Impact of Sewage on Seed Germination and Early Growth of Amaranthus: A Phytotoxicity Study

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ABSTRACT

Aims: To investigate the phytotoxic effects of sewage on the germination of red amaranthus as a preliminary step before field trials.
Study design: Completely Randomized Design (CRD) with four replications.
Place and Duration of Study: Department of soils and environment, Agricultural college and research institute, Madurai. During April – June, 2024.
Methodology: The experiment utilized seven treatment levels - control, 20%, 40%, 60%, 80%, and 100% raw sewage - employing a Completely Randomized Design (CRD) with four replications. The experimental data were collected and analyzed.
Results: The results showed that the physico-chemical parameters such as electrical conductivity (EC) and total dissolved solids (TDS) were relatively high in the sewage, causing toxic to the plant, severely affected seed germination and early seedling growth. The maximum toxicity (85-100%) was recorded at 100% sewage concentration, while the minimum relative toxicity percentage (1.5-3.1%) was observed at a 20% sewage. The highest phytotoxicity (100%) occurred at 7 days after sowing (DAS) in the 100% effluent.
Conclusion: The dilution with lower EC and TDS had the less adverse effect on the growth of roots and shoots as compared with the higher concentrations. This study indicates that raw sewage wastewater could be harmful, but diluting it may allow it to be safely used for irrigating forage crops.

Keywords: Sewage irrigation, phytotoxicity, germination test, Amaranthus, Sewage dilution

1. Introduction

Sewage wastewater, while rich in nutrients essential for plant growth, also contains heavy metals, pathogens, and pollutants. Freshwater accounts for only 2.5 to 3% of Earth's total water, with nearly 70% allocated to agriculture. Given this scarcity, sustainable development increasingly relies on sewage irrigation as an alternative resource (Hassanli, 2013). In urban areas, a significant portion of water used for irrigation is dedicated to maintaining vegetation, aesthetic quality, and municipal amenities (Nouri et al., 2012). Some countries are planning to expand the use of treated wastewater for irrigation, with targets such as Saudi Arabia's goal to increase wastewater use to 65% by 2016 (EPA, 2012). Recycling wastewater for agricultural irrigation offers benefits by adding essential plant nutrients and organic compounds to the soil, while also providing a means of waste disposal (Horswell et al., 2003). Studies have shown that wastewater is enriched with valuable resources, including macronutrients, micronutrients, and organic matter, which are crucial for soil productivity and fertility (Kiziloglu et al., 2008). However, despite these agricultural benefits, wastewater and sewage runoff can contain heavy metals and other substances that pose health risks to humans (Ali and Shakrani, 2011). According to Samarrai (2018), the concentration of heavy metals, bacteria, fungi, and salts in sewage wastewater can vary depending on its treatment and source. Metals such as Cu, Fe, Zn, and Mn in sewage effluents can be phytotoxic, and their accumulation in crops can lead to health hazards (Waheedet al., 2019).

Radosevich et al. (1997) emphasized that seed germination is a critical process for plant reproduction and population control, and it plays a significant role in determining crop yield. Seed germination and early plant development bioassays are commonly used to assess phytotoxicity (Rahman et al., 2018). Research in this area has been conducted sporadically across various countries. Dayama (1987) found that even highly diluted industrial effluent (5%) could significantly reduce seed germination in *Cicer arietinum*, causing phytotoxicity due to the accumulation of toxic substances from the growth medium (Chang et al., 1992). The impact of effluents on plants varies depending on the species, as well as the type and concentration of toxic materials in the effluent (Hassan et al., 2019).

This underscores the need for thorough scientific studies before any specific waste can be used for irrigation on particular crops and under specific environmental conditions. Despite the recognized importance of seed germination in the context of sewage treatment, the mechanisms underlying phytotoxicity or beneficial effects in seeds remain poorly understood. This research aims to investigate the phytotoxic effects of sewage on the germination of *Amaranthus* as a preliminary step before field trials and to recommend that relevant government agencies effectively monitor farmers' activities and discourage the use of sewage for irrigation without proper treatment.

