

Screening the six plant species for phytoremediation of synthetic textile dye waste water

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Abstract

Most of the dyes are carcinogenic and mutagenic in nature. Plants are potential candidates to remediate textile dye wastewater from contaminated sites. The present study aimed to screen potential plant species for removal of synthetic dye solution of triarylmethane dye Methylene Blue (MB) and diazo dye Congo Red (CR). Six plant species were screened for their phytoremediation ability for the removal of dyes present in synthetic wastewater. Six plants selected for screening are *Trachyspermum ammi* L. (*T. ammi*), *Tagetes erecta* L. (*T. erecta*), *Hibiscus rosa-sinensis* L. (*H. rosa-sinensis*), *Chrysanthemum indicum* L. (*C. indicum*), *Bryophyllum fedtschenkoi* (*B. fedtschenkoi*), *Catharanthus roseus* L. (*C. roseus*). The phytotreatment of dyes was done up to 40 h for two different concentrations of dyes 10 mg L^{-1} and 20 mg L^{-1} . Among these plants, the maximum decolouration was obtained from *T. ammi* plant followed by *B. fedtschenkoi* plant. Both of these plants showed active growth even after the phytoremediation process. *T. ammi* decolourised the MB dye 99% (10 mg L^{-1}) and 86% (20 mg L^{-1}) while the decolourisation of the CR dye solution was up to 95% (10 mg L^{-1}) and 84% (20 mg L^{-1}). *T. ammi* found to have maximum potential among screened plants for the removal of MB and CR dye from synthetic dye solution and can be used for decolouration of synthetic dye wastewater.

Introduction

Due to the increasing world population, there is a tremendous growth of various industries, which uses many harmful chemicals for the generation of a commodity for public demands but the side products such as contaminants not only affect water bodies but also the air and soil. Dyes have a major demand and application in the textile industries for the dyeing process. About 10–15% of the azo dyes get lost in the effluent during the dyeing process [1] and 50% other reactive dyes reported for use in the textile industry which throw waste into water [2]. Azo dyes are extensively used in the dyeing process. The effluent containing dyes released into the surrounding thereby seriously affecting the atmosphere by destroying the ecosystem, causing water pollution, and reducing light penetration for aquatic life [3]. Due to textile dye wastewater, the Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), suspended solid values enhance [4]. So, there is a big challenge to treat textile dyes effluent before released into water bodies.

There are so many physical and chemical strategies, for example, adsorption, coagulation, sedimentation, flocculation, filtration, photodegradation, and chemical oxidation, are accessible for managing contamination produced by textile dyes [5]. These strategies relate to the high expense, low productivity, require huge space and undependable to work. Because of these issues, there is a requirement of the advancement of productive, savvy strategy for the treatment of textile dyes [5]. Biological methods are more effective than physical and chemical methods to treat the textile dye wastewater. Bioremediation is a very efficient treatment for removing contaminants from textile dyes effluent [6]. Different enzymes and microorganisms were used for removing the dyes from wastewater. *Phanerochaete chrysosporium*, the most spacious studied white-rot fungus, used to metabolize and decolourise dyes colour and compounds

[7]. Biological decolourisation of lignin-containing pulp and paper wastewater using white rot fungi *Tictoporia species* due to the high oxidative potential of many of the enzymes linked with white rot fungi as ligninase, laccase, Mn-peroxidase [8]. *Aspergillus flavipes* fungus was reported to decolourise the dye xiron orange [9]. From the different bioremediation process, phytoremediation is an energy-efficient, solar-driven process to remove the contaminants from soil, air, water [10]. Phytoremediation is also used to remove pollutants from textile dye wastewater [11]. There are various phytoremediation mechanisms as phytoextraction, phytodegradation, rhizofiltration, phytostabilization, phytovolatilization which helps in the dye removal [12]. Due to these different qualities, we can use plants for the treatment of textile dye wastewater. In the present study, the main focus is to screen the potential of ornamental plants for removing the textile dyes from wastewater.

