ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 08, Issue, 08, pp. 22365-22370, August, 2018

ORIGINAL RESEARCH ARTICLE

OPEN ACCESS

COMPARISON PHYTOEXTRACTION OF Pb, Cd, Cu AND Zn BY THREE PLANT SPECIES: *CYPERUSESCULENTUS, DATURAINNOXIA* AND *RICINUSCOMMUNIS*

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ARTICLE INFO

Article History:
Received 22nd May, 2018
Received in revised form
06th June, 2018
Accepted 11th July, 2018
Published online 31st August, 2018

Key Words:

Pollution, Traces Metallic, Phytoextraction, Cyperusesculentus, Datura innoxia, Ricinuscommunis.

ABSTRACT

Background: Population's exponential growth leads to an increase of human activities that brings large amounts of pollutants that contaminate soils and century plants by metallic elements Trace (ETM). These, like Cu, Pb and Cd cause serious issues. Material and methods: In this study, experiments in culture pots were conducted. Three plant species, Cyperusesculentus, Daturainnoxia and Ricinuscommunis were tested. Cultures were made in two soil types (low polluted and highly polluted soils) contaminated by ETM Cd, Cu, Pb and Zn. They were watered daily with tap water. Results: After one month of culture, the results showed that in the low polluted soil, Cyperusesculentus reduced by 110.96%, 0.025% and 51.26% respectively for an initial Zn concentration of 66.8 mg / kg, in Pb of 61.31mg / kg and in Cu of 33.61%. In highly polluted soil, it reduced by 10.63%, 120%, 34.67% and 44.27% respectively for an initial Pb concentration of 125 mg / kg, Cd of 0.58 mg / kg, Cu of 208.48 mg / kg and Zn of 139.83 mg / kg. In the low polluted soil, Daturainnoxia reduced by 110.96%, 0.025% and 51.26% respectively an initial Zn concentration of 66.8 mg / kg, Pb of 61.31 mg / kg and Cu of 33.61%. While in high polluted soil, it reduced by 10.63%, 120%, 34.67% and 44.27% respectively for an initial Pb concentration of 125 mg / kg, Cd of 0.58 mg / kg, Cu of 208.48 mg / kg and Zn of 139.83 mg / kg. In the case of Ricinuscommunis, this plant species reduced by 110.96%, 0.025% and 51.26% in the low polluted soil respectively for an initial Zn concentration of 66.8 mg / kg, Pb of 61.31 mg / kg and Cu of 33.61%. %. In the highly polluted soil, she reduced by 10.63%, 120%, 34.67% and 44.27%, respectively, an initial Pb concentration of 125 mg / kg, a Cd of 0.58 mg / kg, a Cu of 208.48 mg / kg and a Zn of 139.83 mg / kg. Conclusion: These three plant species are a very good subjects for phytoremediation of multipolluted soils by MTEs like Pb, Cd, Cu and Zn.

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Citation: Fanna Abdou Gado o. 2018. "Comparison phytoextraction of pb, cd, cu and znby three plant species: cyperusesculentus, daturainnoxia and ricinuscommunis", *International Journal of Development Research*, 8, (08), 22365-22370.

INTRODUCTION

Niger is a West African country which the population is estimatedat 20 751 801 inhabitants with a growth rate of 3.90% peryear (INS, 2017). Its capital and largest city is Niamey with an estimated population of 1,175,446 inhabitants in 2017 (INS, 2017). Thus, since the early nine centuries the industrial activity of companies has grown and enabled part of humanity to significantly improve its living conditions. But this intensive exploitation of nature has also had the effect of degrading the environment to the point of becoming a threat to population's health. One of the main environmental concerns is the pollution of soils and waters by metallic trace elements (Franck, 1999).

According to Baize (1997) the contamination of middle by the Metallic Traces Elements (MTEs) designates an increase of the total contents of these elements in the medium following important anthropic contributions. According to Akujobi (2012), MTEs are serious environmental pollutants, especially in areas of high anthropogenic pressure; their presence in the atmosphere, soil and water, even in the form of traces, can cause serious illness for all living organisms. The accumulation of these MTEs in soils is a concern for agricultural production due to their adverse effects on crops growth, the quality of food products and Health Rights (Augusto, 2001). According to Lee *et al.,* (2001), mining is one of the largest sources of HTAs in the environment. Mining and milling operations, concentration and tailings disposal are major sources of environmental contamination (Adriano, 1986). Thus, the pollution of our environment is caused by human activities.

