plant at first period ; n_2= number of root branches per plant at second period; t_1= Age of plant at first period; t_2= Age of plant at first period

Relative growth rate (RGR)

Relative growth rate of the whole plant was calculated by a formula using dry weights at two growth stages as follows.

$$RGR=(\log_e w_2 - \log_e W_1) / \Delta_t$$

Chlorophyll contents

The chlorophyll content in leaves of plants from different treatments was estimated by extracting fresh leaves in acetone according to Arnon[4].

Leaf area

Leaf Area of plants from each treatment was measured by scale and calculated using a constant.

Statistical analysis

Data were analyzed according to Duncan multiple Range Test (DMRT) for the significance at 5%. P.

RESULTS AND DISCUSSION

Germination and biomass production

The mean of percentage germination as affected by different concentrations of textile, tannery and sewage effluents is presented in TABLE 1. It is obvious from data that at lower concentration (0-25%) of all three effluents, germination % was stimulated followed by an enhancement in total biomass also. However, this increase over control was not significant. For example, at 10% effluent concentration, French bean plants exhibited about 130.0, 115.0 and 140.0 mg root dry weight (DW) under textile, tannery and sewage effluent imposition respectively as compared with 110.0 mg root DW under control conditions (0% effluent). On the other hand, germination and biomass production were greatly decreased under higher concentrations (50 and 100%) of effluent. For instance, as compared with 180.0 mg Shoot DW in control condition, plants showed 110.0, 100.0 and 150.0 mg shoot dry weight (DW) due to imposition of textile, tannery and sewage effluents respectively. Interestingly, this decreasing response of crop to higher concentrations was observed in root DW also due to imposition of all effluents under study. However, the extent of reduction was variable (TABLE 2).The overall performance of crop was variable and it performed better under sewage effluent imposition than other two effluents.

TABLE 1 : Physico-chemical characteristics of textile, tannery and sewage effluents (Treated)

Parameters	Textile effluent	Tannery effluent	Sewage effluent
Color	Bluish grey	Dark brown	grey
pH	8.9	8.5	7.8
EC	5.9	4.5	2.8
Suspended solids (mg/l)	350	1150	305
Total Solids (mg/l)	1640	12880	1130
Dissolve Oxygen	1.8	2.2	1.20
BOD (mg/l)	210	1746	107
COD (mg/l)	720	6240	242
Total N (mg/l)	256	327	1.55
Chromium (mg/l)	8.5	13.3	0.10
Nickel (mg/l)	0.40	1.4	ND
Cadmium	2.1	2.4	ND
Na (mg/l)	110	145	80
K (mg/l)	197	382	239
Ca (mg/l)	180	70	310
Mg (mg.l)	12	68	211
Cl (mg/l)	230	350	210
SO_4 (mg/l)	150	260	220
PO4 (mg/l)	25	21	3.4
F (mg/l)	3.1	5.0	4.4.

ND- Not Detected

Chlorophyll contents

It is obvious from data presented in TABLE 3 that the effect of different concentrations of the three effluents viz., textile, tannery and sewage, on various chlorophyll forms was differential in French bean (*Phasolus vulgaris* L.) during the investigation. It was observed that the greening of plants increased when plants were treated with low concentration of effluents (10 and 25%). On the other hand, it was also noticed that higher concentrations were inhibitory to synthesis of all chlorophyll molecules particulary of Chl a. (TABLE 3). For example, at 100% effluent concentration, c plants showed about 0.85, 0.70 and 1.00 mg/gm FW Chl a as compared with 1.80 mg/gm FW Chl a in control plants receiving no effluent.

Leaf area

Data presented in TABLE 4 show the average value of leaf area in plants while subjected to the different concentrations of textile tannery and sewage effluents. Like other parameters, leaf area was also affected differentially by the concentration of three effluents ie. higher levels of effluent (50-100%) were proved deleterious to leaf area whereas lower concentration induced leaf area in considerable manner (TABLE 4).