2. Experimental methods

2.1 Sewage wastewater

Effluent samples were collected in 2 L plastic containers from a sewage dumping site at the Agricultural College and Research Institute in Madurai in May 2021. After collection, the samples were promptly transported to the laboratory for physio-chemical analysis. Parameters such as pH, electrical conductivity, biological oxygen demand (BOD), chemical oxygen demand (COD), carbonate, and bicarbonate were analysed according to standard methods (APHA, 2012). To determine metal concentrations, a 100 mL portion of the effluent sample was digested with Aqua regia. The digest was then filtered using Whatman no. 42 filter paper, and the filtrate was diluted to 100 mL with distilled water before being analysed using Microwave Plasma-Atomic Emission Spectroscopy (MP-AES) (Vigneshwar et al., 2023).

2.2 Seed germination assay

The germination experiment was conducted with Amaranthus (*Amaranthus* sp. L.) CO 2 as test crop. Sterilized petri dishes, lined with a double layer of filter paper, were used for the experiment. These petri dishes were incubated at a controlled temperature of 26±2°C to facilitate germination.

2.3 Germination Experiment

Uniformly sized Amaranthus seeds were selected and sterilized with 0.1% $HgCl_2$ before being thoroughly washed with distilled water to prevent surface contamination. Twenty sterilized seeds were placed in each petri dish. The experiment utilized seven treatment levels - control, 20%, 40%, 60%, 80%, and 100% raw sewage - employing a Completely Randomized Design (CRD) with four replications. The treatments were as follows: Control: 100 mL distilled water (DW); 20% sewage: 20 mL raw sewage + 80 mL DW; 40% sewage: 40 mL raw sewage + 60 mL DW; 60% sewage: 60 mL raw sewage + 40 mL DW; 80% sewage: 80 mL raw sewage + 20 mL DW; 100% sewage: 100 mL raw sewage. Four replicates were maintained for each treatment, including the control. Germination percentages were recorded after 3 and 7 days. Growth parameters, such as shoot and root lengths, were measured after 7 days. Following this period, seedlings were harvested, and fresh weights were recorded. For dry weight determination, seedlings were incubated at 60°C for 24 hours.

2.3.1. Germination Percentage:

The germination percentage was determined using the formula described by Raun et al. (2002).

$$G = \frac{Sg}{ST} \times 100$$

where, G = gerimnaiton (%), Sg = number of seed germinated, and ST = total number of seed set for the test.

2.3.2. Germination energy

Germinated seed percentage at 3 DAS (Bam et al., 2006).

2.3.3. Germination capacity

Germinated seed percentage at 7 DAS (Bam et al., 2006).

2.3.4. Germination speed

Speed of germination was measured by using following formula (Krishnaswamy and Seshu, 1990).

$$G_s = \frac{Sg_{72}}{Sg_{168}} \times 100$$

where, G_s = speed of germination, S_{g72} = number of seed germinated at 72th h, and S_{g168} = number of seed germinated at 168th h.

2.3.5. Relative toxicity

Relative toxicity (% RT) of sewage on the seed germination of Amaranth over control was calculated by using the following formula of Chapagain (1991).

$$R_T = \frac{x-y}{x} \times 100$$

where, RT = relative toxicity (%), x = germination percentage in control at particular hour of incubation, and y = germination percentage in the presence of effluent at the same hour of incubation.

2.3.6. Phytotoxicity

The phytotoxicity was calculated using the formula of Chou and Lin (1976).

$$\text{Phytotoxicity (\%)} = \frac{Rc - Rt}{Rc} \times 100$$

Rc = radical length of control and Rt = radical length of test.

2.3.7. Vigour index

Vigour index of the seedlings was calculated using the formula proposed by Abdul-baki and Anderson (1973).

$$\text{Vigour index} = G \times L$$

where, G = germination (%) and L = seedling length.

2.3.8. Fresh weight

Ten seedlings from each treatment were collected, and their fresh weights were recorded. The weight per plant was subsequently calculated based on these measurements.

2.3.9. Dry weight

The same seedlings used for fresh weight measurement were placed in a hot air oven at 60°C for 24 hours. After drying, the seedlings were removed from the oven and allowed to cool in desiccators. Their dry weights were then recorded.

2.4 Statistical analyses

The physico-chemical analysis of elements present in the sewage was conducted three times, and the data collected from each repetition were compiled for statistical analysis. The data from the seed germination assay were also analyzed to assess the significance of variance ($P<0.05$). To compare treatment means, standard errors were calculated using SPSS and Microsoft Excel.

