Phytotoxic Effect of Paperboard Effluent on Seed Germination and Seedling Growth of Gingelly Crop (*Sesamum indicum* L.Var. VRI 4)

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ABSTRACT

The present study has been conducted to assess the impact of treated paperboard effluent on the seed germination and seedling growth of the gingelly (*Sesamum indicum* L.var. VRI 4). A experiment was conducted with the different concentrations*viz.,* 25%, 50%, 75%, and 100% along with a control. The treated paperboard effluent was analyzed for characteristics such ascolor, pH,electrical conductivity (EC), total solids (TS), total dissolved solids (TDS), total suspended solids(TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), dissolved oxygen (DO), calcium (Ca^{2+}), magnesium(Mg^{2+}), sodium(Na^{+}), potassium(K^{+}), chloride(Cl^{-}), sulphate(SO_4^{2-}), carbonate(CO_3^{2-}), bicarbonate(HCO_3^{-}) and micronutrients. The growth parameters such as germination percentage, seedling vigor, shoot length, root length, fresh and dry weight, tolerance index, and phytotoxicity were measured at 14th DAS (days after sowing). The results indicate that lower concentrations of treated paperboard effluent significantly increase the percentage of seed germination and other growth parameters, but increasing concentrations decrease the germination and other growth parameters.

Keywords: Treated paperboard effluent, Gingelly, Seed germination, Tolerance, Phytotoxicity

1. INTRODUCTION

The pulp and paperboard industry is a significant consumer of water, with each tonne of paper generating 72 to 225 cubic meters of wastewater, depending on the production method used [1]. The Indian paperboard industry ranks third in freshwater usage and has been identified by the Central Pollution Control Board (CPCB, 2000) as one of the 60 most polluting sectors. 75 to 95% of the freshwater used in pulp and paper boards is discharged into the environment as wastewater.This large amount of wastewater must be treated to meet environmental quality standards before reusing it. In the last ten years, many regions in India have experienced repeated droughts. Consequently, the shortage of irrigation water has prompted the search for alternative irrigation methods to sustain crop production [2]. To address this problem, treated wastewater was utilized as a substitute irrigation supply, hence lowering the amount of freshwater usage in agriculture. Using this wastewater for irrigation is advantageous since it offers more nutrients and organic matter in addition to a water supply [3]. The paperboard effluent is typically brown in color or strong black-brown color or light brown color or black color as reported by [4 – 8]. Paperboard effluent has high BOD, COD, TS, and OC [4, 8, 9, 10]. Effluents discharged from pulp and paperboard production are rich in organic and inorganic compounds, TSS, TDS, TS, BOD, COD, and heavy metals, which can accumulate in plants and soil. This accumulation leads to harm to plants and disrupts biological systems [11 – 13] and even to groundwater quality and soil [14 – 16]. Several researchers have investigated the toxic effects of paperboard effluent on the seed germination of various crops, including mustard, pea, and rice [17], mustard and pea [18], black gram [19], Vigna radiata L. [20, 21], wheat, cabbage, greengram, and groundnut [22], fenugreek [23], and gingelly [24, 25].The present study deals with the characterization of treated paperboard effluent and examines its effects on the seed germination and seedling growth of gingelly crops at various concentrations.

2. MATERIAL AND METHODS

2.1 Study area

The laboratory experiment was conducted using paper cups in the AICRB laboratory of the Department of Soil Science and Agricultural Chemistry, ADAC&RI, Tiruchirappalli.

2.2 Sample collection

The sample was collected from Tamil Nadu Newsprint and Paper Limited (TNPL) - Unit II, located in Mondipatti Village, Manapparai Taluk, Tiruchirappalli district, Tamil Nadu. The factory is situated at around 10º 41' N latitude and 78º 26' E longitude Fig. 1,It has a production capacity of about 200,000 tons per year and discharges approximately 5,000 cubic meters of wastewater daily. This wastewater is treated thoroughly in an advanced Effluent Treatment Plant (ETP) and used for irrigation.The treated paperboard effluent samples were collected from the TNPL Unit II factory site. The samples were collected in clean plastic canes and were preserved in a refrigerator for further analysis

