Original Research Article

Effect of Paper Mill Effluent Irrigation with or Without Compost Application on Root Nodulation and Soil Biology in Groundnut under Alfisols

.

ABSTRACT

A Field experiment was conducted at Mondippatti village in Tiruchirappalli district of Tamil Nadu to study the effect of paper mill effluent irrigation with or without compost application on root growth, biological properties and soil nutrient status in *Alfisol* with groundnut as the test crop. The results revealed that the application of paper mill effluent along with compost favourably increased the soil nutrient status during the crop period. The highest concentrations of available nutrients *viz.*, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron and zinc in the surface layer were 309.4 kg/ha, 14.2 kg/ha, 211.9 kg/ha, 64.9 meq/100g, 32.5 meq/100g, 38.8 mg/kg,11.4 mg/kg and 0.8 mg/kg, respectively in 75% PME and press mud compost applications. Similarly, the use of paper mill effluent along with compost has a positive impact on soil microbial properties and highest population of bacteria was observed in 50% PME and press mud application was 9.79 CFU (x10^6/g) followed by 100% PME and press mud application (7.63 CFU (x10^6/g). While fungi and actinomycetes populations are higher in 75% PME and FYM application which were 5.64 CFU (x10^4/g) and 5.62 CFU (x10^4/g) respectively. The highest number of nodules was noticed in 100% PME with press mud at 5 t/ha (45 numbers) followed by 75% PME with press mud at 5 t/ha (42 numbers). From the study, it was concluded that the application of paper mill effluent with compost was found to be a promising source for soil fertility and root growth in groundnut.

Keywords: Paper mill effluent, irrigation, compost, soil nutrient, root growth and soil microbes

1. INTRODUCTION

Water is a main limiting factor in many arid and semi-arid regions [1]. Currently, wastewater is being used for non-food crops such as tree plantations, greenbelts, and forestlands [2,3&4]. But recently, several studies have been undertaken on the use of treated waste water in agricultural crops. Waste water discharged from industry has been a major cause in environmental pollution and also cause negative impact on soil and as well as ground water. Incessant discharge of toxic effluents to the adjoining crop fields and water bodies are reducing soil fertility and causing severe contamination to rivers, ponds, wells, canals, etc., thereby making the water unfit for irrigation and human consumption. The paper industry is one of the major industries that utilize a large quantity of water, resulting in the generation of large amounts of waste water. It is considered as the sixth-largest polluting industry and discharges a variety of pollutants into the environment.

The pulp and paper industry uses a large quantity of freshwater and lignocellulosic materials in the process of producing paper and it generates a large quantity of effluent [5]. The generated effluent is characterized by dark colour, foul odour, high organic content and extreme quantities of chemical oxygen demand (COD), biochemical oxygen demand (BOD) and pH [6]. Pulp and paper industrial waste waters usually contain halogenated organic materials because chlorine-containing compounds are commonly used as bleaching agents during pulp and paper manufacture [7]. Due to the severe toxic effects of pulp and paper mill effluents, reduction and/or removal of pollution loads prior to their discharge into the environment is crucial. The treated wastewater contains organic matter and nutrients that can improve soil and crop productivity. On the other hand, treated paper mill effluent or waste water is considered a resource that can be applied for productive uses since it contains a higher amount of essential plant nutrients that have the potential for use in agriculture [8]. Recently, attention has been diverted to the use of treated waste water for agricultural crops as a source of fertilizer as well as irrigation water. Similarly, the use of treated waste water for both agricultural production and environmental protection has increased in recent years in several countries.
Oil seed is one of the important crops in the agricultural economy of India, which contributes about 13–15% of the world's oilseed area, 8–9% of the world's oilseed output and 10–11% of the world's vegetable oil consumption. The diverse agro-ecological conditions in India are favourable for the growing of annual oilseeds. Groundnut is the second-most important annual oilseed crop after soybean. Groundnut, 'the unpredictable legume' is also known as earthnut, peanut, monkey nut and manilla nut. Groundnut is the 13th most important food crop and the 4th most important oilseed crop in the world. Groundnut is grown mostly in five states, namely Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu and Maharashtra, and together they account for about 90% of the crop's total area. It is the single largest source of edible oils in India and constitutes roughly about 50% of the total oilseed production. Drought is a major limiting factor in aspects of legume-rhizobia symbiosis and affects in pulses, nodulation and nitrogen fixation in the legume-Rhizobium relationship are sensitive to water quality; therefore, poor water quality can prevent legume growth and reduce crop yield. In this connection, an attempt has been made to study the effect of paper mill effluent irrigation and manure application on nodulation and soil biology with groundnut in *Alfisols* of Tiruchirappalli district in Tamil Nadu.

