Journal of
Current Opinion in Crop Science
Journal homepage: www.jcocs.com; ISSN(O):2583-0392

RESEARCH ARTICLE

Growth and biochemical characteristics of tomato (*Solanum lycopersicum* L.) and sorghum (*Sorghum bicolor* L.) treated with tannery effluent

M. Muthumari[1], E. Mohan[2], M. Kannan[3], and S. Shanmugam[2*]

[1]Department of Botany, G.T.N. Arts College, Dindigul, Tamil Nadu, India;
[2]PG and Research Department of Botany, Thiagarajar College, Madurai – 625009, Tamil Nadu, India;
[3]Department of Botany, NMSS Vellaichamy Nadar College, Madurai – 625019, Tamil Nadu, India.

Edited by:

Dr K. Ashokkumar, PhD., School of Agriculture and Animal Sciences, GRI, Gandhigram, India

Reviewed by:

Dr, Maiyammal, Mangayarkarasi College of Engineering, Paravai, Madurai, India.
Dr A. Banso, Federal Polytechnic, Bida Niger State Nigeria.

Article history:
Received: January 28, 2026
Accepted: March 17, 2026
Published: March 31, 2026

Citation:
Muthumari, M., Mohan, E., Kannan, M., & Shanmugam, S. (2026). Growth and biochemical characteristics of tomato (*Solanum lycopersicum* L.) and sorghum (*Sorghum bicolor* L.) treated with tannery effluent. *Journal of Current Opinion in Crop Science, 7*(1), 1-9.
https://doi.org/10.62773/jcocs.v7i1.374

*Corresponding author e-mail address: shanmugambotany@gmail.com
(S. Shanmugam)

ABSTRACT

The current research work showed the effect of tannery effluent at different concentrations on the growth, pigment and biochemical characteristics of tomato (*Solanum lycopersicum*) and sorghum (*Sorghum bicolor*). The results of this study revealed that growth parameters, such as shoot length, root length, fresh weight, dry weight, and leaf area, of both experimental plants significantly declined as tannery effluent concentration increased compared with the water control. Similar substantial decreases were also observed in photosynthetic pigments, such as chlorophyll a, chlorophyll b, total chlorophyll, anthocyanin, and carotenoid, compared with the control plants. The results also showed that biochemical parameters, such as total soluble sugar, soluble protein, free amino acids, L-proline, and nitrate levels in the leaves decreased as the quantity of tannery effluent increased. Toxic metal deposition on roots, cell division and elongation retardation, or disruption of cellular metabolism by tannery effluent are all possible causes of the decrease in overall morphometric and biochemical parameters of tomato and sorghum.

Keywords: Biochemicals, Growth, Pigments, Sorghum, Tannery Effluent, Tomato

INTRODUCTION

Rapid urbanization and industry in emerging countries like India have made industrial pollution a severe issue, and because of its environmental persistence and recalcitrance, its remediation is particularly important (Gupta et al., 2001). Numerous industries, including textiles, tanneries, mining, smelting, alloy manufacturing, and metal plating, discharge various harmful metal ions into their wastewater, contaminating natural waterways (Kadirvelu et al., 2001).

Without treatment, industrial water that has been used once cannot be reused. These wastewater streams from industry are referred to as "industrial effluents". The process of turning raw animal hides or skins into leather is called tanning. According to reports, leather absorbs just 20% of the several chemicals employed in the process; the remainder are expelled as waste (UNIDO, 2005).

The growth and development of agricultural plants are significantly impacted by the organic and inorganic chemicals found in tannery wastewater. Toxic metals accumulate in wastewater, hindering plant development and seed germination and reducing agricultural productivity. Several studies have assessed the impact of different types of effluents on various crops across multiple parameters (Gautam et al., 1992; Sundaramoorthy & Lakshmi, 2000). Many of the elements found in tannery effluent may be beneficial at lower levels, even though they are phytotoxic at higher concentrations. Related to this phenomenon, the present research work was conducted to determine the effects of tannery effluent at different concentrations on morphometric, pigment, and biochemical attributes of tomato (*Solanum lycopersicum* L.), a dicot vegetable crop, and sorghum (*Sorghum bicolor* L.), a monocot millet crop.

