Plant Archives Vol. 22, Special Issue (VSOG), 2022 pp. 103-107 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2022.v22.splecialissue.021

ASSESSMENT OF REMEDIATION POTENTIAL OF NATURALLY GROWN CASTOR IN THE POLLUTED RIVER CATCHMENTS AND ITS SUITABILITY FOR ERICULTURE

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ABSTRACT

Eri silk is the second highest contributor to the raw silk production of India. Presently the ericulture is mainly restricted to traditional states in North East region with minor production coming from non-traditional states. Ericulture has the scope and potential to spread in non-traditional states due to the availability of eri host plants. Major host plant of eri silkworm (*Samia ricini*) castor (*Ricinus communis*) is chiefly used as oil seed crop in the non-traditional states and grows in abundance as a weed in the waste lands, river catchment areas and road sides. Establishing block plantations of castor in non-traditional states will have the competition with the cash crops growing in these regions which will prove a bottle neck for spread of ericulture in these areas. Uttar Pradesh is one of these non-traditional states where castor grows in abundance on contaminated waste lands but the ericulture is presently restricted to castor seed farmers only. Phytoremediation potential of castor is well documented in literature. Therefore, the present study was under taken to ascertain the phytoremediation of heavy metals through castor and its suitability for ericulture. The soil analysis of the river catchment area has indicated that the concentration of heavy metals is higher than pond catchment area. Analysis of castor leaf growing on heavy metals contaminated catchment has shown the normal growth. The suitability of castor leaf growing on contaminated catchment towards ericulture was analyzed through bioassay studies and no significant impact on eri silkworm rearing was observed under the pilot study. However, the detail study is needed to understand the metals specific antagonistic effects as well as to identify the tolerance limit, phytoremediation potential under the specific contamination level.

***Keywords* :** Eri silkworm, heavy metal, non-traditional states, ericulture, castor.

Introduction

India produces all types of silk, viz. muga, mulberry, eri, tasar and oak tasar. The common and commercially exploited non-mulberry or vanya silk producing species are *Antheraea mylitta* Drury, *Antheraea pernyi* Guérin-Meneville, *A. assamensis* Helfer and *Samia ricini* Donovan (Jolly 1985) belonging to the family Saturniidae.Eri silkworm, *Samia ricini* (Donovan), is considered as the mostpopular commercially exploited vanya silkworm now getting national as well as international importance. Eri silk constitutes 70.19 % of the total non-mulberry raw silk production of 6935 MT in India during 2020–21. The eri silkworm is multivoltine and polyphagous in nature feeding on a number of food plants namely castor, *Ricinus communis*, Kesseru, *Heteropanax fragrans*, Tapioca, *Manihot esculenta*, Payam, *Evodia flaxinifolia* and Barpat, *Ailanthus grandis* and several others.

Ericulture is mainly confined to North-Eastern region of India. The states of Assam, Nagaland, Meghalaya and Manipur account nearly 98% of eri silk produced in the country. Presently, ericulture is spreading in different non-traditional states like, Uttar Pradesh, Madhya Pradesh, Bihar, Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Jharkhand, Chhattisgarh etc.

Ericulture is non-significant especially in non-traditional regions as the dominant cash crops are Sugarcane, wheat, Rice, Brassica and horticulture crops which needs to focus for enhancing involving of these regions especially where some resources are easily available. Being a fertile zone, high density cultivation, the land for the sericulture is unavailable in non-traditional states such as Uttar Pradesh and Bihar while few eri food plants like castor and borkesseru are widely available at road side, river banks, waste lands and forest area. The higher population is also needs some alternative high-return occupation to receive the sustainable income for these states. The Ericulture can serve the purpose in this direction. In these conditions, utilization of the wild grown castor can enhance the possibilities to increase the eri-culture production and income generation. Apart from this the water pollution is also a big challenge to address the sustainable re-utilization of the available water. It was observed that NBR castor is having vigorous growth in the river catchments. But utilization of these native castors for ericulture needs to be check along with the safety at initial level through focused effort is summarized in **Figure-1**.

Bioremediation is a natural and environment sociable process, which relies on bacteria, fungi, and plants to remove, reduce, degrade, or immobilize environmental pollutants from soil and water, and accumulated in the different parts of plant (Singh *et al*., 2013; Jain *et al*., 2015; Kumar *et al*., 2017; Pandey *et al*., 2016; Bauddh *et al*., 2016; Kapahi and Sachdeva, 2019; Kumar *et al*., 2020).