2. MATERIAL AND METHODS

2.1 Experimental site

The study was conducted at Mondippatti village in Manappairai village, Tiruchirappalli district, Tamil Nadu under TNPL project sanctioned during 2019–2022 in groundnut crop of 0.20 ha. Tamil Nadu Newsprint and Paper Limited (TNPL) - Unit II located at Mondipatti Village, Manaparai Taluk, Trichy district, Tamil Nadu is an industry producing multi-layer coated paper boards from imported pulp and waste papers as raw materials. The site is situated at the intersection of latitude 10º 41' N and longitude 78º 26'' E. The production capacity of the factory is around 2 lakh tonnes per annum and it discharges around 5,000 m3 of waste water per day. The wastewater is properly treated through modernized Effluent Treatment Plant (ETP) and is being completely utilized for irrigation through drip in about 570 acres of land in the factory, which has already planted 6,80,000 trees in 68 varieties, including teak, mango, neem, coconut and many other flowering trees in the factory area. Hence the current study undertaken to study the use of paper mill effluent in groundnut crop.

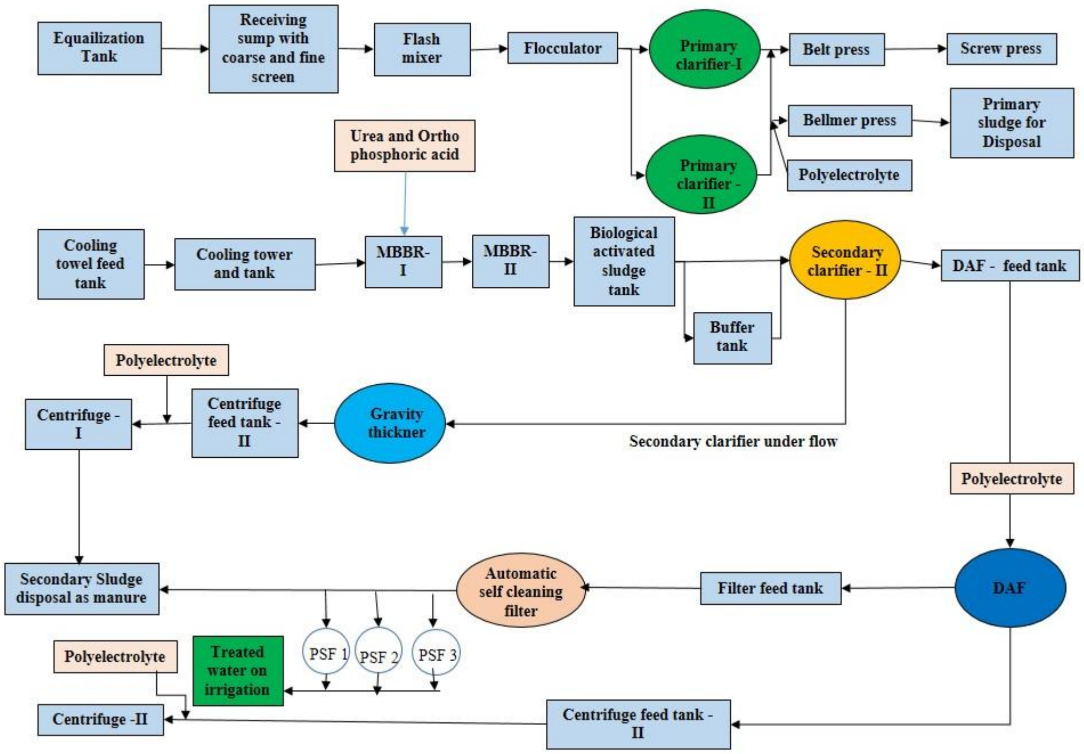


Fig.1. Flow Chart of Effluent Treatment Plant TNPL Unit II, Mondipatti.

2.2 Experiment details

A study was carried out by the Department of Soil Science and Agricultural Chemistry, AnbilDharmalingam Agricultural College and Research Institute, Tiruchirappalli district of Tamil Nadu with Paper mill effluent and compost in groundnut variety VRI 10. In this study, the effect of paper mill effluent application with or without compost was observed on soil biological properties and root growth under *Alfisol* during *Kharif* 2022. Crop was irrigated with well water (S_1) and paper mill effluent (PME) in different concentrations, *viz*., 25% (S_2), 50% (S_3), 75% (S_4), and 