MATERIALS AND METHODS

Experimental Site

For the present study, the tannery effluent samples were collected from Senkulam Lake (10.246434° N latitude 77.947684° E longitude) located in Dindigul district of Tamil Nadu, where the wastewater of treated tannery effluent is stored after processing at the Common Effluent Treatment Plant (CETP) of Tamil Nadu Leather Development Corporation (TALCO).

Collection of Treated Tannery Effluent

The effluent, here after the sample, was gathered from Senkulam Lake and placed in 25 l plastic container. The container was repeatedly washed with distilled water after being thoroughly cleaned with 8M HNO_3 and the same was washed twice with the effluent sample prior to collection as spot sampling technique (Rainwater & Thatcher, 1963). Following appropriate collection, the sample was promptly taken to the lab and stored for upcoming examinations.

Preservation of Water Sample

As per the standard preservation method (APHA, 2012), the collected samples were stored. The samples stored were always kept in a appropriate container in a refrigerator at 15 – 20oC. Only at the time of estimation, the effluent sample was removed from the refrigerator.

Seed Source and Treatment

For the experiment, certified seeds of sorghum and tomato var. TMV 1 were purchased from a certified seed vendor of the Tamil Nadu Seed Certification Department, Madurai. Viable and healthy seeds were surface sterilized for one minute using 0.1% mercuric chloride, then rinsed with running tap water and distilled water.

Raising of Saplings

Various concentrations of tannery effluent, such as 10%, 20%, 30%, 40%, and 50% (v/v), were made. The water was used as the control. The seeds used as control were soaked overnight in ground water and seeds of experimental plants were soaked overnight in their respective concentrations of the effluent. Both the control and experimental seeds were allowed to grow in plastic pots containing a mixture of red, garden and sandy soils in 1:1:1 ratio. The pots were kept in diffused light at room temperature. Ten days after sowing, the experimental pots were irrigated every day, with their respective concentrations of the effluent, with 100 ml. The control pots were irrigated with the water. Both control and experimental plants were maintained in triplicates. On the 21st day, the plants were taken for morphometric, pigmental and biochemical parameter analysis.

Morphometric Studies

From both the control and experimental groups, five randomly chosen seedlings were taken in triplicate for the estimation of each of the morphometric parameters (root length, shoot length, fresh weight, dry weight, and leaf area) and the results exhibited the average of the five seedlings with standard error.

Photosynthetic Pigment Analysis

Using the method described by Wellburn and Lichtenthaler [8], the amounts of photosynthetic pigments such as chlorophyll-a, chlorophyll-b, total chlorophyll, carotenoid and anthocyanin were estimated.

Biochemical Analysis

Using the method of Hedge and Hofreiter (1962), Lowry's method (1951), Jayaraman's Ninhydrin assay method (1981), method of Bates et al. (1973) and method of Cataldo et al. (1978), total soluble sugar, soluble protein, free amino acids, L-proline and nitrate content of leaf samples of both the plants examined were estimated respectively.

RESULTS AND DISCUSSION

Impact of Tannery Effluent on Growth Parameters

Root length

The application of treated tannery effluent at different concentrations (10%, 20%, 30%, 40%, and 50% (v/v)) had significantly decreased in the root length of both experimental plants. The root length was reduced to about 72% in the seedlings of *Solanum* at 50% (v/v) concentration of the effluent. A reduction of about 65% was observed in the seedlings of *Sorghum* at the same concentration over the water control. At 10% (v/v) concentration of the effluent, about 7% and 25% reduction of root length were observed respectively in *Solanum* and *Sorghum* over the water control. When the concentrations of the effluent started increasing from 10% (v/v) up to 50% (v/v), the reduction was very prominent in each concentration over the water control (Figure 1a).

Shoot length

Both *Solanum* and *Sorghum* recorded a significant reduction in shoot length, when the concentrations of the effluent were increased from 10% (v/v) up to 50% (v/v). At 50%, (v/v) concentration of the effluent, *Solanum* seedlings showed a reduction of 50% over the water control. And a reduction of 45% over the water control was observed in *Sorghum* seedlings at the same concentration of 50% (v/v) of the effluent (Figure 1b).