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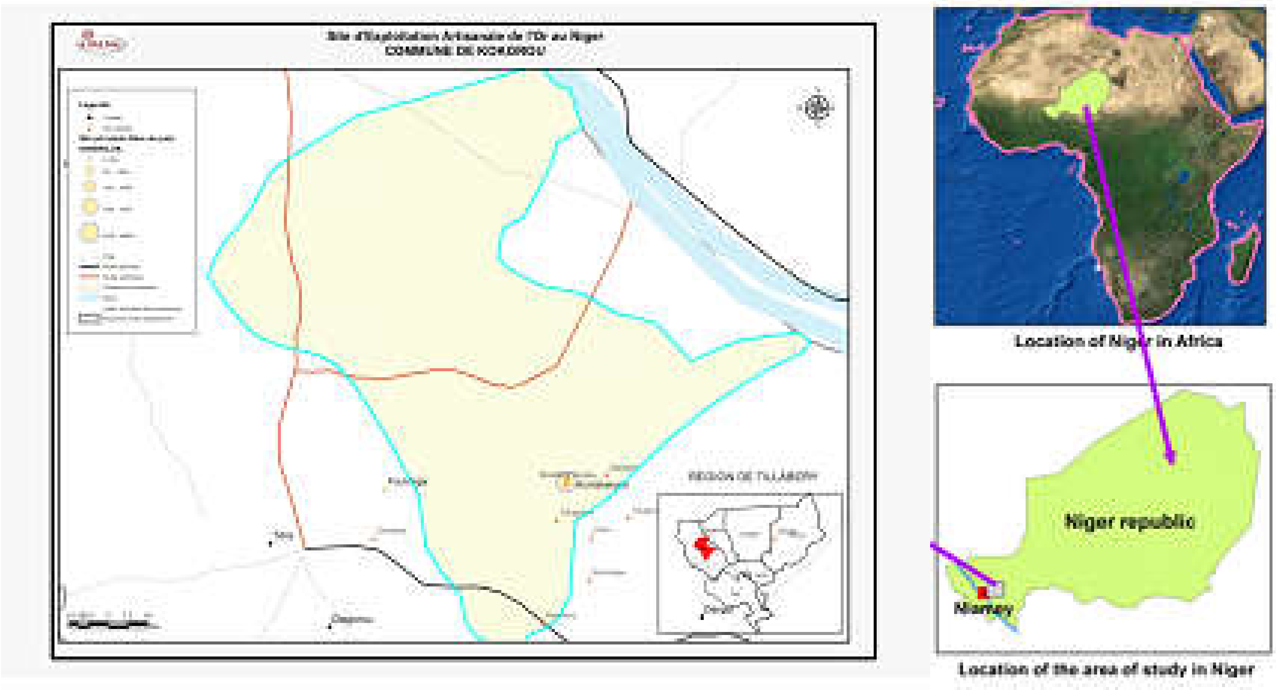

Figure 1. Location of the area (EXOR, 2013)

MTEs found in soils and natural waters may reach very high concentrations. Their presence in soils considerably modifies the floristic composition of the sites, allowing the installation of only a limited number of species supporting their toxicity. However, the accumulation of these non-degradable and potentially toxic MTEs in soils represents a great risk for humans because of their passage through the food chain. In order to preserve environment and restore soil quality, several remediation techniques exist for soils polluted by MTEs: physicochemical techniques and biological techniques. Alternatively, to conventional or physicochemical treatments, biological techniques that use the depolluting power of microorganisms (yeasts, bacteria, fungi) or plants are under development. More and more research is trying to exploit nature's ability to regenerate itself. The interest of these biological techniques rely essentially on the fact that they are natural, do not require excavation or transport, which makes their implementation very effective and less expensive, more extensive and more respectful of environment and soil. This is how phytoremediation has the advantage of not affecting the quality of the soil and it does not cost much. Applied to MTEs, phytoremediation uses the transfer of the element to the plant. However, the main obstacle of this technique of depollution by plants is the generally long treatment time and also the understanding and optimization of this phytoremediation technique. Today, research continues to bring more knowledge on phytoremediation (Abdou Gado *et al.,* 2018). This research aims to provide new data on the extraction and / or accumulation of MTEs by some plants. The research focus on phytoremediation of polluted soils by *Cyperusesculentus, Daturainnoxia* and *Ricinuscommunis*. The objective is to demonstrate how these plant species are able to clean up soils contaminated with ETM through their extraction and accumulation in their vegetative parts.