3.0 Result and discussion

3.1 Physico-chemical properties of Sewage

The physico-chemical characteristics of the sewage are presented in Table 1. The collected sewage appeared yellowish-brown in color. The pH of the sewage was 8.1, indicating a basic nature, which falls within the permissible pH range (5.5-9.0) for irrigation water (CPCB, 2019). This increase in pH is likely due to the presence of various soluble salts in the sewage water. Despite a 3.94% rise, the pH of the sewage remained within the acceptable limits for use on agricultural land (Rana, 2009). The electrical conductivity (E.C.) of the sewage water was 1.7 dS/m. The total dissolved solids (TDS) were found to be 2503 mg/l, exceeding the CPCB standard limit of 2100 mg/l for public sewers. The FAO standard range for TDS in irrigation water is 450 to 2000 mg/L (Ayers and Westcot, 1985). The levels of calcium (51.31 mg/L) and magnesium (39.68 mg/L) were also noted. Among the metals, the iron content in the sewage was 23.5 mg/L, which is higher than the permissible limit set by the CPCB. Chitdeshwari et al. (2003) reported an iron concentration of 36.75 mg/L in the sewage at Madurai, Tamil Nadu. The concentrations of copper and lead were above the permissible limits, with copper exceeding the 0.055 mg/L (Singh and Agrawal 2010). The lead concentration was 2.3 mg/L, which is below the maximum limit of 5 mg/L (Sharma et al., 2016). However, the concentrations of copper, lead, and iron did not exceed the prescribed limits.

Table 1. Physico-chemical properties of sewage

Parameters	unit	Sewage
Turbidity	NFU	45
pH		8.1
EC	ds/m	1.7
Total Dissolved Solids	mg/l	2503
Total suspended solids	mg/l	415
Carbonate	meq/l	2
Bicarbonate	meq/l	12.2
Calcium	mg/l	51.31
Magnesium	mg/l	39.68
Chloride	mg/l	187
Biological oxygen demand	mg/l	580
Chemical oxygen demand	mg/l	1060
Copper	mg/l	3.4
Chromium	mg/l	1.9
Nickel	mg/l	2.5
Lead	mg/l	2.3
Zinc	mg/l	1.04
Iron	mg/l	23.5

3.2 Seed germination Assay

3.2.1 Germination Energy

Seed germination and early seedling growth are crucial stages in the life cycle of plants and are highly susceptible to environmental stress. As germination is the initial physiological process, several growth parameters, including germination rates, as well as the subsequent growth and yield of crops, are used to evaluate the level of pollution (Mishra and Pandey, 2002). In the case of red amaranth, the highest seed germination percentage at 3 days after sowing (DAS) was observed in the control group. But with sewage maximum germination energy (91.5%) was found with 20% sewage (Fig. 1a). At the same time, the minimum germination was recorded in 100% concentration of the sewage. Germination energy increased up to 60% effluent concentration and then slowly decreased to 62.3% at 100% sewage concentration. In stress conditions, the energy forming molecules may be disturbed and subsequently carbohydrates and protein metabolites of the membrane are altered (Kannan and Upreti, 2008), which might lead to reduction in absorption of water by the seeds/seedlings. Suppression of germination at higher concentrations of effluent might be due to high levels of total dissolved solids which enhanced the salinity and conductivity of the solute absorbed by the seeds before germination. The promotion of seedling growth by lower concentration of sewage might be due to the presence of plant nutrient in the sewage.

3.2.2 Germination capacity

The germination capacity of red amaranth was significantly affected by increasing levels of effluent concentration. As shown in Figure 1b, the highest seed germination rate of 98.25% at 7 days after sowing (DAS) was observed in the control group and at 20% sewage concentration. In contrast, a complete inhibition of germination (0%) was recorded at 100% sewage concentration. Within the sewage treatments, the maximum germination occurred at 20% and 40% concentrations, but it progressively declined as the effluent concentration increased. Across all dilutions, the germination capacity decreased with higher sewage concentrations. Some researchers attribute this delayed germination to the presence of elevated salt or metal concentrations (Baruah and Das, 1997), while others link it to reduced auxin production, also a consequence of higher metal ion concentrations.