100% (S_5), with or without organics, *viz*., without organics (M_1), farm yard manure at 12.5 t/ha (M_2) and press mud compost at 5 t/ha (M_3). Soil samples were collected from the research plot and checked for nutrient and microbial populations by dilution plate for the enumeration of microbial population. The plants were uprooted on the 45th day after sowing. The measurements for root length and root volume were made. The number of root nodules and nodulation efficiency in the root system were counted.

3. RESULTS AND DISCUSSION

3.1 Initial soil properties

The initial soil collected from the field was analyzed by following standard procedures and are represented in Table 1. The experimental soil was neutral in pH and EC with a medium organic carbon status. Available nitrogen and phosphorus fall into the low category and potassium was medium in status. Copper and sulphur were low in status and zinc and Fe were falling under sufficient levels. Micro-biological properties of soils *viz*., bacterial population was 32.96×10^{6} CFU g^{-1}, fungi population was 6.39×10^{4} CFU g_{-1} and actinomycetes population was 5.67×10^{3} CFU g^{-1} and *rhizobium* population was 7.05×10^{6} CFU g^{-1}.

Table 1. Initial soil characteristics of the experimental field

S.No.	Parameters	Values
1.	Bulk density (Mg/m^3)	1.76

2.	Particle density (Mg/m^3)	2.17
3.	Porosity (%)	10.8
4.	WHC (%)	35
5.	pH	7.51
6.	EC (dS/m)	0.10
7.	CEC (meq/100g)	49.87
8.	Organic carbon (%)	0.86
9.	N (kg/ha)	203
10.	P (kg/ha)	8.5
11.	K (kg/ha)	208
12.	Ca (meq/100g)	36
13.	Mg (meq/100g)	12.39
14.	Na (meq/100g)	0.27
15.	S (mg/kg)	1.09
16.	Zn (mg/kg)	0.2
17.	Cu (mg/kg)	0.88
18.	Fe (mg/kg)	8.56
19.	Mn (mg/kg)	7.65
20.	Bacteria (10^6) CFU g^{-1},	32.96
21.	Fungi (10^4) CFU g^{-1},	6.39
22.	Actinomycetes (10^3) CFU g^{-1},	5.67
23.	*Rhizobium*(10^6) CFU g^{-1},	7.05