Fresh weight

With the increase in the concentrations of tannery effluent, fresh weight of the seedlings decreased. In *Solanum,* there was 62% decrease in fresh weight at 50% (v/v) concentration of the effluent and in *Sorghum* the reduction was 54% at the same concentration of the effluent (Figure 1c).

Dry weight

Since dry weight is a good indicator of any stress study, it was analysed in tannery effluent treated seedlings of *Solanum* and *Sorghum*. Both the plants showed a reduction in the dry weight over the control seedlings. In *Solanum,* the reduction was 63% and in *Sorghum* it was 61% at 50% (v/v) concentration of the effluent (Figure1d).

Leaf area

The leaf area was reduced with increasing concentrations of tannery effluent. In S*olanum*, the reduction was 17%, 31%, 47%, 69% and 75% at 10% (v/v), 20%, 30%, 40% and 50% (v/v) concentrations respectively. In *Sorghum,* the reduction was 4%, 18%, 26%, 37% and 41% respectively in 10% (v/v), 20%, 30%, 40% and 50% (v/v) concentrations (Figure 1e).

The observed data indicated that as the concentration of the treated tannery effluent increased, seedling development was steadily hindered. More withering was seen when the effluent concentration exceeded 50% (v/v). Excessive levels of EC, TDS, cations, and anions in the effluent inhibit the development of the seedlings. Sisodia and Bedi (2015) found that irrigating crops with industrial effluent with high pH, EC, and TDS levels also reduced the growth of wheat, jawar, and paddy. It was reported that in two ways that an excessive concentration of anions and cations in the effluents can negatively impact plant growth are by reducing the amount of water available due to the effluent's higher osmotic concentration and by increasing the concentration of chemicals that are toxic to plants, such as sodium, calcium, carbonate, bicarbonate, and chlorides (Muthusamy & Jeyabalan, 2001). Nonetheless, it has been noted and well established that diluted effluents have a positive impact on seedling development by Chandra *et al.* (2009), Shreshta & Niroula (2013), and Baby Shakila (2020).