The increased germination rates at lower sewage concentrations (20% and 40%) compared to higher concentrations (over 40%) suggest that sewage treatment stimulated the germination of previously inactive seeds, Vinod (2014). This effect may be due to the creation of favourable environmental conditions by lower sewage concentrations, which supported seed germination and allowed the seeds to utilize the nutrients present in the sewage (Kannan and Oblisamy, 1992). Additionally, the diluted sewage may have promoted plant growth at these lower concentrations (Augusthy and Mani, 2001). However, higher sewage concentrations inhibited red amaranth germination, likely due to the negative impact of increased total solids and heavy metal stress on the germination process. The salt content in the surrounding environment can limit water absorption by osmosis, further inhibiting seed germination (Malla and Mohanty, 2005).

3.2.3 Germination speed

The speed of germination varied across different sewage concentrations, as shown in Table 2. The highest germination speed (100%) was observed in the control group, while the lowest was recorded at 100% sewage concentration. Exposure to different sewage water solutions reduced germination speed by 5.1% to 100% compared to the control. Raw sewage significantly inhibited the growth of red amaranth, with root length in raw sewage being slightly shorter than in the control, which in turn affected germination speed. Germination speed increased up to 60% sewage concentration but decreased as the concentration increased beyond this level. Rashid et al. (2010a,b) also reported that seeds of *Bidens pilosa* and *Lolium perenne* exhibited slower germination speeds when exposed to toxic plant extracts.

Table 2. Effect of different concentration of sewage on Seedling parameters of amaranthus

Treatment	Germination speed (%)	Root length (cm)	Shoot length (cm)	Fresh weight (mg/seedling)	Dry weight (mg/seedling)
Control	100.0 ± 0.0	3.4 ± 1.2	4.5 ± 0.14	1.83 ± 0.23	0.26 ± 0.01
20% Sewage	91.5 ± 4.4	3.5 ±0.6	4.7 ± 0.06	1.85 ± 0.21	0.28 ± 0.02
40% sewage	89.2 ± 3.8	3.2 ±0.15	4.4 ± 0.21	1.80 ± 0.01	0.26 ± 0.00
60% sewage	90.6 ± 4.6	2.7 ±0.20	4.0 ± 0.15	1.75 ± 1.71	0.25 ± 0.02
80% sewage	90.4 ± 3.8	2.2 ±0.6	3.7 ± 0.15	1.69 ± 0.03	0.24 ± 0.02
100% sewage	62.2 ± 7.8	1.7 ±0.09	3.0 ± 0.24	1.56 ± 0.03	0.22 ± 0.01

3.2.4 Root and shoot lengths

The effect of sewage application on plant rooting and shooting varied depending on the concentration used in the experiment. Higher sewage concentrations significantly reduced the fresh and dry weight of seedlings. Growth parameters such as root and shoot length, measured at 7 days after sowing (DAS) (Table 2), decreased as sewage concentration increased. The maximum root length (3.5 cm) and shoot length (4.7 cm) were observed at 20% sewage concentration at 7 DAS. Conversely, the minimum root and shoot lengths were recorded at 100% sewage concentration. No radicle formation occurred at 80% and 100% sewage concentrations, and at 100% concentration, no shoot growth was observed. Similar inhibitory and stimulatory effects of various effluents on the germination of several plant species have been reported by other researchers (Yousaf et al., 2010).

The lack of oxygen for the germinated seeds restricted their energy supply through aerobic respiration, which is crucial for the growth and development of young seedlings. This led to limited growth of both the radicle and plumule, as noted by Hadas (1976). Singh et al. (2006) investigated the effects of fertilizer factory wastewater on seed germination, seedling growth, and the shoot and root lengths of gram (*Cicer arietinum*), they found that a 25% concentration of effluent promoted growth, particularly in root and shoot length, at 21 days. The lower effluent concentrations likely provided essential nutrients like nitrogen and phosphorus, which may have enhanced plant growth, Augusthy and Mani (2001).

Higher concentrations of heavy metals interfered with root and shoot length, likely due to their impact on physiological processes within the plant. This interference may include the inhibition of enzyme activities, disruption of nutrient absorption, water imbalance, and changes in hormonal balance, resulting in altered membrane permeability (Sharma and Dubey, 2005). Similarly, Vaithiyanathan and Sundaramoorthy (2017) observed that African marigold seedlings exhibited the greatest shoot length (29.10 cm) and root length (6.80 cm) at a 10% concentration of sugar mill effluent, whereas the lowest shoot length (9.43 cm) and root length (1.83 cm) were recorded at a 100% concentration of the effluent.