3.2 Characteristics of treated paper mill effluent

The raw and treated effluents of TNPL-II paperboard industry were dark and light brown colour respectively (Table 2). The pH of raw effluent ranged from 6.01 to 6.39 and the pH of treated effluent was slightly alkaline in nature (7.28 to 7.74). The EC of the raw effluent was ranged from 2.94 to 3.09 dS m^{-1} and treated effluent ranged from 2.58 to 2.71 dS m^{-1}. The amounts of TSS in raw and treated effluent ranged from 333.68 to 354.32 mg L^{-1} and 92.00 to 94.76 mg L^{-1}, respectively. TDS in raw and treated effluent were ranged from 1304.65 to 1385.35 mg L^{-1} and 968.06 to 1027.94 mg L^{-1}, respectively. The BOD and COD values of raw and treated effluent were ranged from 44.14 to 46.87 mg L^{-1} and 31.04 to 32.96 mg L^{-1} and 93.22 to 98.98 mg L^{-1} and 86.72 to 92.08 mg L^{-1}, respectively. Among the cations, Na^+ was the dominant ion followed by calcium, magnesium and potassium. The sodium, calcium, magnesium and potassium content for raw effluent and treated effluents were ranged from 486.86 to 506.74 mg L^{-1}, 65.96 to 70.04 mg L^{-1}, 70.71 to 75.09 mg L^{-1} and 52.58 to 55.84 mg L^{-1} and 733.14 to 763.06 mg L^{-1}, 128.04 to 135.96 mg L^{-1}, 94.28 to 100.12 mg L^{-1} and 49.18 to 52.22 mg L^{-1}, respectively. The anionic species *viz*., bicarbonate, chloride, sulphate and carbonate content of raw effluent and treated effluents were ranged from 201.37 to 213.83 mg L^{-1}, 279.65 to 296.95 mg L^{-1}, 64.51 to 68.5 mg L^{-1} and 35.60 to 37.80 mg L^{-1} and 296.14 to 314.46 mg L^{-1}, 204.86 to 217.54 mg L^{-1}, 90.11 to 95.69 mg L^{-1} and 23.77 to 25.24 mg L^{-1}, respectively.

Table 2. Characteristics of raw and treated paper mill effluents

S.No.	Parameters	Raw effluent	Treated effluent
1.	pH	6.01-6.39	7.28-7.74
2.	EC (dS/m)	2.94-3.09	2.58-2.71
3.	K (mg/lit)	52.58 - 55.84	49.18 - 52.22
4.	Ca (mg/lit)	65.96 - 70.04	128.04 - 135.96
5.	Mg (mg/lit)	70.71 - 75.09	94.28 - 100.12
6.	Na (mg/lit)	486.86 - 506.74	733.14 - 763.06
7.	Sulphate (mg/lit)	64.51 - 68.5	90.11 - 95.69
8.	Chlorides (mg/lit)	279.65 - 296.95	204.86 - 217.54
9.	Carbonate (mg/lit)	35.60 - 37.80	23.77 - 25.24

10.	Bicarbonate (mg/lit)	201.37 - 213.83	296.14 - 314.46
11.	BOD (mg/lit)	44.14 - 46.87	31.04 - 32.96
12.	COD (mg/lit)	93.22 - 98.98	86.72 - 92.08
13.	TDS (mg/lit)	1304.65 - 1385.35	968.06 - 1027.94
14.	TSS (mg/lit)	333.68 - 354.32	92.00 - 94.76

3.3 Effect of paper mill effluent and manures on root growth

The root length, weight of nodules and nodules/plant showed an increasing trend as treated with PME and compost and no negative effects found on nodulation (Table 3). The highest number of nodules was noticed in 100% PME + press mud (45 numbers) followed by 75% PME + press mud (42 numbers.). On the other hand, nodulation percentage decreased in paper mill effluent combined with farm yard manure application compared to control. There is no significant increase in nodulation in effluent with FYM application over control. While lower number of nodules was observed in 0% PME or well water irrigated plots without compost. Fresh weight and dry weight of nodules increased at the highest concentration of paper mill effluent (100%) + press mud at 5 t/ha application which was 1.3 g and 0.86 g, respectively which was followed by 25% paper mill effluent + Press mud compost application (1.2 g and 0.82 g). the lowest nodules weight observed in 25 % paper mill effluent + farm yard manure compared to paper mill effluent alone. There was no significant increase from the control at 25% and 50% effluent concentrations + farmyard manure application. Thus, farm yard manure reduced the overall nodulation efficiency on groundnut.Fig 2(a) depicts the effect of paper mill effluent and press mud application on root and nodulations in groundnut. Similar effects of the positive influence of paper mill effluent water irrigation were found in alfalfa [9, 10, 11&12].