MATERIAL AND METHODS

Sitesand soils of the study: The polluted soils studied come from the Komabangouin NIGER gold zone at latitude The polluted and unpolluted soils were taken 0-10 cm from the ground with a shovel and transported in bags to the soil science laboratory of the Faculty of Agronomy of AbdouMoumouni's University of Niamey. After drying at room temperature (<30 ° C), they are crushed and sieved at a fraction of 2 mm. Soils samples are then sent to the Geology Laboratory of the Faculty of Sciences at the University of Lomé in Togo for the determination of Pb, Cu, Cd and Zn by atomic absorption.

Plant material

In this study, our choice fell on three plant species namely: *Cyperusesculentus*, *Daturainnoxia* and *Ricinuscommunis*. They were selected following the inventory of plant species in the GountiYena valley and the search for those likely to be used in phytoremediation (AbdouGado *et al.,* 2016).

Presentation of*Cyperusesculentus*

From its scientific name *Cyperusesculentus*, commonly referred to as "nutmeg", is a herbaceous plant belonging to the large family Cyperaceae, highly invasive plants that compete with other plant species in mineral and water nutrition (Toukoua *et al.,* 2002). The plant species of the genus Cyperus have a very wide distribution. Several plant species are identified and distributed in the regions of America and tropical Africa. In Niger, about thirty species of sedges have been identified.

Classification

According to the classical classification, *Cyperusesculentus* belongs to:

- Kingdom: Plantae
- Class: Lilipsidae (monocotyledons)
- Order: Cyperales (lemmas)
- Family: Cyperaceae

- Genus: Cyperus
- Species: *Cyperusesculentus*

Inflorescences: The inflorescence is a compound umbel. The 3 to 4 involucral bracts are similar to the leaves. The racemes comprise 3 to 30 spikelets with parallel edges. They are more or less elongated depending on the variety, but always pale yellow or dark brown and contain from 6 to 30 flowers (Dodet, 2006).

Leaves: With a tritium phyllotaxis, the leaves are almost all basal, with sheaths with flat probing edges, and their lamina is traversed by a very tight network of small longitudinal veins. At maturity, in the first 7 leaves formed, there are 11 vascular bundles (Dodet, 2006).

Rods: The stems are herbaceous without full secondary formations. There are two types of stems: aerial stems and underground stems.

Roots: They are fasciculate, short and have a diameter of about 1mm. They have rhizomes at the ends of which tubers are formed. They can reach a depth of 50 cm or more (Dodet, 2006).

Tubercules: The tubers result from thickening on several distal internodes of certain rhizomes. On the same foot, the shapes and dimensions of these tubers can be quite variable. Lorougnon (1969) thus describes an African variety whose tubers can reach 2.5 cm of lengh and 1.5 cm thick and are sometimes sub-spherical, sometimes elongated and elliptical.

Ecology: Sedges prefer moist, swampy areas. Some species are aquatic, others terrestrial (Illiassou, 1994). The dose of water required for its vegetative cycle is between 400 to 600 mm / year. However, a rainfall of about 350 mm may be suitable for its vegetative cycle. However, a dryness at the stage of tuberizationcan seriously compromises the yield (Adere, 2010). In general, light soils rich in organic material are suitable for nutgrass cultivation. However, sedges grow equally well on sandy soils, moist sandy clay (stream bed, shallow bottom, lake edges) as on dune soils (Gambo, 2005). Soils rich in organic material are suitable for sedges and this is why a large amount of organic manure was added to traditional culture. *Cyperusesculentus* responds well to phosphorus, nitrogen and potassium. The late intake of these causes the excessive development of the organs to the detriment of the formation of the tubers (Adere, 2010). Nutsedge is very noisy both on field and during storage, however, some animals that dig almonds can cause significant losses onthe field and at the store, termites, breccias and rats can cause damage importance is negligible (Toukoua*et al.,* 2002).

Presentation of *Daturainnoxia*

Daturainnoxia is a perennial annual plant that usually grows near homes. This plant is well known for an ability to quickly drugging and its negative effect on the nervous system (AbdouGado*and al.,* 2016). This plant comes from Central America in tropical and subtropical areas. It belongs to the Solanaceae's family. It is an her baceous robust port drawn little or shortly branched from 0.3 to 1.5m in height.

- The underground part consists of fleshy roots, very developed. The aerial part is covered with a dense, clear down.
- The stems: 50 to 150 cm high, are thick, cylindrical, robust and branched.
- Leaves borne by a rather long petiole, can reach 20cm long, they are simple leaves, alternate, are of dark green color, a little bluish and some are asymmetrical.
- Flowering: the flower from a conical bud at the beginning, which extends considerably and whose envelope is constituted by the welded sepals.
- The fruit is an open capsule of non-sharp spines and can reach 5 to 7 cm in diameter. It contains several hundred seeds reminiscent of tomato.