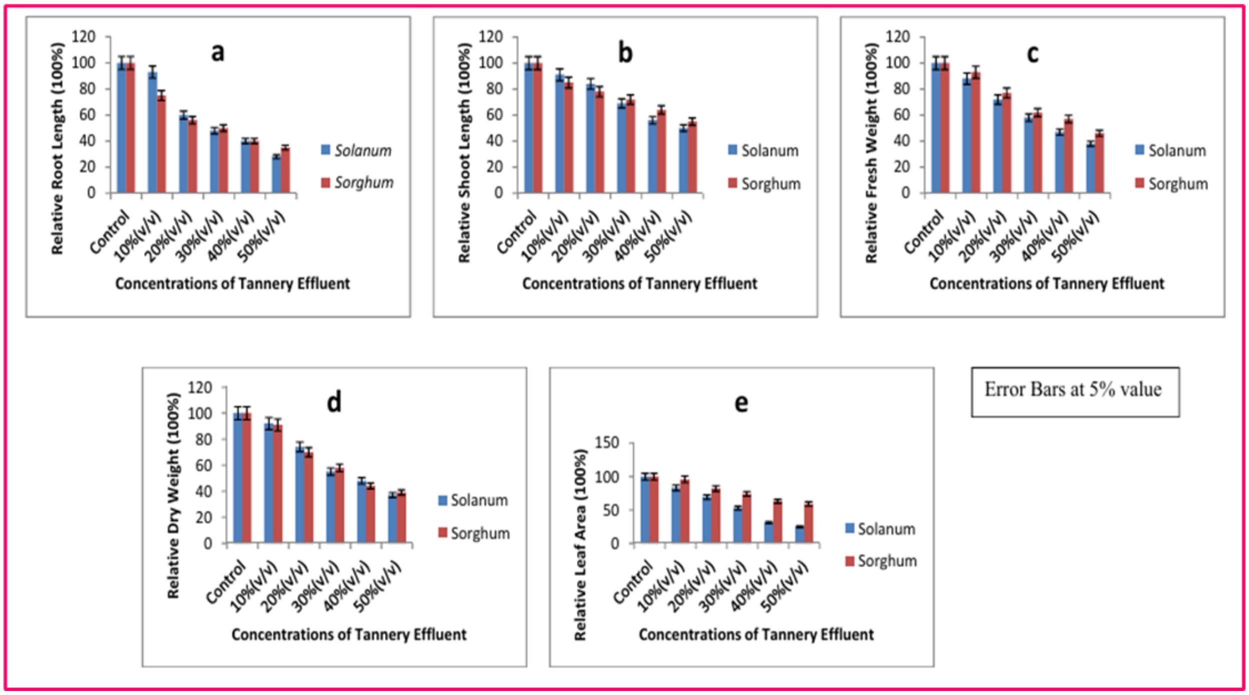

Figure 1. Effect of various concentrations of treated tannery effluent on the morphometric parameters of Solanum and Sorghum.

Impact of Tannery Effluent on Pigment Parameters

The photosynthetic productivity of plants can be expressed by quantitative analysis of the pigments. The application of various concentrations of treated tannery effluent had brought considerable reduction in the pigment parameters of both plants (Table 1 & 2).

Table 1. Effect of various concentrations of tannery effluent on pigments parameters of *Solanum*

Pigments (mg/g lfw)	Control (Water)	10% (v/v)	20% (v/v)	30% (v/v)	40% (v/v)	50% (v/v)
Chlorophyll-a	3.02 ± 0.036 (100)	2.78 ± 0.024 (92)	2.17 ± 0.039 (71)	1.78 ± 0.053 (58)	1.56 ± 0.028 (51)	1.38 ± 0.053 (46)
Chlorophyll-b	3.36 ± 0 .087 (100)	2.94 ± 0.098 (87)	2.28 ± 0 .088 (68)	1.74 ± 0.052 (52)	1.64 ± 0.065 (48)	1.47 ± 0 .059 (44)
Total chlorophyll	6.38 ± 0.102 (100)	5.67 ± 0.109 (89)	4.47 ± 0.099 (70)	3.52 ± 0.091 (55)	3.20 ± 0.046 (50)	2.88 ± 0.060 (45)
Carotenoid	4.54 ± 0.041 (100)	3.78 ± 0.056 (83)	3.09 ± 0.042 (68)	2.55 ± 0.025 (56)	2.08 ± 0.026 (46)	1.69 ± 0.020 (37)
Anthocyanin	0.988 ± 0.044 (100)	1.175 ± 0.043 (119)	1.271 ± 0.052 (128)	1.572 ± 0.058 (159)	1.70 1 ± 0.043 (173)	1.963 ± 0.046 (199)

Values are an average of five observations; Values in parentheses are percentage activity with respect to control; Mean ± SE.

Table 2. Effect of various concentrations of tannery effluent on pigments parameters of *Sorghum*

Pigments (mg/g lfw)	Control (Water)	10% (v/v)	20% (v/v)	30% (v/v)	40% (v/v)	50% (v/v)
Chlorophyll-a	4.97 ± 0.024 (100)	4.48 ± 0.041 (90)	4.07 ± 0.131 (82)	3.42 ± 0.040 (69)	2.98 ± 0.035 (60)	2.53 ± 0.048 (51)
Chlorophyll-b	3.69 ± 0.041	3.24 ± 0.048	2.91 ± 0.046	2.47 ± 0.037	2.17 ± 0.051	1.80 ± 0.068

	(100)	(88)	(79)	(67)	(59)	(49)
Total chlorophyll	8.66 ± 0.051	7.72 ± 0.040	6.92 ± 0.128	5.89 ± 0.061	5.20 ± 0.050	4.33 ± 0.087
	(100)	(89)	(80)	(68)	(60)	(50)
Carotenoid	5.92 ± 0.015	5.15 ± 0.006	4.67 ± 0.016	3.96 ± 0.037	3.43 ± 0.018	2.78 ± 0.025
	(100)	(87)	(79)	(67)	(58)	(47)
Anthocyanin	2.02 ± 0.060	2.44 ± 0.059	2.80 ± 0.105	3.41 ± 0.119	3.79 ± 0.069	4.14 ± 0.146
	(100)	(121)	(139)	(169)	(188)	(205)

Values are an average of five observations; Values in parentheses are percentage activity with respect to control; Mean ± SE.