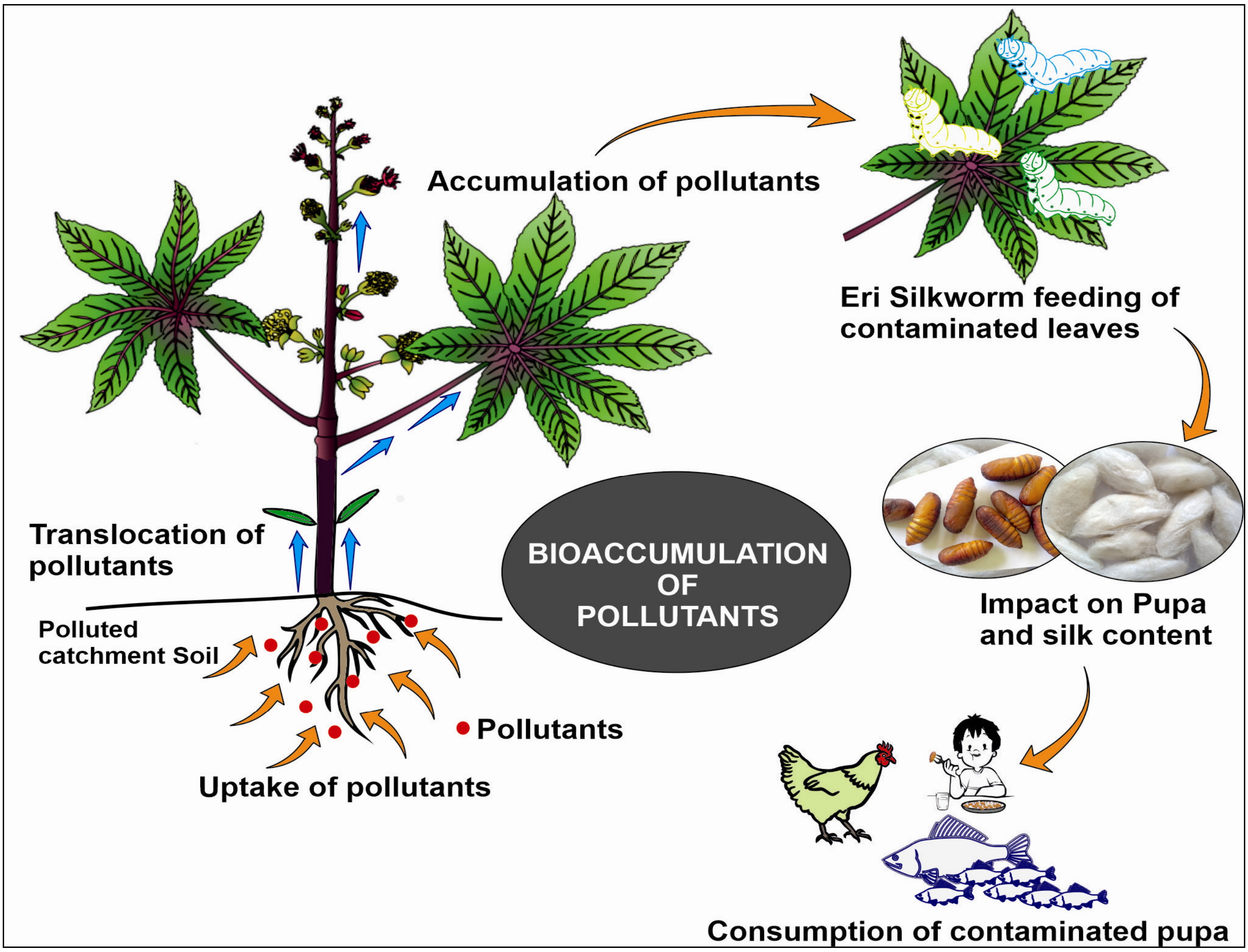

Fig. 1 : Schematic representation of bioaccumulation of pollutants in castor plants, Eri silkworm larva and pupa.