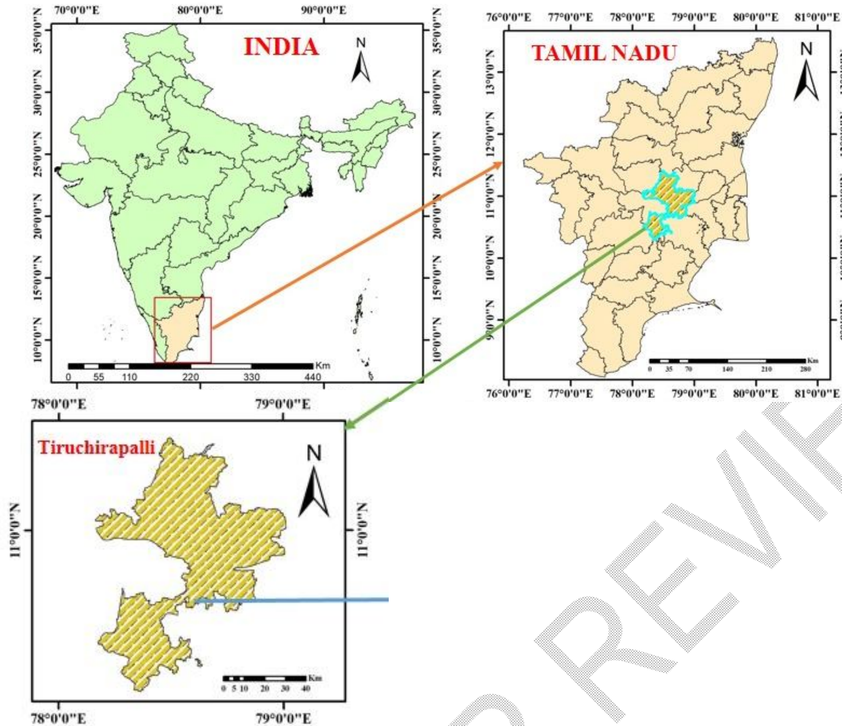


Figure 1: Location of the study area

2.2 Phytotoxicity test

In this study,the impact of treated paperboard effluent was assessed using disposable paper cups filled with air-dried sandy clay loam soil. The experiment followed the methodology described by [27], where healthy and uniform size seeds were selected and surface sterilizedwith the test seeds of 0.1% mercuric chloride ($HgCl_2$) for 5 minutes to prevent fungal growth, followed by 4-5 washes with distilled water to remove traces of $HgCl_2$. Twenty seeds were sown in each cupwith various concentrations of treated paperboard effluent*viz.,*25%, 50%, 75%, and 100%along with a control. The initial parameters were recorded on the 14th day. The initial growth parameters such as germination percentage, seedling vigor, plant length, radicle length, fresh and dry weight [26].

2.3 Germination percentage

Germination percentage was calculated by using the following formula:

$$\text{Germination percentage} = \frac{\text{Total number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

2.4 Seedling vigor index

The Vigor index of the seedling was calculated by using the formula [27].

$$\text{Seedling vigor index} = \text{Germination percentage} \times \text{seedling length}$$

2.5 Tolerance index

The tolerance index of the seedlings was calculated by using the formula [28].

$$\text{Tolerance index} = \frac{\text{Mean length of longest root in treated plants}}{\text{Mean length of longest root in control plant}}$$

2.6 Phytotoxicity

The percentage of phytotoxicity of treated paperboard effluent was calculated by using the formula [29].

$$\text{Phytotoxicity (\%)} = \frac{\text{Radical length of control plant} - \text{Radicle length of treated plant}}{\text{Radicle length of control plant}} \times 100$$

2.7. Statistical analysis

The data obtained from the phytotoxicity test were analyzed statistically using one-way analysis of variance (ANOVA) in a completely randomized block design (CRD). The statistical analysis was conducted using computer-based AGRES 3.01 and AGDATA software.

