



Evaluation of Jatropha and Jacaranda growth performance in cadmium and lead contaminated soil

By
HAYAM MOHAMED ALI EBRAHIM

**A Thesis Submitted on Partial Fulfillment
of the Requirements
Governing the Award of the Degree of**

Philosophy Doctor

In

**AGRICULTURAL SCIENCE
(Horticulture - Ornamental Plants)**

Plant Production Department

Alexandria University

2022

CONTENTS

ACKNOWLEDGEMENT	
CONTENTS.....	I
LIST OF TABLES	III
LIST OF APPREVIATIONS.....	V
1. INTRODUCTION.....	1
2. REVIEW OF LITERATURE	5
2.1. Heavy metals and their effects.....	5
2.2. Some defense mechanisms used by plants against heavy metals stress.....	9
2.2.1. Physical barriers	9
2.2.2. Root exudates	9
2.2.3. subcellular structure.....	10
2.2.4 Chelation	10
2.3. phytoremediation technology.	12
2.4. Heavy metal (HM) uptake mechanisms in plants.....	13
2.5. Reasons affecting the uptake mechanisms of phytoremediation.....	16
2.6. Phytoremediation advantages.	18
2.7. Usage of <i>Jatropha</i> and <i>Jacaranda</i> plants as phytoremediators for heavy metal contaminated soils.	19
2.8. Effect of heavy metals on vegetative growth and chemical composition of the plants.....	23
2.8.1. Vegetative growth	23
2.8.2. Chemical composition	25
2.9. Soil properties after the plantation.....	28
3. MATERIALS AND METHODS	32
4. RESULTS AND DISCUSSION	37
4.1. Vegetative growth, chemical composition and phytoextraction efficiency of <i>Jatropha curcas</i> as affected by various levels of Cd and Pb in the soil	37
4.1.1. Aerial parts traits	37
4.1.2. Roots parameters	39
4.1.3. Leaf N, P, K, total carbohydrate % and green color degree.	41

4.1.4. Cd and Pb contents and uptake in the plant parts and total plant uptake.....	43
4.1.5. Phytoextraction potential of cadmium and lead by jatropha.....	47
4.1.6. Soil analysis after the experimental period.....	51
4.2. Vegetative growth, chemical composition and phytoextraction efficiency of <i>Jacaranda mimosifolia</i> as affected by various levels of Cd and Pb in the soil.	53
4.2.1. Aerial parts traits	53
4.2.2. Roots characters	55
4.2.3. Leaf N, P, K, total carbohydrates % and green color degree.....	57
4.2.4. Cd and Pb contents and uptake in the plant parts and total plant uptake.....	59
4.2.5. The relation between Cd and Pb levels in the soil and their concentrations in plant organs.	62
4.2.6. Soil analyses at the end of experiment	65
5. SUMMARY AND RECOMMENDATION.....	67
6. LITERATURE CITED.....	71
7. ARABIC SUMMARY	7

LEST OF TABLES

<u>Table</u> <u>NO</u>		<u>Pages</u> <u>NO</u>
1	Soil analysis before plantation.	36
2	Growth traits of jatropha as affected by Cd and Pb levels in the soil after the experimental period	38
3	Roots traits of jatropha as affected by Cd and Pb levels in the soil after the experimental period	40
4	Leaf chemical composition of jatropha as affected by Cd and Pb levels in the soil after the experimental period	42
5	The content of Cd and Pb in jatropha parts as affected by Cd and Pb levels in the soil after the experimental period	45
6	The uptake of Cd and Pb of jatropha parts and total uptake/plant as affected by Cd and Pb levels in the soil after the experimental period	46
7	The BCF shoots, BCF roots, TF% and Cd and Pb total accumulation rate (TAR) of jatropha as affected by Cd and Pb levels in the soil after the experimental period	48
8	The TI biomass and TI roots of jatropha as affected by Cd and Pb levels in the soil after the experimental period	50
9	Soil physical and chemical analysis before planting and soil chemical analysis at the end of experiment as affected by Cd and Pb levels in the soil after plantation of jatropha	52
10	Growth traits of jacaranda as affected by Cd and Pb levels in the soil after the experimental period	54
11	Root traits of jacaranda as affected by Cd and Pb levels in the soil after the experimental period	56
12	Leaf chemical composition of jacaranda as affected by Cd and Pb levels in the soil after the experimental period	58
13	The content of Cd and Pb in jacaranda parts as affected by Cd and Pb levels in the soil after the experimental period	60

14	The uptake of Cd and Pb of jacaranda parts and total uptake/plant as affected by Cd and Pb levels in the soil after the experimental period	61
15	The BCF shoots, BCF roots, TF% and Cd and Pb total accumulation rate (TAR) of jacaranda as affected by Cd and Pb levels in the soil after the experimental period	63
16	The TI biomass and TI roots of jacaranda as affected by Cd and Pb levels in the soil after the experimental period	64
17	Soil physical and chemical parameters before planting and soil chemical analysis as affected by Cd and Pb levels in the soil after plantation of jacaranda	66