Phytoremediation is a plant-based approach, green, sustainable bioremediation process that uses green plants to remove heavy metal pollutants from contaminated soil and water (**Figure-1**). In recent research studies, castor is considered to have great potential for contaminated soil remediation which is showing good adaptability and tolerance to the contaminated environment due to nature of its fast propagation and growth rate (Cleide Aparecida de Abreu *et al*., 2012; Pandey *et al*., 2016; He *et al*., 2020; Bauddh *et al*., 2016; Kumar *et al*. 2021). The results on biomass and chlorophyll revealed that castor plants have good tolerance to the pollution with 0-5 mg/kg Cd and 380 mg/kg Zn (He *et al*., 2020). Kiran *et al*. (2017) suggested that castor plant is suitable for remediation of crude oil contaminated soil, ideal for re-vegetation on fly ash dump sites and it promotes arbuscular mycorrhizal fungi-assisted phytoremediation process. Angelova *et al*. (2020) suggested that the castor oil plant is tolerant to heavy metals and bioaccumulation factor and translocation factor values were recorded greater than one, which shows the heavy metal accumulation efficiency in the shoots of castor plant. Screening of metal-tolerant *R. Communis* cultivars is very effective method to utilize for the remediation of metal-contaminated soils, owing to their high capacity for metal tolerance (Akwasi Yeboah *et al*. 2020; Khan *et al*., 2019). Research study indicates that castor has great potential for removing DDTs and Cd contamination from contaminated soils due to its fast growth, high biomass, strong absorption and accumulation for both DDTs and Cd (Huagang Huang *et al*., 2011). Niu and Sun (2017) suggested that castor bean plant is a hyper accumulating candidate for cadmium and lead in hydroponic system. He also suggested that bio concentration factors (BCF) of Cd or Pb increased with time and decreased with concentrations.

Castor plants grown in contaminated area can be utilized for ericulture effectively is the main focus of present study and also assess the remedial potential of these castor plants.

Thus, the present investigation has been propose to understand the transfer factor, biomagnifications potential, bioremediation potential of native castor and their suitability for the successful ericulture practices.

Materials and Methods

The two sites (River Dhamola in Saharanpur, which is highly polluted and carrying effluents from industries and urban and Pond in Fatehpur, which is main reservoir filled with effluents from small industries and urban discharge) were identified for present research study (**Figure-1**). These sites are fully occupied with native castor. The Eri silkworm rearing for the native castor grown on the river Dhamola catchment was not attempted due to the insufficient infrastructure for the same. The eri silkworm rearing was conducted at REC Fatehpur by feeding the castor leaves collected from the pond catchment area only. The water and samples were collected and analyzed for both of the identified location as per the standard guidelines and process (APHA 1998; Khanna and Bhutiani 2005; Page *et al.*, 1968). The biochemical parameters of the castor leaves collected from the contaminated environment were estimated as per the standard methodology. The statistical analysis was conducted using the MS excel 2007.

Results and Discussion

River and pond water and their soil characteristics

The measured physicochemical and elemental parameters of soil and water collected from catchment area of river and pond are summarized in Table-1. The total suspended solids (TSS) of River water ranged between 12-85 mg/l and Pond water ranged between 44-142 mg/l. Total dissolved solids (TDS) is significantly higher than the standard (100 mg/l) in both pond water (401-444 mg/l) and river water (406-703 mg/l), respectively. The pH of pond water is in between 6.8- 7.46 and pH of soil ranged from 6.4 – 7.5, and pH recorded 7.2- 8.0 in river water and 6.8-7.4 in river catchment soil. Nitrate content is significantly less than standard ranging from 2.4-6.7 ppm (River) and 5.6-13 ppm (pond). Nitrite content (ppm) is slightly in higher side in the both samples. Dissolved oxygen recorded in river water ranged from 7.6- 14.8 ppm and 3.42-6.52 ppm in pond water. BOD and COD content (ppm) was significantly higher than standard in both the water types. The phosphate amount found in river water (1.1-2.6 ppm) and pond water (8.2-9.84 ppm). In both soil and water, the potassium content is very less ranging from 0.3-7.9 ppm. Salinity of river water ranged from 1.4-2.0 ppt and pond water ranged from 2.9- 3.8 ppt. River catchment soil recorded the salinity in the range of 1.2-2.5 ppt and pond catchment soil has the salinity between 2.4-4.2 ppt. Alkalinity ranged from 44-483 ppm where 200 ppm is the standard alkalinity value. Lead content was high in pond water (1.2-56 ppb) and river catchment soil showed (1.1-12 ppb) along with it pond catchment soil showed 0.1-3.6 ppb. Soil catchment showed 14-178 ppb copper concentration and water showed 2-102 ppb copper content. These heavy metals uptake by plants and accumulated in its parts which are used by humans and animals for food production that ultimately get accumulated in the food chain (Yadav *et al.*, 2018).