3. RESULTS AND DISCUSSION

The results of the physicochemical analysis of the treated paperboard effluent are presented in Table 1. The treated paperboard effluent was colorless. The pH of the treated paperboard effluent was 7.21 (neutral condition) and the electrical conductivity of the treated paperboard effluent was 1.92 dS m^{-1}. The total suspended solids, total dissolved solids, and total solids were 86 mg L^{-1}, 950 mg L^{-1}, and 1036 mg L^{-1} respectively. The values of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Dissolved Oxygen (DO) were 40 mg L^{-1}, 145 mg L^{-1} and 23.6mg L^{-1}. The treated paperboard effluent contained 0.44% organic carbon. The levels of calcium present at 163.5 mg L^{-1}, magnesiumat 123.9 mg L^{-1}, sodiumat

331.7 mg L^{-1}, potassiumat 21.89 mg L^{-1}, chlorideat 191.4 mg L^{-1}, sulphate at 156 mg L^{-1},carbonate at (nil), and bicarbonate at292.8 mg L^{-1}, respectively. Among the micronutrients, zinc was present at 12.98 mg L^{-1}, while iron, manganese, and copper were below the detection limit (BDL). The heavy metals *viz.,* lead, nickel, chromium, and cadmium were also below the detection limit (BDL) in the treated effluent [4, 8-10].

Table 1. The physicochemical analysis of treated paperboard effluent (TPBE)

S.NO	Parameters	Units	Treated paperboard effluent
1.	Color	-	Colorless
2.	pH	-	7.21
3.	Electrical conductivity	dS m^{-1}	1.92
4.	Total suspended solids	mg L^{-1}	86
5.	Total dissolved solids	mg L^{-1}	950
6.	Total solids	mg L^{-1}	1036
7.	Dissolved oxygen	mg L^{-1}	23.6
8.	Biological oxygen demand	mg L^{-1}	40
9.	Chemical oxygen demand	mg L^{-1}	145
10.	Organic carbon	Per cent	0.44
11.	Calcium	mg L^{-1}	163.51
12.	Magnesium	mg L^{-1}	123.95
13.	Sodium	mg L^{-1}	331.74
14.	Potassium	mg L^{-1}	21.89
15.	Chloride	mg L^{-1}	191.43
16.	Sulphate	mg L^{-1}	156.09
17.	Carbonate	mg L^{-1}	0
18.	Bicarbonate	mg L^{-1}	292.88
19.	Iron	mg L^{-1}	BDL
20.	Zinc	mg L^{-1}	12.98
21.	Manganese	mg L^{-1}	BDL
22.	Copper	mg L^{-1}	BDL
23.	Lead	mg L^{-1}	BDL
24.	Nickel	mg L^{-1}	BDL
25.	Chromium	mg L^{-1}	BDL
26.	Cadmium	mg L^{-1}	BDL

The observations made on the effect of treated paperboard effluent on the growthparameters of gingelly (*Sesamum indicum* L. Var. VRI 4) are presented in Tables 2 and 3 (Fig 2).The highest germination percentage was observed at 50% effluent concentration, where as a lower germination percentage was observed at 100% effluent concentration (Fig 3). These findings align with the work of [26, 31]. From the concentration of 50% onwards, the germination percentage had a noticeable decline. ANOVA analysis revealed that increasing the effluent concentration significantly impacted germination CD (0.05) compared to the control. The maximum shoot and root length were recorded at 25% and 50% effluent concentrationsand it gradually decreased with increasing concentration of effluent (Fig 4, 5). The vigor index was highest at 25% and 50% effluent concentrations but gradually decreased with further increases in concentration. Seedling vigor was also significantly affected by the effluent concentration CD (0.05) compared to the control (Fig 6). The maximum value of fresh and der weight was recorded at 25% and 50% effluent concentrations (Fig 7, 8). The tolerance index value decreased as the effluent concentration increased, showing an inverse trend with the phytotoxicity percentage value (Fig 9, 10). These observations were aligned with the findingsof [32]. The inhibitory effect of paperboard effluent on the growth parameters of gingelly became more prominent with increasing effluent concentration compared to the control. This inhibitory effect may be attributed to the excess levels of total nitrogen, phosphate, potassium, sulfate, and chloride in the effluent, which can harm plant growth by reducing water absorption and disrupting other metabolic processes [26, 33, 34]. A progressive decrease in germination and seedling growth was recorded with increasing concentrations of paperboard effluent. Similar observations have been reported by other researchers [17, 18, 35, 36]. The growth parameters of the gingelly crop were graphically represented.