LIST OF APPREVIATIONS

HMs	Heavy metals
Cd	Cadmium
Pb	Lead
L	LOW
M	Medium
H	High
D.W.	Dry weight
F.W.	Fresh weight
BCF_s	Bioconcentration factor of shoots
BCF_r	Bioconcentration factor of roots
TAR	Total accumulation rate
TF	Translocation factor
T_{ib}	Tolerance index of biomass
T_{ir}	Tolerance index of roots
EC	Electrical conductivity
pH	Power of hydrogen
ROS	Reactive oxygen species
O.M.	Organic matter
μM	Micro mole
mM	Milli mole
SO₂⁻	Superoxide
SPAD	Soil plant analysis diagnosis
mg Kg⁻¹	Milligram/kilogram
%	Percentage
H₂O₂	Hydrogen peroxide
TWW	Treated wastewater

5- SUMMARY

A pot experiment was conducted at Antoniadis Garden, Hort. Res. Inst. Alex. Branch, Ministry of Agric., Egypt to study the combinations effect of Cd and Pb at different levels during the period of 1st April 2020 to 1st August 2021 on vegetative growth, chemical composition and phytoextraction potential of *Jatropha curcas* and *Jacaranda mimosifolia* plants, as well as, the soil properties after the experimental period.

The treatments were conducted as follows:

- 1- control.
- 2- L Cd + L Pb (Cd nitrate and Pb nitrate at 40 and 400 mg/kg soil, respectively).
- 3- M Cd + M Pb (nitrate of Cd and Pb at 80 and 800 mg/kg soil, respectively).
- 4- H Cd + H Pb (nitrate of Cd and Pb nitrate at 120 and 1200 mg/kg soil, respectively).
- 5- L Cd + H Pb.
- 6- H Cd + L Pb.
- 7- M Cd + H Pb.
- 8- H Cd + M Pb.

The experimental design was randomized complete design (RCD). The results could be summarized as follows:

Effect of Cd and Pb treatments on vegetative traits, chemical composition and phytoextraction potential of jatropha and jacaranda plants, also soil characters after the plantation.

5.1. Aerial parts traits:

- The two species tolerated Cd and Pb till the highest concentrations with survival 100%.
- All treatments of Cd and Pb in the most cases caused significant reduction in plant height, stem diameter, branches number, area/leaf and fresh and dry weights of leaves and stems in relative to the control of two plant kinds. The values of such traits were related with the levels of HM_S in the treatment.

5.2. Root parameters:

- The length of the longest root and roots fresh and dry weights of the two species were negatively affected by all used combinations of Cd and Pb in comparison to the control treatments, with one exception in case of L Cd L Pb which resulted in nonsignificant increase in the root length of jatropha over than the control.
- The differences among the applications treatments of Cd and Pb did not reach the significant level in the most cases of such traits for the two species.

5.3. The leaf chemical composition:

- The all used Cd and Pb treatments caused significantly decreases in the leaf green color degree and the percentages of N, P, K and total carbohydrate in comparing to the control of two plant kinds. Also, the differences among Cd and Pb used combinations reached the significant level in the some cases of such parameters.

5.4. Cd and Pb contents and uptake in the plant organs:

- The contents and uptake of Cd and Pb in the leaves, stems, roots and total uptake/plant of jatropha and jacaranda plants were related with their levels in the soil. Where high level of either Cd or Pb in the treatment raised its contents and uptake in the plant organs.
- The contents of Cd and Pb in the fallen leaves of the two plant kinds were negligible in relative to their contents in the green leaves. Therefore, the risk of the fallen leaves is not dangerous.
- The content and uptake of Cd and Pb of jatropha were in order of roots > leaves > stems. While in jacaranda the content of Cd was in order of roots > stems > leaves for some treatments and it was stems > roots > leaves for the other ones. On the other side the uptake of Cd and Pb and the content of Pb were in order of roots > stems > leaves of jacaranda, with some exceptions.

5.5. Relationship between Cd and Pb concentration in the plant organs and their concentrations in the soil:

- In general, the values of BCF_s , BCF_r , TAR, TI_b and TI_r were dependent on the levels of Cd and Pb in the soil.

For jatropha, BCF_s and $BCF_r < 1$ of Cd and Pb, while $TF\% > 100 (> 1)$ with one exception of Pb $TF\%$ of control. TAR was increased with increasing Cd and Pb levels in the soil. Also, TI_b and TI_r were less than one and the values of $TI_b > TI_r$ under the same treatment except for L Cd L Pb $TI_r > TI_b$. From the results of BCF_s , BCF_r , TF, TAR, TI_b and TI_r it can be concluded that jatropha plants can use as a phytoextractor for Cd and Pb contaminated soil.

Concerning jacaranda plant, Cd BCF shoots and roots < 1 and Cd $TF\% > 100 (> 1)$. It means that jacaranda can use as a phytoextractor for Cd contaminated soil, while, Pb BCF shoots and roots < 1 and $TF\% < 100 (< 1)$, it means that jacaranda can use as a phytostabilizator for Pb contaminated soil. Also, TAR of Pb $>$ Cd under the same treatment and TAR of Cd and Pb was related to their levels in the soil. TI_b and TI_r did not take certain trend for the different treatments and they were < 1 .

5.6. Soil properties at the end of experiment:

- In general, after planting of either jatropha or jacaranda in various levels of Cd and Pb contaminated soil, some changes in soil parameters were occurred. Where, soil pH, EC, Na⁺, Cl⁻, HCO₃⁻ and SO₄⁻ values increased over than before planting.
- On contrast, the values of O.M, CaCO₃, Ca⁺⁺, Mg⁺⁺, K⁺, and available N, P, and K were reduced in comparison their values prior to planting.
- Also, the levels of Cd and Pb after plantation were decreased in relative to their added levels before planting.