Table 1 : River and pond water and their soil characteristics

Parameters	Analytical Methods	Water Quality		Catchment Soil Quality		Standard value (BIS & WHO) for water quality
		River	Pond	River	Pond	
TSS	Filtration and Gravimetric	12-85	44-142	NA	NA	500
TDS	Filtration and Gravimetric	401-444	406-703	NA	NA	100
pH	pH meter	7.2-8.0	6.8-7.46	6.8-7.4	6.4-7.5	6.5-7.5
Nitrate (ppm)	Hach Spectrophotometric	2.4-6.7	5.6-13	-	-	45
Nitrite (ppm)	Hach Spectrophotometric	0.12-0.50	0.31-0.42	NA	NA	0.06
DO (ppm)	Electrometric DO meter	7.6-14.8	3.42-6.52	NA	NA	5
BOD (ppm)	5 days incubation, 20°C	10.8-48.5	35-67	NA	NA	5
COD (ppm)	Open Reflux	17-70.5	42-92	NA	NA	20
Phosphate (ppm)	Hach Spectrophotometric	1.1-2.6	8.2-9.84	NA	NA	5
Turbidity (NTU)	Nephelometric	15.4-45	27-56	NE	NE	1
Cl (ppm)	Titrimetric	8-12.7	22-25	NE	NE	250
Mg	Titrimetric	12-18	45-65	08-16	35-52	30
Total hardness	Titrimetric	-	-	NE	NE	300
Sulphate	Hach Spectrophotometric	1.8-3	5.0-6.8	NE	NE	150
Potassium	Hach Spectrophotometric	0.3-3.9	4-7.3	2.-2.8	3.6-7.9	200
Alkalinity (ppm)	Titrimetric	44-107	105-483	NE	NE	200
Salinity (ppt)	-	1.4-2.0	2.9-3.8	1.2-2.5	2.4-4.2	-
EC (µs cm-1)	Electrometric	148-243	282-378	142-250	102-298	300
Pb (ppb)	Atomic absorption spectro-photometric (AAS)	0.0-45	1.2-56	1.1-12	0.1-3.6	-
Cu (ppb)	AAS	4.6-102	2-24	14.173	87.8-178	-
Ni(ppb)	AAS	0.0-19	10-90.8	0.9-58	58-186	-
Zn(ppb)	AAS	0.0-161	42-84	1.1-174	64-105	-
Cr(ppb)	AAS	0.0-13.10	10-130	0.0-18	12-62	-
Fe(ppb)	AAS	10-174	121-1758	2.8-458	358-897	-
Cd(ppb)	AAS	0.0-1.2	0.2-3.5	0.0-2.6	0.0-1.8	-
As(ppb)	AAS	0.68-2.8	0.5-6.4	0.4-2.9	1.01-7	-
Mn(ppb)	AAS	0.0-15	14-173	1-45	57-185	-
Co(ppb)	AAS	8-13	12-48	1.5-18	56-189	-

The content of Nickel in was high in pond water (10-90.8 ppb), even pond catchment soil showed the highest value (58-186 ppb). The amount of Zinc ranged from (0-161 ppb), (42-84 ppb), (1.1-174 ppb) and (64-105 ppb) in river water, pond water, rover catchment soil, pond catchment soil, respectively. Chromium was found in the range of (0-130 ppb) in water and (0-18 ppb) in catchment soil. Iron content was highest in pond water (121-1758 ppb) and the least was found in river catchment soil (2.8-458 ppb). Cadmium was found in very less amount and Arsenic content ranged from (0.5-2.8 ppb) in water and (0.4 - 7 ppb) in soil catchment. Highest Manganese and Cobalt was found in pond soil (57-185 ppb) and (56-189 ppb), respectively.

The physical and chemical characteristics of the river as well as pond were found inferior in comparison to the freshwater quality. The heavy metals contamination was observed significantly higher in different samples. The soil of the catchment also contains the significant amount of the heavy metal concentrations. The bioaccumulation of the heavy metals in different samples was significantly differ may be due to the season variation in the water inputs. The variation among the metals is also subject to the input of the contaminated waters or source variation. As there were no control over the water inflow so the specific source could not be possible to identify.