Different ornamental plants are utilised for phytoremediation study such as Marigold, Euphorbia, Bryophyllum, etc. These ornamental plants are widely used as hyperaccumulators for metals for removal of heavy metals from soil, water and air. *Euphorbia pithyusa* is proved to be as phytostablizer to remediate low trace element concentration in highly contaminated soils [13]. Marigold variety *T. erecta* has leaf plasticity when exposed to Cr, indicating the presence of the tolerance mechanism to Cr [14]. Decorative plants are also used for the treatment of dye wastewater as *Hibiscus sabdariffa* is used to treat CR dye [15]. *Ipomoea hederfolia* plant is reported for treatment of Scarlet red dye [5]. The *petunia grandiflora* plant reported to remove the triphenylmethane textile dye Brilliant Blue G [16]. The main investigation of this research to find and screen the new ornamental plants which have the ability to decolourise the textile dye waste water. Textile dye effluent treated with wild plants such as *Blumea malcolmii* [17], *Rheum rabarbarum* [18], *Typhonium flagelliforme* [19], *Rumex hydrolapathum* [20], and *Phragmites australis* [21]. Aquatic plants are having potential to decolourise and detoxifiers of wastewater containing dyes. They are experimented at laboratory scale studies for degradation of dyes in situ [22]. Recently, some tested plants areaquatic macrophytes such as *Ipomoea aquatic* [23], *Salvinia molesta* [4], *Typha angustifolia* [24]. Garden ornamental and flowering plants such as *Glandularia pulchella* [25], *Petunia grandiflora* [16], *Portulaca grandiflora* [26], *Aster amellus* [27] and *Ipomoea hederfolia* [5] have also been observed as potential candidate for degradation of textile dyes. The *petunia grandiflora* tissue culture plantlets have the potential to decolourise the Brilliant Blue-green dye [16]. Plants and bacterial consortium of *Portulaca grandiflora* and *Pseudomonas putida* showed complete decolourisation of a sulfonated diazo dye direct red 5B [26]. *Aster amellus* Linn used to decolourise a sulfonated azo dye Remazol Red (RR), a mixture of dyes and a textile effluent [27]. *Phragmites australis* is commonly used in constructed wetlands either for domestic sewage or industrial effluent ts treatment [21]. The aerobic mineralization mechanisms of Acid Orange 7 (AO7) in a Vertical Flow Constructed Wetland (VFCW) planted with *Phragmites australis* suggested thatAO7 degradation pathway may involve enzymes like peroxidases (POD), known to degrade some recalcitrant contaminants [21]. *Glandularia pulchella* explored to decolourise the dye green HE4B [25], *Ipomoea hederfolia* ornamental plant able to decolourise the dye mixtures and scarlet red dye [5]. *Nerium oleander* plant is used to remove fluoride in comparison to *Portulaca oleracea* and *Pogonatherum crinitum* [28]. *Nerium oleander* plant also has ability to phytoextract the Cr and Ni heavy metals [29]. *Alcea rosea* plant has the potential to remove disperse red

60 and reactive blue 19 dye [30]. The major research work of screened plants is reported on the removal of heavy metals from the soil, as the *T. erecta* plant was used to remove Ni and Pb from the soil [31]. Comparison of *Chrysanthemum indium* plant is exhibited with Dahlia and Calendula for the removal of the Cr metal from the soil [32]. *C. indium* plant is used to remove CR dye in which flower of the plant act as an adsorbent to remove the CR dye [33]. *Bryophyllum pinnatum* indicated the tendency to remove Co, Pb, Zn from the soil in comparison with other plants such as *Telfaira occidentalis*, *Talinum triangular*. *Bryophyllum pinnatum* is capable to remove the heavy metals such as Cd, Cr, Cu, Ni, Pb, V [34]. Hibiscus plant helps to eradicate the Cadmium from the soil [35]. *C. roseus* plant used to remove Cr metal from the soil such as roots, leaves and stems [36]. This research study is aimed to assess the textile dyes removal by using selected ornamental plants as *T. ammi*, *B. fedtschenkoi*, *C. indicum*, *T. erecta*, *H. rosa-sinensis*, *C. roseus* to decolourise the MB and the CR dyes. These plants have an efficient root system and plants do not affect the food chain. There is no research work based on textile dye removal by these ornamental plants. Due to less explore of these plants for dyes removal, this research study focussed the ability of screened plants for decolourisation of MB and CR dyes.