Total chlorophyll content

In general, the pigment contents showed a declining trend with increase in concentrations of the tannery effluent over the water control. At 50% (v/v) concentration of the effluent, total chlorophyll content in the leaves of *Solanum* was 45% (Table 1) and 50% in *Sorghum* (Table 2). Total Chlorophyll content in the leaves of both seedlings using 50% (v/v) concentration of the effluent were found significantly reduced over the seedlings grown without the effluent.

Carotenoid

The carotenoid content in the leaves of both seedlings were found reduced with increasing concentrations of tannery effluent. A reduction of 63% and 53% were observed in *Solanum* (Table 1) and *Sorghum* (Table 2) respectively, when compared with the control at 50% (v/v) concentration.

Anthocyanin

Anthocyanin showed increasing level, when comparing to the control, with the increase in concentrations of the tannery effluent. In *Solanum,* the amount of anthocyanin at 50% (v/v) concentration was 99% more than the control (Table 1) and in *Sorghum* it was 105% more, at the same concentration of the effluent, than the control (Table 2).

In the current research work, the leaves of stressed seedlings of both plants had lower levels of total chlorophyll, chlorophyll-a, chlorophyll-b, and carotenoid than the corresponding controls. The reduction in overall chlorophyll concentration indicates pollution-induced damage to plastids (Baby Shakila, 2020). Salt stress and excessive chromium sulfate usage during the tannery process, which damages photosynthetic equipment, may also be to reason for the decrease in total chlorophyll concentration (Mariappan et al., 2003) or due to chlorophyll degradation by increased chlorophyllase activity (Sharma & Dubey, 2015). The decrease in chlorophyll content in the experimental plants may also be caused by chemicals employed in the tannery process and found in the effluent.

In results of present study indicated that the tannery effluent treated seedlings of both the plants showed a similar trend of decrease in carotenoid with an increase in the effluent concentration. These results are in agreement with those of Mariappan and Rajan (2012). Vajpayee et al. (2001) reported chromium induced degradation of carotenoid in *Vallisneria spiralis*. The decrease may be due to excessive generation of reactive oxygen species (Gupta et al., 2013).

The present study's findings also showed that plants treated with tannery wastewater had higher levels of anthocyanins. An increase of 199% in *Solanum* and 205% in *Sorghum* observed at 50% (v/v) concentration of the treated tannery effluent. The anthocyanin accumulated in the upper epidermal cells of the leaves, exposed to heavy metal or pollutants can act as scavengers, before it reach the sensitive targets such as chloroplast. Hence, the increase in the anthocyanin content observed in the present study can be ascribed to its protective function. Higher quantities of anthocyanins may also be the result of plants adapting to stressful conditions brought on by an excess of cations and anions in dyeing industry effluent residue.

Impact of Tannery Effluent on Biochemical Parameters

In the present study, an analysis was made to find out the changes in biochemical parameters after irrigating the seedlings of *Solanum* and *Sorghum* using various concentrations of the treated tannery effluent and the results were tabulated in Tables 3 & 4.

Total soluble sugar

A significant decrease was observed in the TSS content in both seedlings with increase in the concentrations of the tannery effluent (Tables 3 & 4). The amount of total soluble sugar in *Solanum* (Table 3) was reduced to 9%, 25%, 37%, 43% and 64% respectively at 10%, 20%, 30, 40% and 50% (v/v) concentrations of tannery effluent. And in *Sorghum* (Table 4), the decrease was 9%, 13%, 23%, 31% and 41% respectively at the same concentrations.