3.2.5 Fresh weight and dry weight

The fresh and dry weights of seedlings increased at lower sewage concentrations and decreased at higher concentrations, as shown in Table 2. The highest fresh weight (1.85 mg per seedling) and dry weight (0.28 mg per seedling) were recorded at 7 days after sowing (DAS) in the 20% sewage concentration. In contrast, the lowest fresh and dry weights were observed in 100% sewage concentration across all dilutions. In all cases, fresh weight consistently decreased as sewage concentration increased. These findings align with previous reports on the effects of various industrial effluent treatments on different crops (Sarathchandra et al., 2006).

The presence of optimal nutrient levels in the lower sewage concentrations likely contributed to the increased fresh and dry weights of seedlings, due to the presence of various chemicals in the sewage (Mishra, 1987). Conversely, higher sewage concentrations led to a decrease in seedling weight, possibly due to poor growth under effluent stress. According to Balashouri (1994) in *Vigna radiata*, *Cajanus cajan* , and *Sorghum bicolor* . The roots, which are in direct contact with the effluent, may be particularly affected by higher concentrations, potentially inhibiting cell multiplication and root growth (Kannan and Upreti, 2008). Vaithiyanathan and Sundaramoorthy (2017) also reported that African marigold exhibited the highest fresh weight (3.59 g per seedling) and dry weight (0.420 mg per seedling) at a lower concentration (10%) of sugar mill effluent, while the lowest fresh weight (0.760 mg per seedling) and dry weight (0.074 mg per seedling) were observed at the highest concentration (100%) of the effluent.