Material And Method

Chemicals and plant material

MB dye and CR dyes were purchased from Sanjay lab Amritsar, India. All the chemicals were used of the highest purity and of an analytical grade on the market. Screened plants *T. ammi*, *T. erecta*, *H. rosa-sinensis*, *C. indicum*, *B. fedtschenkoi*, *C. roseus* were harvested from the Botanical garden of Guru Nanak Dev University campus, Sathiala and Government High School, Sathiala (Punjab). The plants were washed completely to remove mud, dirt and particulate matters and acclimatized for three days. The synthetic wastewater was prepared with the help of MB blue and CR dye with two different concentrations as 10 mg L⁻¹ and 20 mg L⁻¹. The whole apparatus was sterilized before experimentation. Table 1 shows the description of screened plants used for the research study.

Table 1
Description of screening plants

Plant name	Common name	Family	References
<i>T. ammi</i>	Ajwain	Apiaceae	(Kumar and Dwivedi 2013).
<i>B. fedtschenkoi</i>	Lavender scallops	Crassulaceae	———
<i>C. indicum</i>	Guldaudi	Asteraceae	(Chukki et al. 2018)
<i>T. erecta</i>	Marigold	Asteraceae	(Khusboo et al. 2017)
<i>H. rosa sineses</i>	Chiana rose	Malvaceae	(Assma, 2018)
<i>C. roseus</i>	Periwinkle	Apocynaceae	(Ahmadet al. 2014)

The triarylmethane dye (MB) and a diazo dye (CR) dye used for experimentation. MB is a heterocyclic aromatic chemical compound with molecular formula $C_{16}H_{18}N_3S$. The molecular weight of MB dye is $319.85 \text{ g mol}^{-1}$. CR dye is a diazo dye can be synthesized by a coupling reaction containing hydroxyl, amino or other groups with an aromatic diazotized base. The chemical formula of CR dye is $C_{32}H_{22}N_6Na_2O_6S_2$ and molecular weight is 696 g mol^{-1} . The chemical structure of MB and CR is given in Fig. 1.

Experimental design

Initial experiments were performed to identify the plants having the potential to decolourise the textile dyes, for which *T. ammi*, *T. erecta*, *H. rosa-sinensis*, *C. indicum*, *B. fedtschenkoi*, *C. roseus* plants were selected. Firstly, the roots of these plants were washed with running tap water to remove adherent soil after which plants were entirely washed with distilled water. Plants were put into fresh water for hydroponic treatment to check the growth of the plant in to water up to 7 days. The treatment of selected plants was done with 10 and 20 mg L^{-1} concentrations of both dye solution. The decolourisation was noticed up to 40 h. Each batch of dye concentration and screened plants had triplicates for each biological sample for obtaining concordant results. The absorbance was determined with the help of UV-Visible spectroscopy. The percentage decolourisation was calculated as per equation:

$$\text{Decolourisation(\%)} = \frac{A_0 - A_1}{A_0} \times 100$$

Where A_0 is an initial concentration of dye and A_1 is a final concentration of dye. All the decolourisation experiments were performed with the same time limit and average values were determined. Both biotic and abiotic controls were also maintained as shown in Fig. 2. The abiotic controls contained the MB and CR dye solution without plants whereas plants in distilled water were kept as biotic controls.