TABLE 2 : Effect of textile, tannery and sewage effluents on germination and biomass in *Phaseolus vulgaris L*

Effluents	Effluent Conc.(%)	Germination %	Root DW (mg/plant)	Shoot DW (mg/plant)	Total DW (mg/plant)
Textile	0	100a	110.0a	180.0a	290.0a
	10	100a	130.0a	195.0a	325.0a
	25	100a	134.0a	190.0a	324.0a
	50	90b	80.0b	110.0b	190.0b
	100	80c	70.0c	90.0c	160.0c
Tannery	0	100a	110.0a	180.0a	290.0a
	10	100a	115.0a	190.0a	305.0a
	25	100a	120.0a	188.0a	308.0a
	50	80b	60.0b	100.0b	160.0b
	100	70c	50.0b	80.0c	130.0c
Sewage	0	100a	110.0a	180.0a	290.0a
	10	100a	140.0a	210.0a	480.0a
	25	100a	146.0a	220.0a	466.0a
	50	90b	105.0b	150.0a	255.0b
	100	90c	89.0b	90.0c	179.0c

Values followed by same letters in a column are not significantly different ($P \leq 0.05$)

TABLE 3 : Effect of textile, tannery and sewage on chlorophyll contents (mg/gFW) in *Phaseolus vulgaris*

Effluent	Textile			Tannery			Sewage		
Conc. (%)	Chl a	Chl b	Total chl	Chl a	Chl b	Total chl	Chl a	Chl b	Total chl
0	1.80	0.65a	2.70a	1.80a	0.65a	2.70a	1.80a	0.75a	2.70a
10	1.90a	0.70a	2.80a	1.45a	0.95a	2.60a	1.95a	0.78a	2.90a
25	1.98a	0.82b	2.86a	1.50a	0.95a	2.69a	1.90a	0.90b	2.98a
50	1.10b	0.70c	1.90b	1.10b	0.50b	1.70b	1.05b	0.78c	2.30b
100	0.85c	0.40d	1.60c	0.70c	0.45c	1.45c	1.00b	0.50d	2.00c

Values followed by same letters in a column are not significantly different ($P \leq 0.05$)

Root development

Root development i.e., number of branching and other attributes like MER, RMR and RGR were differentially affected by effluent application depending upon the type and concentrations of the effluent (TABLE 4& 5). Lower concentrations of effluent were proved pro-

TABLE 4 : Effect of textile, tannery and sewage effluents on mean extension rate (MER), relative multiplication rate and relative growth rate sewage in *Phaseolus vulgaris*

Effluents	Effluent Conc.(%)	Mean Extension Rate(cm//day)	Relative Multiplication Rate (no.root/day)	Relative Growth Rate (cm/day)
Textile	0	0.078a	0.008a	0.155a
	10	0.085a	0.008a	0.160a
	25	0.087a	0.007a	0.165a
	50	0.055b	0.006b	0.130b
	100	0.045c	0.004c	0.070d
Tannery	0	0.078a	0.008a	0.155a
	10	0.080a	0.008a	0.105a
	25	0.084a	0.008a	0.115a
	50	0.045b	0.004b	0.085b
	100	0.035c	0.003c	0.060c
Sewage	0	0.078a	0.008a	0.155a
	10	0.090a	0.008a	0.165a
	25	0.095a	0.007a	0.160a
	50	0.065b	0.005b	0.090b
	100	0.050c	0.005c	0.080c

Values followed by same letters in a column are not significantly different ($P \leq 0.05$)

TABLE 5 : Effect of textile, tannery and sewage effluents on Leaf area, primary, secondary and tertiary branches in *Phaseolus vulgaris*