Figure 2. Gingelly (*Sesamum indicum*. L Var. VRI 4)

Table 2. Growth parameters of gingelly (Var. VRI 4) under different concentrations of treated paperboard effluent

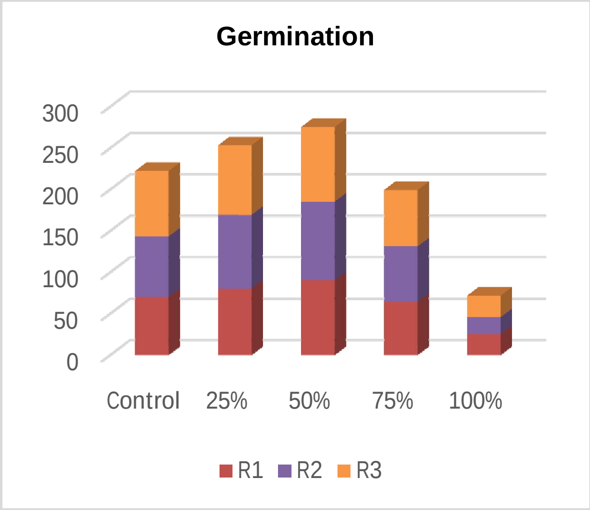
Treatment	Germination (%)	Root length (cm)	Shoot length (cm)	Vigor index	Fresh weight (gm)	Dry weight (gm)
Control	74±2.64^{c}	2.04±0.012^{c}	5.75±0.02^{b}	636.4±22.7^{c}	0.05±0.003^{c}	0.04±0.003^{b}
25 %	84.3±2.60^{b}	2.60±0.174^{b}	6.42±0.28^{ab}	737.07±22.7^{b}	0.07±0^{b}	0.04±0.003^{b}
50%	91.6±1.66^{a}	3.00±0.088^{a}	7.13±0.005^{a}	889.16±16.16^{a}	0.08±0.003^{a}	0.03±0.008^{a}
75%	66.3±1.20$^{d\,**}$	1.57±0.008$^{d\,**}$	5.13±164$^{ab\,**}$	446.42±8.08^{d**}	0.04±0.003$^{d\,**}$	0.01±0$^{c\,**}$
100%	23.8±1.72$^{e\,**}$	1.23±0.165$^{d\,**}$	3.74±0.310$^{c\,**}$	129.23±9.36^{e**}	0.02±0.003$^{e\,**}$	0.01±0$^{d\,**}$
SEd	2.89	0.16	0.55	24.0824	0.004	0.003
CD (.05)	6.45	0.36	1.24	53.6593	0.009	0.008

*=Significant at (.05), ** = significantly different to control, (n=3, Mean ± SE)*

Table 3. Effluent tolerance index and phytotoxicity (%) under different concentrations of treated paperboard effluent

Treatments	Tolerance index	Phytotoxicity (%)
Control	-	-
25%	0.68±0.01^{b}	13.3±4.81^{b}
50%	0.86±0.04^{a}	13.4±4.86^{b}
75%	0.50±0.01$^{c\,**}$	48.8±2.03$^{a\,**}$
100%	0.31±0.01^{d}**	58.5±6.51$^{a\,**}$
SEd	0.03	6.11
CD (.05)	0.08	13.6

*=Significant at (.05), ** = significantly different to control, (n=3, Mean ± SE)*