3.4 Effect paper mill effluent and manures on microbial properties

The microbial population *viz*., *rhizobium*, bacteria, fungi and actinomycetes in the vegetative stage soil as a result of paper mill effluent and organics was significantly increased and no negative effects were found on the microbial population as presented in Table 4. The highest population of bacteria observed in 50% PME and press mud application was 9.79 CFU ($x10^6$/g) and *Rhizobium* population was higher in 100% PME and press mud application at 7.63 CFU ($x10^6$/g). While fungi and actinomycetes populations are higher in 75% PME and FYM applications, they were 5.64 CFU ($x10^4$/g) and 5.62 CFU ($x10^4$/g) respectively. The lowest population of bacteria, fungi, actinomycetes and *rhizobium* found in the lower concentration of paper mill effluents which was 8.90 CFU ($x10^6$/g), 4.95 CFU ($x10^4$/g), 5.11 CFU ($x10^4$/g), 7.10 CFU ($x10^6$/g), respectively.Fig 2(b). depicts the effect of paper mill effluent and compost application on *Rhizobium* and microbes in soil. More microbial populations in the surface soil layer were observed in paper mill effluent with organic manures compared to paper mill effluent alone. A positive influence of paper mill effluent irrigation on soil microbial load was observed by [7]. The application of treated wastewater had not significantly changed the microbial dynamics of the soil [13&14].

3.5 Effect of paper mill effluent and manures on soil properties

The available macro and micronutrient status of soil samples collected on the 45th day after sowing is presented in Tables 5 and 6. From the results, it could be noticed that paper mill effluent and manure application had a significant effect on the available nutrient status of the soil. Generally, the addition of both paper mill effluent and compost improves the soil fertility status more than paper mill effluent alone *viz*., OC, N, P, K, Zn and Fe. The highest concentration of paper mill effluent (75%) and press mud compost application have more influence on available nutrients compared to the application of farmyard manure and control. The highest nutrient concentrations of available nutrients *viz*., nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and iron and zinc concentration in the surface layer were 309.4 kg/ha, 14.2 kg/ha, 211.9 kg/ha, 64.9 meq/100g, 32.5 meq/100g, 38.8 mg/kg,11.4 mg/kg and 0.8 mg/kg respectively, on 75% PME and press mud compost application. The lowest nutrient concentration found on application of paper mill effluent alone that was 207.7 kg/ha of nitrogen, 8.1 kg/ha of phosphorus, 189.3 kg/ha of potassium, 42.8 meq/100g of calcium, 18.1 meq/100g of magnesium, 9.7 mg/kg of sulphur, 8.4 mg/kg of iron, 0.2 mg/kg of zinc. There is no significant difference observed in physical parameters like bulk density, particle density, porosity and water holding capacity and also, no significant differences observed in pH, EC and CEC of the soil.

Positive influences of paper mill effluent irrigation on available nutrients like macro and micronutrients in soil were observed by Harshini *et al*., (2014). The presence of nutrients in effluents may increase the nutrient levels in the soil. These findings were similar to earlier reports [14].