Results And Discussion

The treatment of synthetic dye was done hydroponic system, instead of soil [39]. The growth of the plant was observed in the distilled water up to 7 days and then plants were exposed with dyes. The results of each plant were compared with the controlled dye solution. The adsorption on the roots of plants was detected which was responsible for decolourisation. The absorbance was documented up to 40 h. From the absorbance value, the decolourisation percentage was determined. The result data suggested that *T. ammi* plant was the best in decolourisation and in survival.

Figure 3 (a) and (b) shows the decolourisation pattern of MB and CR dye by utilising *T. ammi* plant. Out of six screened plants, excellent decolourisation of MB was observed in the case of *T. ammi* plant. Decolouration percentage of dye increases with increase in the time. The decolouration of 10 mg L^{-1} and 20 mg L^{-1} MB was 99% and 86% respectively. Plant growth was normal after adsorption of the dye into the roots. The decolouration (%) of CR dye by *T. ammi* shown in Fig. 3 (b) clearly indicates the admirable

efficiency of *T. ammi* to decolourise the CR. The percentage decolourisation of 10mgL^{-1} and 20mgL^{-1} of CR dye were 95% and 84% respectively. The plant remains survived after adsorption of dye into the roots. However, percentage decolouration decreases with increase in the concentration. These outcomes showed that *T. ammi* plant is an outstanding plant to decolourise the azo dye CR and triarylmethane dye MB at lower concentration. The decolouration graph of MB and CR dye by using *B. fedtschenkoi* plant was shown in the Fig. 3 (c) and (d) respectively. The plant *B. fedtschenkoi* shows significant decolouration of triarylmethane dye MB having percentage decolourisation of 85% (10mgL^{-1}) and 69% (20mgL^{-1}). The response of *B. fedtschenkoi* plant towards the removal of a toxic azo dye, CR was also observed as significant for textile waste water treatment. The *B. fedtschenkoi* decolourised the CR dye 77% and 70% for 10mgL^{-1} and 20mgL^{-1} dye concentrations respectively. It was observed that plant parts remained active after adsorption the dye and plant was able to remove more dye concentration than 20mgL^{-1} . These results proved that *B. fedtschenkoi* plant has good tendency to decolourise synthetic wastewater of CR azo dye as well as MB, triaryl methane dye. Thus, the *B. fedtschenkoi* can be actively used for remediation of textile waste water.

Figure 3 (e) and (f) showed the decolouration (%) graph of MB and CR respectively by using *C. indicum*. The percentage decolourisation obtained for 10mgL^{-1} and 20mgL^{-1} MB dye concentrations were 87% and 70% respectively. Initially plant leaves becomes dried, later stems and roots of the plant also showed the dryness with the removal of dyes. The plant becomes died after treatment with more dye concentrations. However, the MB colour expulsion by this plant was acceptable yet plant endurance was not significant for treatment of triarylmethane dye, MB. The results with CR dye synthetic waste water revealed only 44% and 42% decolourisation with the 10mgL^{-1} and 20mgL^{-1} concentration respectively. Wilting of the plant takes place after treatment of CR dye. The plant was not able to treat with more dye concentration than 20mgL^{-1} . Hence, *C. indicum* is not suitable for the phytotreatment of CR dye synthetic wastewater.

T. erecta plant was also used for a screening test to remove MB dye from synthetic wastewater. It was observed that plant had the more capacity to decolourise the triarylmethane dye, MB in comparison to CR dye. Figure 3 (g) and (h) shows the decolourisation (%) of MB and CR dye respectively. The decolourisation for 10mgL^{-1} and 20mgL^{-1} MB dye waste water was 84% and 68% respectively. After decolourisation the MB dye plant shows withering. Initially, the leaves become dry then subsequently stems and roots. Due to these conditions, plant was no more active for treatment with more MB dye concentrations than 20mgL^{-1} . The percentage decolouration was observed 67% & 66% for 10mgL^{-1} and 20mgL^{-1} CR dye concentrations respectively. Though, plant was able to decolourise the azo dye, CR and MB but *T. erecta* plant dryness after removal of the toxic dye makes it unsuitable for the treatment of synthetic dye waste water.