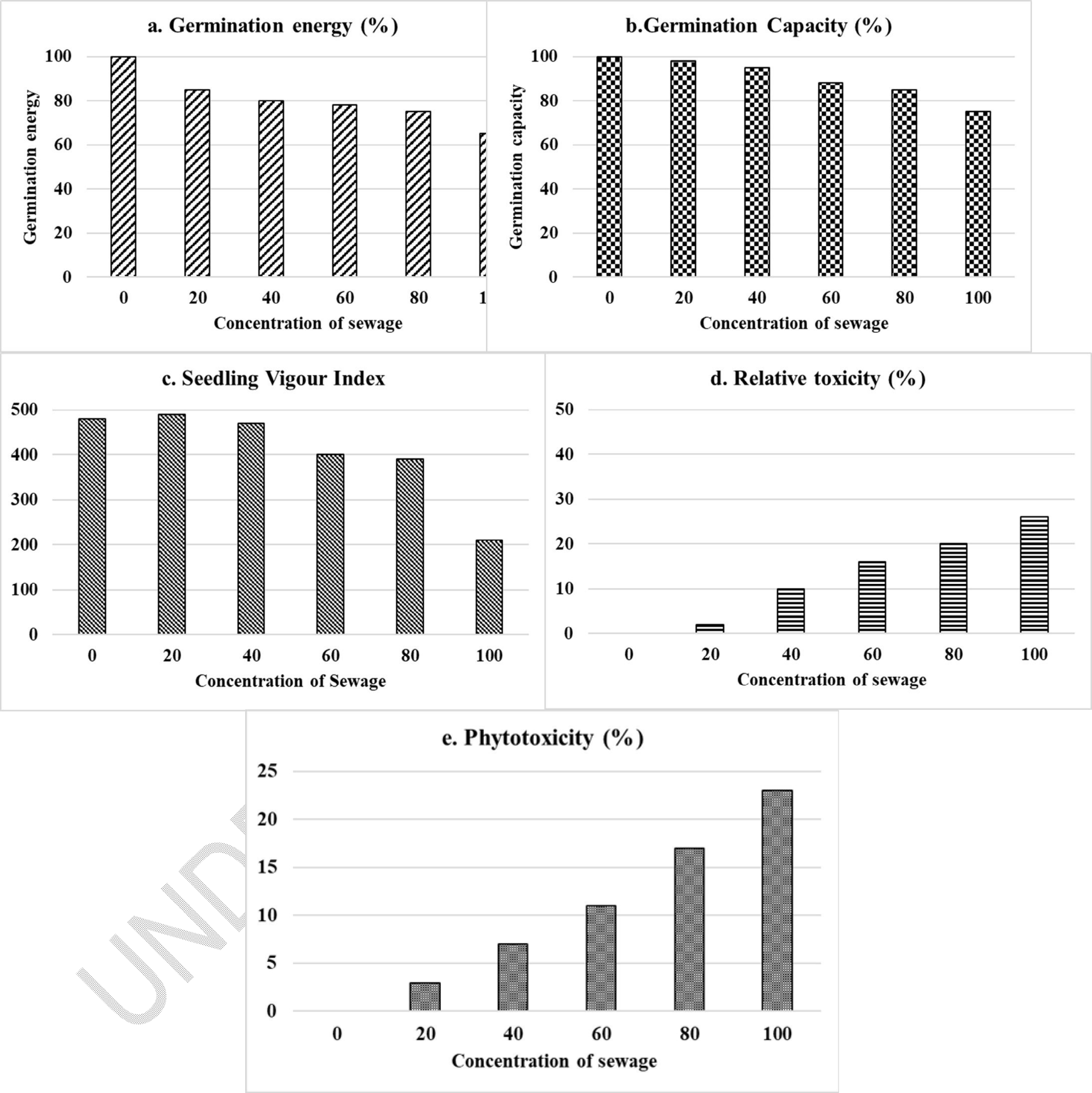

Figure 1. Effect of sewage on a. Germination energy, b. Germination capacity, c. seedling vigour, d. relative toxicity, e. phytotoxity of Amaranthus

3.2.6 Seedling vigour index

A decrease in the seedling vigor index of amaranth was observed across all tested effluent solutions as their concentrations increased (Fig. 1c). The highest vigor index (430%) was recorded at 7 days after sowing (DAS) in the 20% sewage concentration, while the lowest was observed at 100% concentration at the same time point. The variation in seedling vigor may be attributed to genotypic differences and the varying levels of effluent stress across different concentrations. The seedling vigor index was more significantly affected by the black and violet effluents compared to the pink effluent.

3.2.7 Relative toxicity of seed germination

The minimum relative toxicity percentage of red amaranth seed germination (1.5–3.1%) was observed at a 20% sewage concentration, while the maximum toxicity (85–100%) was recorded at 100% concentration (Fig. 1d). Toxic effects became evident at higher sewage concentrations. Regarding the relative toxicity percentage in red amaranth treated with sewage, the lowest toxicity was observed at 20% concentration, and the highest at 100%. Notably, relative toxicity significantly increased above 40% effluent concentration, reaching its peak at 100%. David and Rajan (2015) similarly found that the minimum relative toxicity percentage occurred at 60% effluent concentration, with a gradual increase as the concentration rose further.

3.2.8 Phytotoxicity

Phytotoxicity significantly increased with rising effluent concentrations. The highest phytotoxicity (100%) was recorded at 7 days after sowing (DAS) in the 100% sewage concentration, while the lowest was observed in the control group (Fig. 1e). The high level of phytotoxicity in amaranth exposed to sewage could be attributed to the sewage's elevated pH, electrical conductivity (EC), total dissolved solids (TDS), and metallic content. The lowest phytotoxicity was observed at a 20% sewage concentration, which was comparable to the phytotoxicity at 40% concentration. The highest phytotoxicity was recorded in the raw sewage. Similar toxic effects of dyeing industry effluent were reported by David and Rajan (2015) in lady's finger.

4 Conclusion

Germination and early seedling growth of amaranthus were significantly affected by the different concentrations of sewage. Based on the experimental observations, it is concluded that the physico-chemical parameters such as electrical conductivity, total dissolved solids were relatively high in the sewage causing toxic to the plant, severely affected seed germination and early seedling growth. Germination energy, germination capacity, germination speed, root length, shoot length and seedling vigour index were declined gradually with increasing effluent concentrations. Sewage dilution with lower EC and TDS had the less adverse effect on the germination and early growth of roots and shoots. But the dilution with high EC and TDS affected the germination and growth drastically. The exposure of seeds to the low concentration of sewage during germination gave no or lower phytotoxicity to early seedling growth of amaranth as compared with the higher concentrations. As a result, the raw sewage effluent could possibly lead to soil deterioration and low productivity. The results of this study suggest that the physico-chemical properties of the sewage wastewater might be harmful for crops and human being with food chain contamination. So, the use of sewage should be restricted in crop fields without proper treatment.