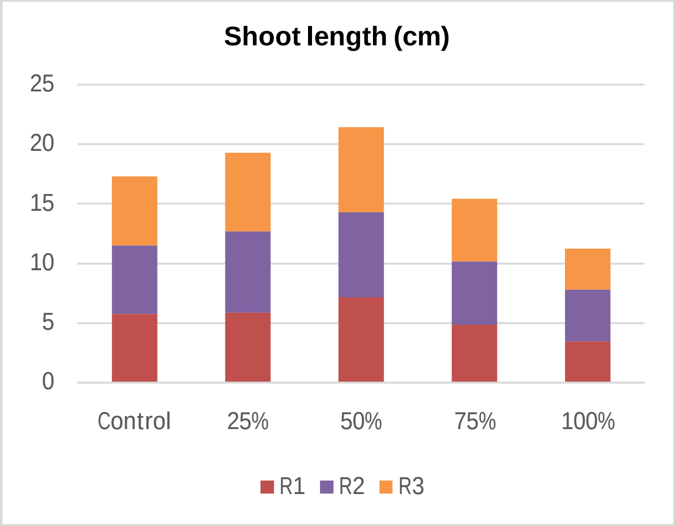
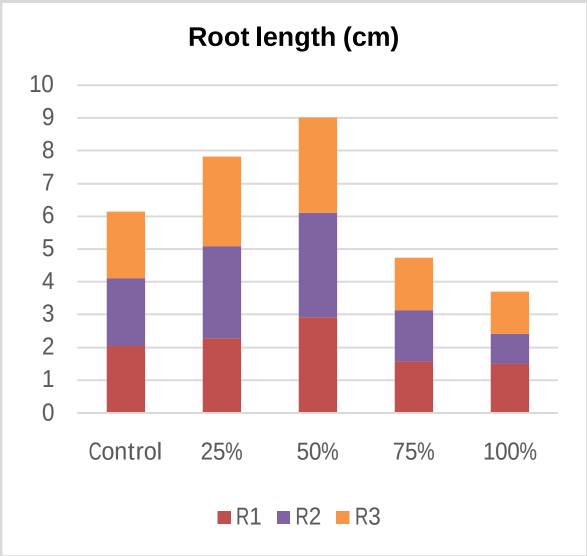


Figure 3 Germination percentage on different concentrations of treated paperboard effluent

Figure 4 Shoot length (cm) on different concentrations of treated paperboard effluent



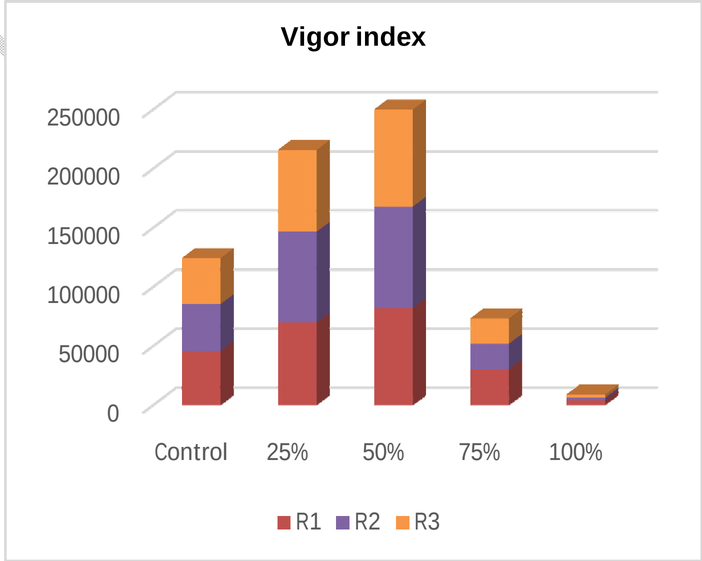


Figure 5Root length (cm) on different concentrations of treated paperboard effluent

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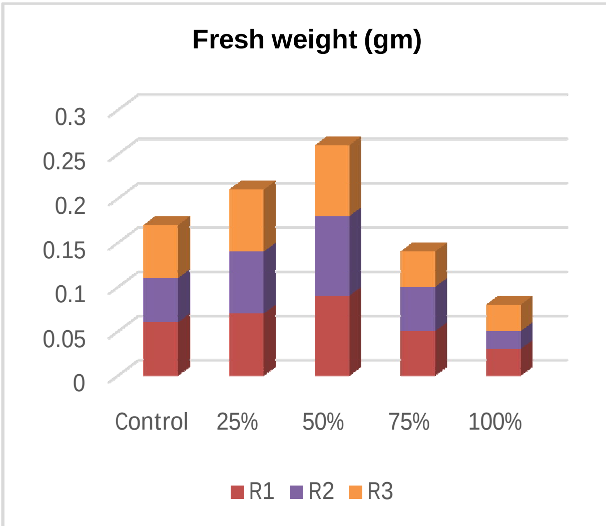