Figure 3 (i) and (j) shows the decolourisation of MB and CR respectively by *H. rosa-sinensis* plant. The percentage decolourisation obtained were 86% and 71% from the 10mgL^{-1} and 20mgL^{-1} MB

ation obtained from the 10mgL^{-1} and 20mgL^{-1} CR dye concentrations respectively.

L^{-1} CR dye solution. It indicated the potential of *H. rosa-sinensis* for MB synthetic dye waste water decolourisation. But the toxicity of dye affects on plant's growth and plant was unable to remove dye concentrations than 20 mg L^{-1} .

Figure 3 (k) and (l) shows the percentage decolourisation of MB and CR dye respectively by *C. roseus*. The decolourisation percentage obtained for MR 10 mg L^{-1} and 20 mg L^{-1} was 35% and 34% respectively and 48% and 43% for CR 10 mg L^{-1} and 20 mg L^{-1} respectively. In case of *C. roseus* plant, it was found that plant remain active after dye removal however plant removal rate is quite slow for both the dyes. It was observed that plant could not effectively decolourise the synthetic waste water up to 40 h.

All these decolourization results and impact of synthetic dye waste water on growth of plant used for screening were summarized in Table 2. Hence, the results obtained from the screening experiments clearly indicate that the maximum percentage decolourisation obtained from the *T. ammi* plant followed by *B. fedtschenkoi* and both the plant also remained active after removal the both MB and CR dyes. *C. indicum* and *T. erecta* plants also showed their potential for decolourisation of synthetic dye waste water however, their survival rate makes them insignificant for phytoremediation process. *H. rosa-sinensis* plant was also not considerable for survival because flowers withered after dye removal. The plant *C. roseus* able to bear the toxic impact of dyes but the rate of decolourisation is quite slow for both MB and CR dyes.

Table 2
Decolourization pattern of MB and CR dyes and their impact on plant growth

Plant name	% Decolourisation				Plant Growth (After dye removal)
	MB	MB	CR	CR	
	(10 mg L^{-1})	(20 mg L^{-1})	(10 mg L^{-1})	(20 mg L^{-1})	
<i>T. ammi</i>	99	86	95	84	Active
<i>B. fedtschenkoi</i>	85	69	77	70	Active
<i>C. indicum</i>	87	70	60	52	Inactive
<i>T. erecta</i>	84	68	67	66	Inactive
<i>H. rosa sineses</i>	86	71	59	47	Inactive
<i>C. roseus</i>	35	34	48	43	Active

In the preceding work, the removal of MB was also reported through phytoremediation process with the help of aquatic plant *Eichhornia crassipes* and *Lemna minor* [40, 3]. The researcher reported that *E. Crassipes* removed the colour of MB dye (50 mg L^{-1}) in 20 days experiment up to 98.4% while *L. minor* (2 g) was exposed into 50 mg L^{-1} of MB dyes for 24 h decolourise up to was $80.5 \pm 0.4\%$. *L. minor* has

potential as a phytoremediation agent to remove MB dye from wastewater. In the present research work, *T. ammi* plant showed the decolourisation up to 99% (10 mg L⁻¹) and 86% (20 mg L⁻¹) for MB dye in 40 h experiment only. Hence, *T. ammi* plant proven to be more effective than *E. crassipes* and *L. minor*. The earlier works of CR dye removal by water hyacinth up to 94.5% [41, 43]. The maximum decolourisation up to 95% and 84% from the 10 mg L⁻¹ and 20 mg L⁻¹ CR dye concentrations respectively by *T. ammi*. The maximum dye was found to adsorb on the roots of *T. ammi* plant and it is possibly due to rhizofiltration process, plant could able to give maximum decolourisation. Therefore, *T. ammi* plant acts as potential candidate for future research where it can be used as phytoremediator for decolourisation of dye waste water.