Table 3. Effect of various concentrations of tannery effluent on biochemical parameters of *Solanum*

Biochemical	Control (Water)	10% (v/v)	20% (v/v)	30% (v/v)	40% (v/v)	50% (v/v)
Total Soluble Sugar (mg/g lfw)	11.1 ± 0.023 (100)	10.2 ± 0.031 (91)	8.32 ± 0.023 (75)	6.99 ± 0.023 (63)	6.32 ± 0.027 (57)	5.10 ± 0.027 (46)
Soluble Protein (mg/g lfw)	10.4 ± 0.035 (100)	9.15 ± 0.023 (88)	7.59 ± 0.024 (73)	6.97 ± 0.151 (67)	6.03 ± 0.171 (58)	4.88 ± 0.141 (47)
Free Amino Acids (µ mole /g lfw)	2.71 ± 0.220 (100)	3.11 ± 0.210 (115)	3.61 ± 0.171 (133)	3.98 ± 0.152 (147)	4.31 ± 0.081 (159)	4.63 ± 0.201 (170)
L-Proline (mg/g lfw)	2.81 ± 0.021 (100)	3.06 ± 0.031 (108)	3.52 ± 0.032 (125)	4.06 ± 0.031 (144)	4.23 ± 0.041 (150)	4.51 ± 0.031 (161)
Leaf Nitrate (mg/g lfw)	9.83 ± 0.801 (100)	10.42 ± 0.351 (106)	11.60 ± 0.361 (118)	12.48 ± 0.621 (127)	13.17 ± 0.721 (134)	14.15 ± 0.771 (144)

Values are an average of five observations; Values in parentheses are percentage activity with respect to control; Mean ± SE

Table 4. Effect of various concentrations of tannery effluent on biochemical parameters of *Sorghum*

Biochemical	Control (Water)	10% (v/v)	20% (v/v)	30% (v/v)	40% (v/v)	50% (v/v)
Total Soluble Sugar (mg/g lfw)	12.3 ± 0.023 (100)	11.2 ± 0.031 (91)	10.71 ± 0.029 (87)	9.49 ± 0.020 (77)	8.48 ± 0.025 (69)	7.25 ± 0.022 (59)
Soluble Protein (mg/g lfw)	10.12 ± 0.025 (100)	9.31 ± 0.027 (92)	8.80 ± 0.020 (87)	8.09 ± 0.023 (80)	7.38 ± 0.036 (73)	6.98 ± 0.033 (69)
Free Amino Acids (µ mole /g lfw)	3.69 ± 0.283 (100)	4.39 ± 0.312 (119)	4.97 ± 0.418 (134)	5.25 ± 0.267 (142)	5.74 ± 0.184 (155)	6.08 ± 0.153 (165)
L-Proline (mg/g lfw)	3.01 ± 0.012 (100)	3.41 ± 0.014 (113)	4.13 ± 0.010 (137)	4.65 ± 0.008 (154)	5.12 ± 0.012 (170)	5.47 ± 0.023 (181)
Leaf Nitrate (mg/g lfw)	10.74 ± 0.544 (100)	11.70 ± 0.488 (109)	12.46 ± 0.471 (116)	13.10 ± 0.442 (122)	14.18 ± 0.429 (132)	15.46 ± 0.499 (144)

Values are an average of five observations; Values in parentheses are percentage activity with respect to control; Mean ± SE.

Soluble protein

The soluble protein content in the leaves of *Solanum* and *Sorghum* seedlings recorded a significant reduction compared to their respective water control seedlings. The 50% (v/v) tannery treated seedlings of *Solanum* (Table 3) showed the presence of 47% of soluble protein comparing the water control (100%) seedlings. And in *Sorghum* (Table 4), the soluble protein content was 69% comparing the control (100%).

Free amino acid

The reduction of soluble protein probably leads to an increase in free amino acid content. The analysis of free amino acid showed increasing amounts with an increase in the concentrations of the effluent. The increase was about 70% in *Solanum* (Table 3) and 65% in *Sorghum* (Table 4) at 50% (v/v) concentration of tannery effluent when compared to the water control (100%).

L-proline

The content of L-proline was analysed in both the seedlings and presented in Tables 9 & 10. The content was increasing with an increase in the concentrations of the effluent comparing to control. An increase of 61% was observed in *Solanum* (Table 3) and 81% in *Sorghum* (Table 4) over the control at 50% (v/v) concentration of the tannery effluent.

Leaf nitrate

The leaf nitrate content level showed variations in response to various concentrations of the tannery effluent. The tannery effluent treatment caused an accumulation of leaf nitrate, with effluent concentrations higher than those in the water control. In Solanum (Table 3), 13.92mg/g of leaf nitrate, which is 44% more than the water control, was observed at 50% (v/v) concentration of the effluent, and 15.51mg/g was observed in Sorghum (Table 4) at the same effluent concentration.