Heavy metals accumulated in Castor leaves

The accumulated heavy metal in castor leaves grown in the catchment area of river and pond are depicted in **Table-2.** Heavy metal Lead (Pb) accumulation in River catchment ranged from 0.45-0.61 mg/kg and 0.37-0.53 mg/kg in pond catchment. Copper ranged from 2.86-3.73 mg/kg and 2.32-4.91 mg/kg, respectively in castor leaves grown in catchment of river and pond. Nickel accumulated ranged from 0.16-0.56 mg/kg in river catchment and 0.23-0.47 mg/kg in pond catchment. The accumulation of Zinc ranged from 5.23-18.53 mg/kg and 4.75-19.23 mg/kg and Chromium ranged from 0.12-2.54 mg/kg and 0.23-2.11 mg/kg in river and pond catchment respectively. Iron content was ranged from 3.45-4.32 mg/kg and 3.55-5.02 mg/kg. The amount of Cadmium accumulated in river was around the range of 0.42-0.53 mg/kg and in pond 0.38-0.60 mg/kg. Manganese ranged from 0.11-4.35 mg/kg and 0.23-1.65 mg/kg where else Cobalt amount ranged from 0.63-1.78 mg/kg and 0.72-1.55 mg/kg in river and pond catchment, respectively. The As content was observed only in river catchment i.e., 0.72-1.55 mg/k g.

Table 2 : Heavy metals accumulated in Castor grown (mg/kg) in the river and pond catchment.

Castor grown site	Pb	Cu	Ni	Zn	Cr	Fe	Cd	As	Mn	Co
River	0.45-4.61	2.86-3.73	0.16-0.56	5.23-18.53	0.12-2.54	3.45-4.32	0.42-0.53	0.018-0.119	0.11-4.35	0.63-1.78
Pond	0.37-0.53	7.32-8.91	0.23-0.47	4.75-19.23	0.23-2.11	3.55-5.02	0.38-0.60	ND	0.23-1.65	0.72-1.55

Rearing performance of Eri silkworm

The larval period for both control and contaminated was 18 days and average larval weight was 5.2 g shown in **Table-3**. Number of cocoons harvested from control fed was 1830 and contaminated fed was 1744. The yield per 100 dfls was 52 kg for control and 49 kg for contaminated fed.There was no significant variation observed among the silkworm rearing conducted by feeding the controlled and contaminated leaves in terms of the larval weight and larval periods. However, yield of the cocoon harvest after feeding the contaminated leaves found lower than the control. There was no variation observed under the cocoon and shell weight of the cocoon obtained after the eri rearing on the control as well as contaminated leaves.

Table 3 : Rearing performance of eri silkworm fed on the contaminated leaves and controls

Treatments	Larval Period (days)	Average Larval wt. (g)	No. of Cocoons Harvested			Yield (kg per 100 dfls)
			Seed cocoon	Defected cocoon	Total	
Control	18	5.2	1820	10	1830	52
Contaminated	18	5.2	1715	22	1744	49

Table 4 : Cocoon parameters of the control and contaminated fed silkworms

Treatments	Cocoon wt (g)	Shell wt (g)	Pupa wt (g)	Shell ratio (SR%)	Total silk (g)	Avg silk content/cocoon	Deguming lost in %
Control	3.0± 0.32	0.4± 0.04	2.6± 0.31	12.9± 1.62	7.10	0.284	15.48
Contaminated	3.0± 0.29	0.4± 0.08	2.7± 0.24	12.6± 2.00	7.90	0.316	11.24

Cocoon parameters

Pooled results of cocoon parameters of eri silkworm are presented in **Table-4**. With no difference the cocoon weight of both control fed and contaminated fed was 3.0 gm and shell weight were 0.4 gm. Pupal weight for control was found to be 2.6 ± 0.31 gm and 2.7 ± 0.24 gm for contaminated. Eri cocoon shell ratio (%) was recorded 12.9±1.62 and 12.6±2.00 for control and contaminated, respectively. Total silk content was high in contaminated fed (10 %) than control. The average silk content per cocoon was recorded 0.284 gm in control and 0.316 gm in contaminated. The degumming loss was recorded high in control (15.48%) and contaminated (11.24 %) fed castor leaves. However, the degumming loss observed in cocoon under rearing on the contaminated leaves was significantly lower. The average silk content per cocoon were found significantly higher under the eri rearing conducted on contaminated leaves than the controls.

The suitability of castor leaf growing on contaminated catchment towards ericulture was analyzed through bioassay studies and no significant impact on eri silkworm rearing was observed under the present research study. However, the detail study is needed to understand the metals specific antagonistic effects as well as to identify the tolerance limit, phytoremediation potential under the specific contamination level.

Acknowledgements

The authors are very thankful to Central Muga Eri Research and Training Institute, Lahdoigarh, Jorhat, Assam and Central Silk Board, Bangalore, for providing financial support to present work.

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