Conclusion

The results from present research support the ability of six screened plants for removal of MB and CR dyes. *T. ammi* and *B. fedtschenkoi* are the efficient plants for removal the both dyes. Moreover, survival of both the plants seems to be significant. Maximum percentage of decolourisation obtained from the *T. ammi* plant as 99% (10 mg L⁻¹), 86% (20 mg L⁻¹) for MB dye and 95% (10 mg L⁻¹), 84% (20 mg L⁻¹) for CR dye because of maximum adsorption on the roots of the plant. Therefore further research work can be focus on the dye removal by using *T. ammi* plant on the bases of adsorption mechanism.

Declarations

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Not applicable

• Competing interests:

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Navjeet Kaur : Conducted the experimental studies and drafting the manuscript; Jyotsna Kaushal: Conceptualization, expert view and overall Supervision; Pooja Mahajan: Data interpretation; Arun L. Srivastva: Suggestions and interpretation on the chemical analysis All authors read and approved the final manuscript.

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Figures

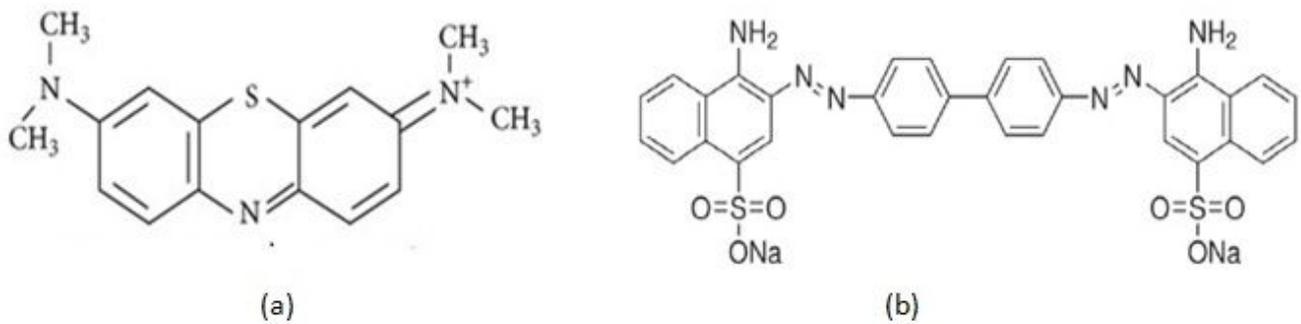


Figure 1

Chemical structure of (a) MB dye (b) CR dye.