Table 3. Effect of paper mill effluent irrigation with or without compost application on root growth and nodulation in groundnut

Treatment details	Nodulation						Root studies					
	Without Organics		FYM		Press mud compost		Without Organics		FYM		Press mud compost	
	Nodules (No.)	Efficiency %	Nodules (No.)	Efficiency %	Nodules (No.)	Efficiency %	Root length (cm)	Root volume (cm^3)	Root length (cm)	Root volume (cm^3)	Root length (cm)	Root volume (cm^3)
0 % PME	15	-	27	-	21	-	12.7	0.50	2.80	12.3	9.9	5.30
25 % PME	19	26.6	16	0	27	28.5	12.8	1.20	3.40	14.4	11.3	5.60
50 % PME	22	46.6	26	0	35	66.6	14.3	1.50	3.90	14.7	12.9	6.20
75 % PME	25	66.6	32	18.5	42	100	16.5	1.90	4.40	17.0	15.2	7.20
100%PME	29	93.3	35	29.6	45	100	16.3	2.60	4.90	16.8	13.7	7.50
							M	M	S	S	M at S	M at S
Sed							0.92	0.07	0.04	0.65	1.36	0.09
CD (p=0.05)							NS	0.21	0.07	1.34	NS	0.24

Table 4. Effect of paper mill effluent irrigation with or without compost application on soil microbial and *Rhizobium* population

Treatment details	Bacteria CFU (x10^6/g)			Fungi CFU (x10^4/g)			Actinomycetes CFU (x10^4/g)			*Rhizobium* CFU (x10^6/g)		
	M1	M2	M3	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3
S1	9.5	9.7	9.8	5.2	5.6	5.4	5.6	5.3	5.6	7.3	7.5	7.5
S2	9.2	9.7	9.8	5.0	5.3	5.1	5.2	5.2	5.3	7.3	7.6	7.1
S3	8.9	9.7	9.8	5.2	5.3	5.0	5.2	5.2	5.2	7.3	7.4	7.6
S4	9.2	9.9	9.6	5.3	5.6	5.3	5.6	5.4	5.3	7.3	7.5	7.5
S5	9.4	10.0	9.6	5.1	5.6	4.8	5.3	5.2	5.1	7.3	7.6	7.6
Mean	9.2	9.8	9.7	5.1	5.5	5.1	5.4	5.3	5.3	7.3	7.5	7.5
	M	S	M at S	M	S	M at S	M	S	M at S	M	S	M at S
SEd	0.01	0.01	0.02	0.01	0.01	0.03	0.02	0.03	0.05	0.41	0.54	0.93
CD (P=0.05)	0.02	0.03	0.05	0.04	0.03	0.06	0.05	0.06	0.10	NS	1.11	2.05

N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (meq/100g)	Mg (meq/100g)

Treatment details	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3
S_1	205.3	216.2	201.5	7.5	8.9	7.8	187.2	194.3	186.4	40.7	42.4	45.2	15.6	17.9	20.9
S_2	245.0	224.0	223.9	8.9	11.2	9.0	192.5	194.9	196.5	43.8	45.8	47.5	18.9	20.7	22.6
S_3	299.5	229.9	256.2	8.8	13.9	9.4	195.0	209.1	199.1	51.9	45.9	53.8	24.2	23.1	23.8
S_4	332.2	245.6	289.6	9.4	15.7	14.9	206.8	210.0	208.7	62.3	54.6	60.2	28.7	26.7	27.6
S_1	356.1	267.1	305.1	10.1	16.8	15.8	208.9	213.7	213.2	65.0	65.3	64.4	32.3	34.6	30.6
Mean	287.6	236.6	255.3	8.9	13.3	11.4	198.1	204.4	200.8	52.7	50.8	54.2	23.9	24.6	25.1
	M	S	M at S	M	S	M at S	M	S	M at S	M	S	M at S	M	S	M at S
Sed	0.63	0.63	1.17	0.55	0.72	1.25	0.07	0.13	0.22	0.04	0.13	0.21	0.01	0.08	0.12
CD (P=0.05)	1.75	1.32	2.66	1.50	1.49	2.75	0.21	0.28	0.48	0.11	0.27	0.44	0.03	0.17	0.26