In the current research work, the amount of soluble sugars in the leaves of Solanum and Sorghum was significantly reduced following the application of various quantities of the tannery effluent. The same findings had been reported in paddy seedlings with increased industrial effluent concentration (Behra & Mishra, 2013). The decrease in the leaf chlorophyll concentration might be the cause of the drop in soluble sugar levels. It was reported that a decrease in chlorophyll levels may have affected the plant's photosynthetic activity and, consequently, carbohydrate content (Swaminathan et al., 2019).

Additionally, the protein level steadily dropped compared to the control. Protein fragmentation caused by the harmful effects of reactive oxidative stress or by increased activity of proteases and other catabolic enzymes might be the cause of a reduction in protein content (Mishra et al., 2007). Revathi Lakshmi and Ramasubramanian (2017) also reported a decrease in treated *Cyamopsis tetragonoloba* seedlings under metal stress. It might be due to the adsorption of necessary elements by plants. It was also reported that an increase in free amino acid concentration was linked to a decrease in soluble protein (Sahai & Neelam, 2013).

CONCLUSION

The findings of current research highlighted that the hazardous effects of treated tannery effluent can be reduced and used for other purposes, such as crop growth. However, a study on the mass scale level should be carried out before it is brought to farmers.

ACKNOWLEDGEMENTS

Not applicable

AUTHORS CONTRIBUTION

Muthumari, M.: The conceptualizing, methodology and collection of data. Mohan, E.: Writing, review and editing. Kannan, M: Collection of data and analysis. Shanmugam, S.: Writing original manuscript and editing. All authors read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICAL APPROVAL

Not applicable.

FUNDING

Funding was not involved in this study.

AVAILABILITY OF DATA AND MATERIALS

All datasets analyzed and described during the present study are available from the corresponding author upon reasonable request.

REFERENCES

APHA. (2012). In: *Standard methods for the examination of water and wastewater*. 21st Edition. American Public Health Association, Washington D.C, New York.

Baby Shakila, P. (2020). *Effect of tannery effluent on water and soil profile, plant growth and human health*. Ph.D., Thesis, Submitted to Bharathidasan University, Tamil Nadu, India.