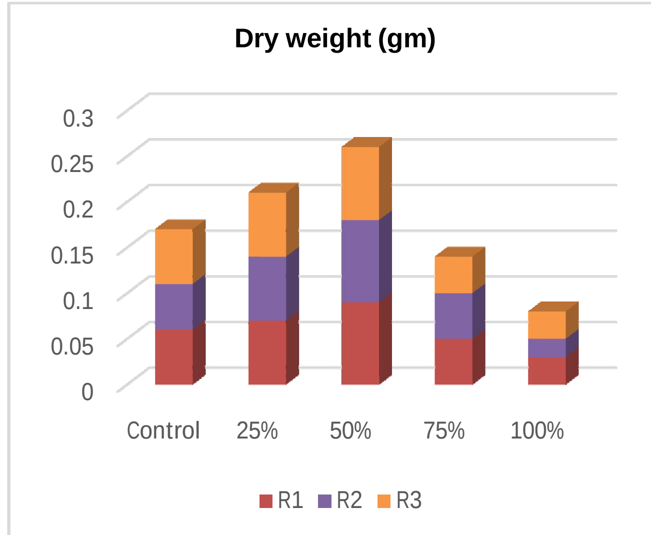
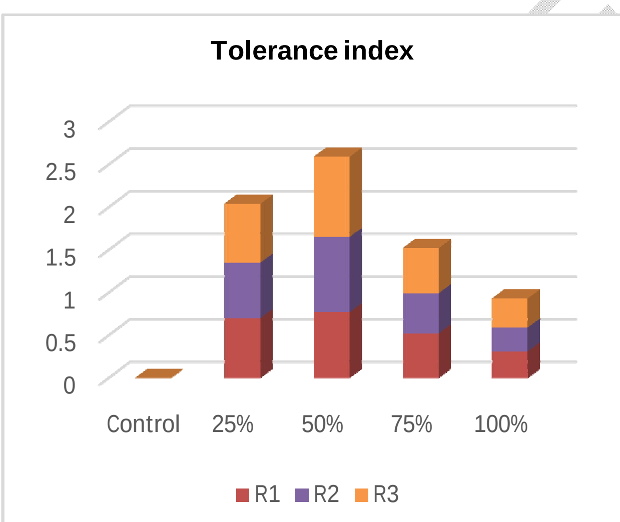


Figure 7 Fresh weight (gm) on different concentrations of treated paperboard effluent

Figure 8 Dry weight (gm) on different concentration of treated paperboard effluent



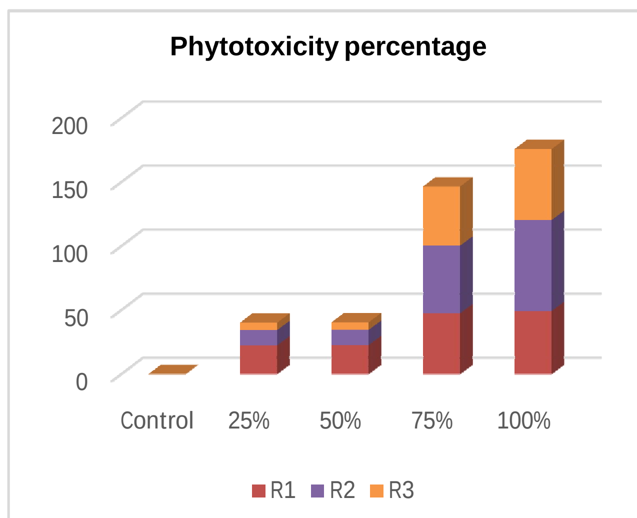


Figure 9 Tolerance index on different concentrations of treated paperboard effluent

Figure 10 Phytotoxicity percentage on different concentrations of treated paperboard effluent

4. CONCLUSION

The research concludes that lower concentrations of treated paperboard effluent are beneficial for the initial growth of gingelly crops, while higher concentrations have a negative impact on growth parameters. To fully comprehend its effects, long-term research work should be conducted to explore the effect of paperboard effluent before recommending the use of paperboard effluent for irrigation purposes.

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