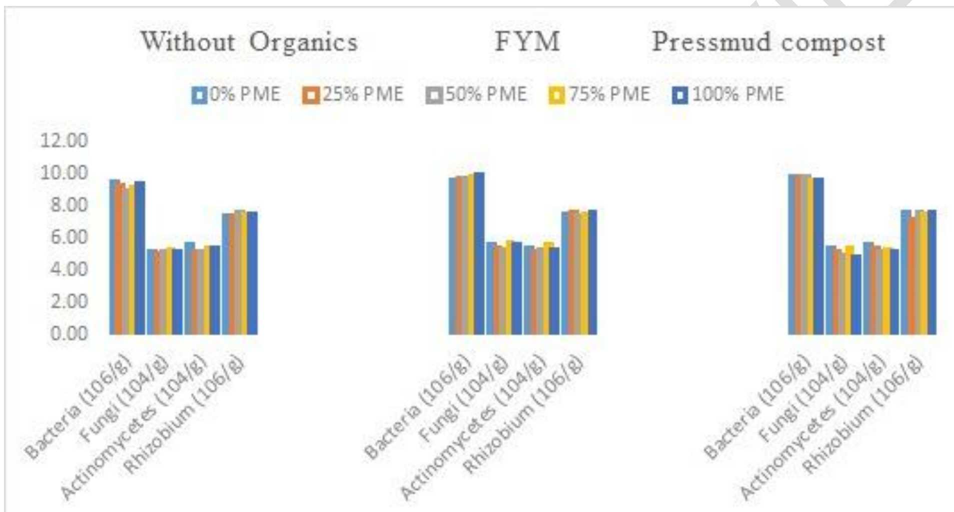
Table 5. Effect of paper mill effluent irrigation with or without compost application on soil macro nutrient status

Table 6. Effect of paper mill effluent irrigation with or without compost application on soil micronutrient status

	S (mg/kg)			Zn (mg/kg)			Fe (mg/kg)		
Treatment details	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3
S_1	7.1	9.9	12.2	0.2	0.2	0.3	8.4	8.4	8.4
S_2	16.4	14.5	15.7	0.2	0.3	0.4	8.4	9.6	9.6
S_3	33.5	19.7	18.7	0.4	0.5	0.5	8.4	9.9	9.7
S_4	39.9	26.4	27.5	0.7	0.7	0.8	8.4	12.1	12.1
S_1	41.3	39.8	35.4	0.7	0.8	0.9	8.4	12.9	12.8
Mean	27.6	22.1	21.9	0.4	0.5	0.6	8.4	10.6	10.5
	M	S	M at S	M	S	M at S	M	S	M at S
Sed	0.08	0.17	0.28	0.01	0.10	0.15	0.03	0.06	0.09
CD (P=0.05)	0.22	0.35	0.59	0.04	0.20	NS	0.08	0.11	0.19

0 % PME 25 % PME 50 % PME 75 % PME 100 % PME

a). Effect of paper mill effluent and press mud application on root and nodulations in groundnut



b). Effect of paper mill effluent and compost application on *Rhizobium* and microbes in soil

Fig 2. Effect of paper mill effluent irrigation with or without compost application on root growth (a) and microbial properties (b) in groundnut

4. CONCLUSION

It was concluded from the study that the application of effluent from paper mill industry with compost was found to be a promising source for soil fertility, root growth and a substantial yield of groundnut. From the study, it was observed that treated paper mill effluents combined with composts were effective in increasing seedling growth, root growth and nodulation and could be used as an alternative water resource in groundnut. The results also indicated that, when combined with the application of the treated wastewater, with press mud compostsignificantly improved the microbial properties and soil macro and micronutrient content. In conclusion, this study showed that treated paper mill effluents could be used as a potential source of nutrients and water for groundnut. However, continuous monitoring of the wastewater used for agricultural purposes is essential in order to ensure that the water is of a suitable quality before it is readily used as an irrigation resource.

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