Reference:

1. Hassanli A. Recycled wastewater for parkland plant irrigation and sustainability measures. In14 th National Street Tree Symposium 2013;34.
2. Nouri, H., Beecham, S. Kazemi, F. and Hassanli, A. A Review of ET Measurement Techniques for Estimating the Water Requirements of Urban Landscape Vegetation, Urban Water, Taylor and Francis, 2012; pp1-13.

3. Balashouri DP. 1994. Effect of tannery effluent on germination and growth of selected pulse and cereal crop plants. J Ecotoxicol Environ Monit 4:115–120.
4. EPA. (2012) Guidelines for Water Reuse. http://www.waterreuseguidelines.org/
5. Horswell, J., Speir, T. W., and van Schaik, A. P. Bio-indicators to assess impacts of heavy metals in land-applied sewage sludge. Soil Biology and Biochemistry,2003; (35):1501-1505.
6. Kiziloglu, F. M., Turan, M., Sahin, U., Kuslu, Y., and Dursun, A. Effects of untreated and treated wastewater irrigation on some chemical properties of cauliflower (Brassica olerecea L. var. botrytis) and red cabbage (Brassica olerecea L. var. rubra) grown on calcareous soil in Turkey. Agricultural Water Management 2008; (95):716-724.
7. Ali M F., and Shakrani S A. (2011). Soil and soilless cultivation influence on nutrients and heavy metals availability in soil and plant uptake. International Journal of Applied Science and Technology, 1.(5):54-160
8. Al-Samarrai GF. Utilization of treated municipal sewage wastewater for agricultural irrigation purpose. Journal Tikrit Univ. For Agri. Sci. Vol. 2018;18(3).
9. Waheed H, Ilyas N, Iqbal Raja N, Mahmood T, Ali Z. Heavy metal phyto-accumulation in leafy vegetables irrigated with municipal wastewater and human health risk repercussions. International journal of phytoremediation. 2019 Jan 28;21(2):170-9.
10. Radosevich SR, Holt JS, Ghersa C. Weed ecology: implications for management. John Wiley & Sons; 1997 Feb 5.
11. Rahman MA, Rayhan MY, Chowdhury MA, Mohiuddin KM, Chowdhury MA. Phytotoxic effect of synthetic dye effluents on seed germination and early growth of red amaranth. Fundamental and Applied Agriculture. 2018 May 24;3(2):480-90.
12. Dayama O.P., (1987). Changes inyield of chickpea biocomponents of chickpea (CicerarietinumL.)sprayed with potassium napthenate and napthenicacetic acid. Bangladesh J. Bot., 35(1): 39-43.
13. Yousaf I, Ali SM, Yasmin A. 2010. Germination and early growth response of Glycine max varieties in textile and paper industry effluents. Pak J Bot 42:3857–3863
14. Chang AC, Granato TC, Page AL. A methodology for establishing phytotoxicity criteria for chromium, copper, nickel, and zinc in agricultural land application of municipal sewage sludges. Journal of environmental quality. 1992 Oct;21(4):521-36.
15. Hadas A. 1976. Water uptake and germination of leguniinous seeds under changing external water potential in osmotic solutions. J Exp Bot 27:480– 489.
16. Hassan MU, Chattha MU, Khan I, Chattha MB, Aamer M, Nawaz M, Ali A, Khan MA, Khan TA. Nickel toxicity in plants: reasons, toxic effects, tolerance mechanisms, and remediation possibilities—a review. Environmental Science and Pollution Research. 2019 May 1;26:12673-88.
17. APHA. 2012. Standard Methods for the Examination of Water and Wastewater, 22nd edition. American Public Health Association, Washington, DC, USA.
18. Vigneshwar PS, Bharani A, Prasanthrajan M, Raviumar V, Vijayalakshmi D. Assessment of Biodrainage Potential of Existing Plant Species Along the Sewage Drains of Vedapatti Drainage Stretch, Coimbatore, Tamil Nadu, India. International Journal of Environment and Climate Change. 2023 Sep 30;13(10):4406-13.
19. Bam R, Kumaga F, Ofori K, Asiedu EA. Germination, vigour and dehydrogenase activity of naturally aged rice (Oryza sativa L.) seeds soaked in potassium and phosphorus salts. Asian J Plant Sci 2006; 5:948–955.