Crops	Effluent conc (%)	Leaf area (cm^2)	Primary branches/plant	Secondary branches/plant	Tertiary branches/plant
Textile	0	6.10a	1a	55a	48a
	10	6.30b	1a	63b	52a
	25	6.28b	1a	68b	55b
	50	5.60c	1a	38c	35c
	100	4.00d	1a	30d	28d
Tannery	0	6.10a	1a	55a	48a
	10	6.00a	1a	60a	46a
	25	5.90b	1a	58b	48a
	50	4.90c	1a	33c	28b
	100	3.10d	1a	25d	20c
Sewage	0	6.10a	1a	55a	48a
	10	6.50b	1a	69b	54b
	25	6.45c	1a	70c	56b
	50	5.90d	1a	44d	36c
	100	5.10e	1a	38e	30d

Values followed by same letters in a column are not significantly different ($P \leq 0.05$)

motive to the number of root branches/plant and other parameters. For example, French bean plants produced about 63 secondary branches at lower concentration (10%) of textile effluent as compared with 55 branches/ plant in control. This was a similar case with other two effluents also (60 and 69 branches due to tannery and sewage effluent respectively). On contrary, higher concentrations (50-100%) proved detrimental to all parameters of root development (TABLE 5). For each effluent, primary root remained unaffected at all treatments. Similarly, MER and RMR were also affected at higher concentrations and were found stimulated by lower concentration of the three effluents applied. For example, MER in plants was recorded about 0.095 cm/cm/day at 25% concentration of sewage effluent as compared with 0.055cm/cm/day in plants raised without effluent (control). Moreover, Mean Extension Rate (MER) of roots in French bean plants was also affected by other two effluents i.e., textile and tannery in a similar manner (TABLE 4). Such performance of crop to different effluents shows the probability of using effluents like sewage and textile for irrigation purposes.

It is evident from our results that plants exhibited a stimulation in seed germination %, biomass, chlorophyll contents, leaf area and various attributes of root development at lower concentrations of three effluents. In contrary, a substantial decrease was observed in these parameters at higher concentrations of effluents. Our results are in agreement with some earlier reports which have also demonstrated a same response of plants when irrigated with effluent[10,11,21]. It has been established by various analysis that effluents contain heavy metals and also nutrients[2,25] which affect plants and soils in a variety of ways. Several workers[23,26,27,30,] reported that different types of effluents influenced the growth of various crops. It is argued that imposition of effluent in plant nutrient medium may cause disturbances in the iso-osmotic relation of plants making water availability to roots more difficult. Moreover, the presence of heavy metals in effluent may also compete for essential nutrients leading to their deficiency in nutrient medium. Our results indicate that at lower concentrations, the effect of effluent was either negligible or promotive which is indicative of promotive action of heavy metals in lower concentration. This may be attributed to the presence of several essential plant nutrient like N, P, K, Ca and Mg in the textile or sewage waste water[3,16,17,26]. It may also be argued that heavy metals like iron, manganese may contribute to the synthesis of chl a that resulted into stimulation of Chlorophyll under lower concentrations.

On the basis of overall performance as exhibited by French bean, it can be suggested that effluents released either from industrial establishments i.e., textile, tannery or sewage can be used for irrigation purposes after appropriate dilution. However, the extent of remediation depends upon the plant species, plant growth stage and dilution of the effluent applied. It is therefore obvious that some kind of treatment is necessary to minimize the pollution effects before the textile effluent is discharged on the land.. After dilution, the effluent's characteristics come within the prescribed disposal limits and pollution load per unit effluent volume is decreased. In fact, such recommendation needs some more in-depth studies involving different effluents and crop species to minimize the risk.

ACKNOWLEDGEMENTS

We are thankful to AMU administration and Director, Research Core Process for encouragement and financial assistance in form of a research project No. AMU-Bio-2/10. We are also thankful to Dean, College of Natural Sciences, Arba Minch University for providing facilities. We are grateful to Director ILRI, Addis Ababa for providing seeds of crops. Thanks are also due to Lab technician Ato Bedilu for technical assistance, and Management of Textile factory Awassa/ ELICO Tannery, Addis Ababa for permitting us to procure effluent

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