Bates, L. S., Waidren, R. P., & Teare, I. D. (1973). Rapid determination of the proline in water stress studies. *Plant & Soil*, 39, 205–208.
Behra, B. K., & Mishra, B. N. (2013). Analysis of the effect of industrial effluent on the pigments, protein, nucleic acids and 2-6 dichlorophenol, indophenols Hill reaction of rice seedlings. *Environmental Research*, 31, 231–251.
Cataldo, D. A., Harron, M., Schroades, L. E., & Younger, V. C. (1978). Rapid colorimetric NR determination in plant by nitrate salicylic acid. *Communication in Soil Science and Plant Analysis*, *6*, 71–80.
Chandra, R., Bharagava, R. N., Yadav, S., & Mohan, B. (2009). Accumulation and distribution of toxic metals in wheat (*Triticum aestivum*) and Indian mustard (*Brassica juncea*) irrigated with distillery and tannery effluents. *Journal of Hazardous Materials*, *169*, 1514–1521. https://doi.org/10.1016/j.jhazmat.2008.06.040
Gautam, D., Kumar, K., & Bishnoi, S. (1992). Effect of diary effluent on seed germination of some rabi and kharif crop plants. *Journal of Environmental Biology*, 13(1), 7–12.
Gupta, K., Gaumat, S., & Mishra, K. (2011). Chromium accumulation in submerged aquatic plants treated with tannery effluent at Kanpur. *Indian Journal of Environmental Biology, 32*(5), 591–597.
Gupta, V. K., Gupta, M., & Sharma, S. (2001). Process development for the removal of lead and chromium from aqueous solution using red med – An aluminum industry waste. *Water Research*, *35*(5), 1125–1134.
Hedge, J. E., & Hofreiter, B. T. (1962). *Methods of estimating starch and carbohydrates. In carbohydrate chemistry for food Scientists*. (Eds.) R.L. Whistler, & J.N. BeMiller. Eagan Press, pp. 163–201.
Jayaraman, J. (1981). *Laboratory Manual in Biochemistry*. Willey – Eastern Company Limited, Madras, pp: 53–55.
Kadirvelu, K., Thamaraiselvi, K., & Namasivayam, C. (2001). Removal of heavy metal from industrial wastewaters by adsorption onto activated carbon prepared from an agricultural solid waste. *Bioresources Techno*logy, 76, 63–65. https://doi.org/10.1016/S0960-8524(00)00072-9
Lowry, O. H., Rosenburg, N. J., Farr, A. L., & Randall, R. J. (1951). Protein measurement with folin phenol reagent. *Journal of Biological Chemistry,* 193, 262–275.
Mariappan, V., & Rajan, M. R. (2012). Effect of tannery effluent on seed germination, *Journal of Ecobiology*, *14*(4), 241–246.
Mariappan, V., Rajan, M. R., & Ramasubramanian, V. (2003). Influence of organic and inorganic amendments in tannery affected soil on growth and biochemical characteristics of *Hardiwickia binata* Roxb. *Journal of Current Science*, 3(1), 19–24.
Mishra, K., Rai, U. N., & Om Prakash, S. (2007). Bioconcentration and phytotoxicity of cadmium in *Eichhornia crassipes*. *Environment Monitoring & Assessment*, *130*, 237–343.
Muthusamy, A., & Jeyabalan, N. (2001). Effect of factory effluents on physiological and biochemical contents of *Gossypium hirsutum* L. *Journal of Environmental Biology*, *22*(4), 237–242.
Rainwater, E. H., & Thatcher, L. L. (1963). In: *Methods of collection and analysis of water samples*. U.S. Government Print Office, Washington, pp: 134–138.
Revathi Lakshmi, S., & Ramasubramanian, V. (2017). Growth and biochemical responses of the seedlings of *Cyamopsis tetragonoloba* Taub. to metal stress with special reference to antioxidants. *ANJAC Journal of Sci*ence, *6*(1), 31–37.
Sahai, R. N., & Neelam, S. (2013). Effect of fertilizer and distillery effluents on seed germination, seedling growth, pigment content and biomass of *Phaseolus radiatus* L. *Indian Journal of Ecology*, *14*(1), 21–25.
Sharma, P., & Dubey, R. S. (2015). Lead toxicity in plants. *Brazilian Journal of Plant Physiology*, *17*(1), 35–52.
Shrestha, M. K., & Niroula, B. (2013). Germination behavior of pea seeds on municipality sewage and some industrial effluents of Biratnagar. *Our Nature*, *1*, 33–36.
Sisodia, G. S., & Bedi, S. J. (2015). Impact of chemicals and industrial effluent on seed germination of wheat. *Indian Journal of Ecology*, *12*, 189–192.
Sundaramoorthy, P. and Lakshmi, S. (2000). Screening of groundnut varieties for tolerance to tannery effluent. *Pollution Research*, *19*, 543–548.
Swaminathan, K., Arjunan, J. and Gurusamy, R. (2019). Effect of glucose factory effluents on seed germination and seedling development of groundnut *Arachis hypogea.* In: (Ed.) R. C. Dalela, *Environmental Impact on Biosystems*, Muzzafarnagar. pp. 187–189.
UNIDO (United Nations Industrial Development Organization). (2005). Cost of tanned waste treatment. 15th Session of the Leather and Leather Products Industry Panel, Leon, Mexico.

Vajpayee, P., Rai, U. N., Rai, M.B., Tripathi, R.D., Yadav, V., Sinha. S., & Singh, S. N. (2001). Chromium induced physiologic changes in *Vallisneria Spiralis* L. and its role in phytoremediation of tannery effluent. *Bulletin of Environmental Contamination and Toxicology*, 67, 246–256. https://doi.org/10.1007/s001280117

Wellburn, A. R., & Lichtenthalar, H. (1984). Formulae and program to determine total carotenoids and chlorophyll a and b of leaf extracts in different solvents. In: (Ed.) Sybesma Martinus, *Advances in photosynthesis research*, Maretinus Nijhoff Co., The Hague. pp. 9–12.