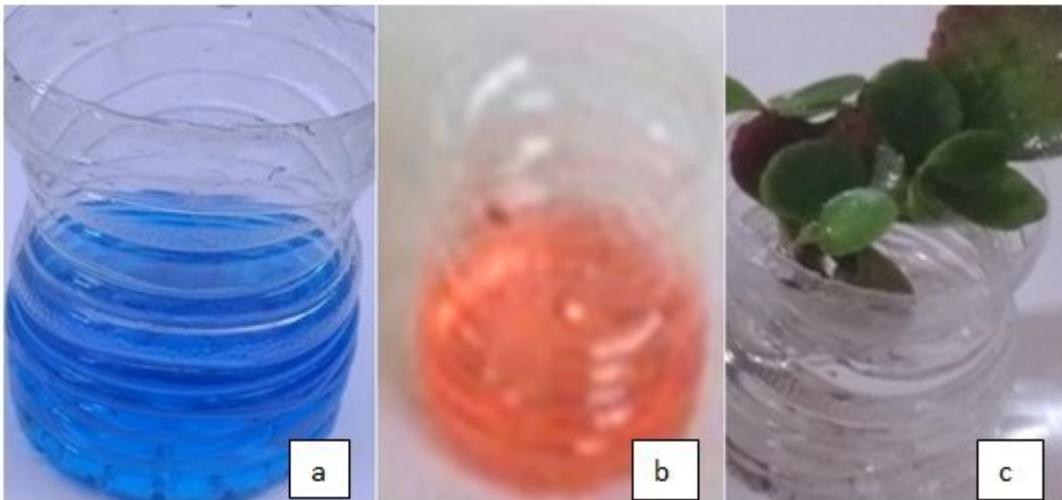


Figure 2

(a) Abiotic control of MB dye (b) Abiotic control of CR dye (c) Biotic control of *B. fedtschenkoi* plant.

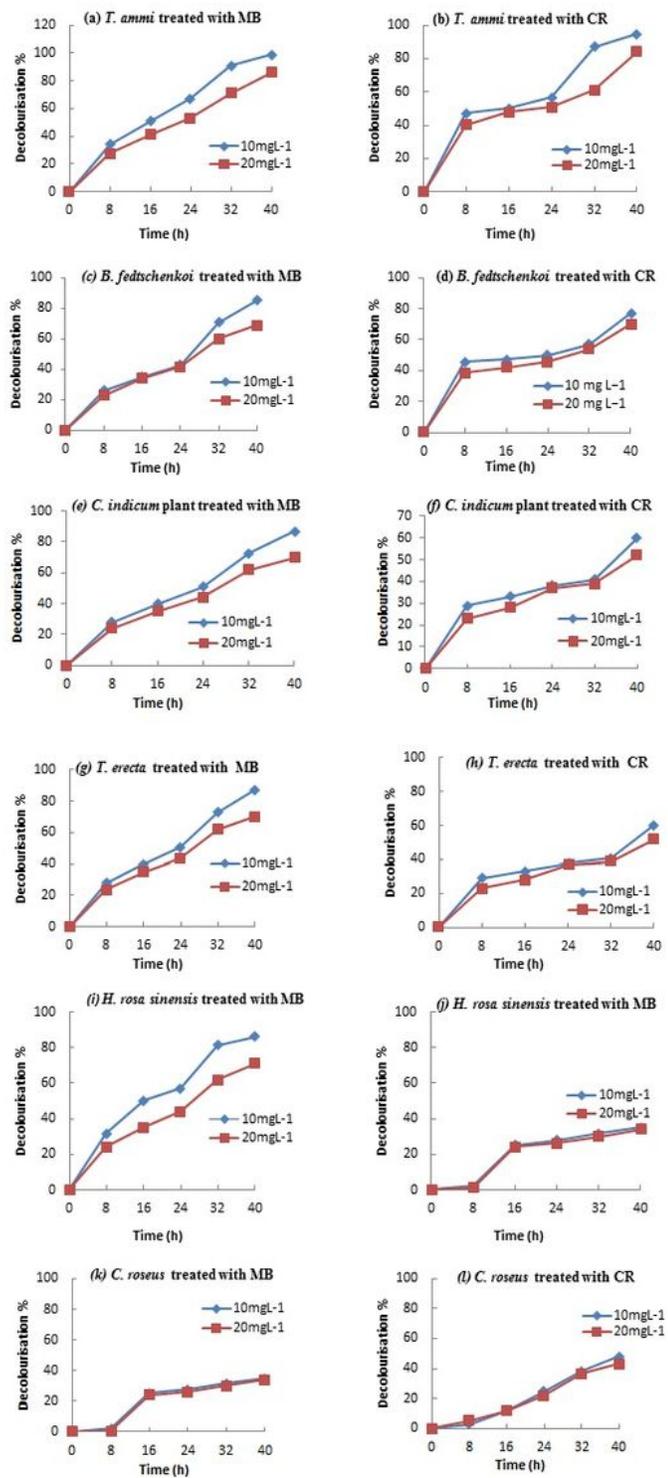


Figure 3

Decolourisation potential of different screened plants for MB and CR dye solution