20. Krishnaswamy V, Seshu DV. Germination after accelerate aging associated characters in rice varieties. Seed Sci Tech 1990; 8:147–150
21. Chapagain N. 1991. Physiological impact of Dhobikhola (Kathmandu) water pollution of Persicariaperfoliata L. leaves and germination of some vegetable seeds. M.Sc. Thesis, Central Department of Botany, TribhuvanUniversity, Kathmandu. Nepal.
22. Chou CH, Lin HJ. 1976. Auto intoxication mechanism of Oryza sativa L. phytotoxic effects of decomposing rice residues in soil. J Chem Ecol 2:353–367.
23. Sarathchandra U, Ghani A, Waller J, Burch G, Sayer S, Waipara N, Dexter M. 2006. Impact of carbon-rich dairy factory effluent on growth of perennial ryegrass (Lolium perenne) and soil microorganisms. Euro J Soil Biol 42:13–22.
24. Sharma, A.; Katnoria, J.K.; Nagpal, A.K. Heavy metals in vegetables: Screening health risks involved in cultivation along wastewater drain and irrigating with wastewater. SpringerPlus 2016, 5, 488.
25. Abdul-baki AA, Anderson JO. 1973. Vigour determination in soybean application of dairy manure on germination and emergence of some selected crops. J Environ Qual 3:396–399.
26. Central Pollution Control Board, 2019.
27. Singh PP, Manish M, Singh J. 2006. Impact of fertilizer factory effluent on seed germination, seedling growth and chlorophyll content of gram (Cicer aeritinum). J Environ Biol 27:153–156
28. David NS, Rajan MR. 2015. Phytotoxic effect of dyeing industry effluent on seed germination and early growth of lady’s finger. J Pollut Eff Contr 2:10–4172.
29. Mishra LC. 1987. Effect of fertilizer factory effluent on growth and development of corn and rice seedlings. Proc 74th ind Sci Cong Part III, Abstract Book
30. Kannan A, Upreti RK. 2008. Influence of distillery effluent on germination and growth of mung bean (Vigna radiata) seeds. J Haz Mat 153:609–615. doi: 10.1016/j.jhazmat.2007.09.004.
31. Ayers RS, Westcot DW. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper 29:8– 96
32. Chitdeshwari T, Duraisami VP, Poongothai S, Singh MV. Chemical Composition Of Sewage Effluents Of Major Cities Of Tamil Nadu. InWastewater Treatment and Waste Management: Proceedings of the International Conference on Water and Environment (WE-2003), December 15-18, 2003, Bhopal, India 2003 (Vol. 4, p. 227). Allied Publishers.
33. Mishra V, Pandey SD. 2002. Effect of distillery effluent and leachates of industrial sludge on the germination of blackgram (Cicer arietinum). Pollut Res 21:461–467.
34. Singh A, Agrawal M. Effects of municipal waste water irrigation on availability of heavy metals and morpho-physiological characteristics of Beta vulgaris L. Journal of Environmental Biology. 2010 Sep 1;31(5):727.
35. Vaithiyanathan T, Sundaramoorthy P. 2017. Analysis of sugar mill effluent and its influence on germination and growth of African marigold (Tagetes erecta L.). Appl Water Sci 7:4715–4723.
36. Sharma P, Dubey RS. 2005. Lead toxicity in plants. Brazilian J Plan Phsyiol 17:35–52.
37. Augusthy PO, Mani AS. 2001. Effect of rubber factory effluent on seed germination and seedling growth of Vigna radiatus L. J Environ Res 22:137– 139.
38. Kannan K, Oblisamy G. 1992. Effect of raw and treated paper mill effluent irrigation on vigour induces of certain crop plants. Madras Agric J 79:18–21.

39. Vinod K. 2014. Sugar mill effluent utilization in the cultivation of maize (Zea mays L.) in two seasons. J Waste Manag 408509:1–12
40. Baruah LBK, Das M. 1997. Effect of paper mill effluent on seed germination of crop plant Oryza sativa L. Environ Ecol 15:904–906.
41. Vinod K. 2014. Sugar mill effluent utilization in the cultivation of maize (Zea mays L.) in two seasons. J Waste Manag 408509:1–12. doi: 10.1155/2014/408509.
42. Malla L, Mohanty BK. 2005. Effect of paper mill effluent on germination of green gram (Phaseolus aureus Roxb.) and growth behaviour of it's seedlings. J Environ Biol 26:379–382.