Presentation of *Ricinuscommunis*

Known as castor, *Ricinuscommunis* is a shrub of Euphorbiaceae's family. It is poorly represented in the Gounti Yena Valley, but only grows on places where pollution is very remarkable. It grows only close to wastewater, which would justify that the castor, in addition to the nematic virtues would be an accumulator of ETM or at least one plant tolerant to the pollution.

Experimental apparatus

The experimental setup is a completely randomized Fischer block. Soils are distributed at a rate of 1.5 kg in pots of 12 cm of diameter and 13 cm of height. The tubers of *Cyperusesculentus* are introduced into the pots as well as the seeds of *Daturainnoxia* and *Ricinuscommunis*. The pots are watered daily with tap water (100 ml / pot).

MATERIALS AND METHODS

The length of aerial parts are measured weekly using a graduated ruler. That s roots and stems were made s at the end of the culture and after separation of different vegetative parts. After one (1) month of cultivation, the plants are gently removed from the pots. They are carefully washed with tap water and then with distilled water and all the precautions (contact between the different parts of the plant and the substrate) are taken to avoid possible contamination of samples. The roots, stems and leaves are separated with a chisel. These different vegetative parts are dried at room temperature and then in a 60 ° oven for 24 hours for total dehydration. The dry matter produced by each plant species is weighed, crushed, well-conditioned and well labeled. The crushed parts of each part are sent to the Geology Laboratory of the Faculty of Sciences of the University of Lomé in Togo to determine the concentrations in the plant in Pb, Cd, Cu and Zn by atomic absorption.

Calculation of Treatment Efficacy

From the concentrations of metals in the soil before and after phytoremediaion, the treatment efficiency (ET) can be calculated for each plant species according to the following formula:

$$ET (\%) = [(Ci - Cf) / Ci] \times 100$$

Ci (Initial Concentration) and Cf (Final Concentration) represent, respectively, the metal concentrations (mg / kg) in the soil in the initial state before phytoremediation and in the soil in the final state after phytoremediation.

RESULTS AND DISCUSSION

MTEs concentrations in soils: The results of ETM concentration analysis in little polluted soils and in very polluted are summarized in Table 1. The table shows that in low polluted soils the concentrations of ETM are higher than those measured in highly polluted soils. Indeed, they are 61.3090 mg / kg, 0.0005 mg / kg, 33.615 mg / kg and 66.7030 mg / kg respectively for Pb, Cd, Cu and Zn in the soil highly polluted against 125.056 mg / kg, 0.5817 mg / kg, 208.4805 mg / kg and 139.8387 mg / kg respectively for Pb, Cd, Cu and Zn in highly polluted soil.

Table 1. Concentrations of MTE in mg / kg in soils before phytoremediation

	Low polluted soil	Highly Polluted Soil
Pb	61.309	125.056
Cd	0.0005	0.5817
Cu	33.615	208.4805
Zn	66.7030	139.8387

Compared with the standards of Baize (2005) which are 54 mg / kg for Pb, 0.5 mg / kg for Cd, 28 mg / kg for Cu and 88 mg / kg for Zn all concentrations in ETM in low polluted soils exceed these standards except for Zn which the concentration of 66.30 mg / kg is near to the standard of 88 mg / kg. On the other hand, in highly polluted soil all the concentrations measured exceed the standards of Baize (2005). Indeed, the Pb is 2.31 times higher than the normal, the Cu is 7.44 times higher than the standard and the Zn is 1.58 times higher than the normal.

Phytoextraction of MTEs by plant species

Table 2 shows the quantities of metals extracted from soils that are low and highly polluted per plants species growth on both types of soils. This table shows that the levels taken by *Cyperusesculentus* in highly polluted soil are 10.63%; 120% ; 34.67% and 44.27% respectively for Pb, Cd, Cu and Zn. It is therefore the Cd that is most extracted by *Cyperusesculentus.* This result is corroborated by the results of Kirpishchikova et *al.* (2009) who found that Willow extracts more Cd than Pb and Cu. The Cd concentration extracted by *Cyperusesculentus* in the highly polluted soil which is 0.6963 mg / kg or 120% is higher than the initial Cd concentration in the highly polluted soil, 0.5817 mg / kg. Here, it should be known that the speciation and mobility of an MTE evolves over time, and this evolution can lead to more and more stable or increasingly mobile forms of MTE (Chang *et al.,* 1997; Grath *etal.,* 2000). Dere *etal.* (2006) conducted studies on the long-term speciation of MTEs in soil polluted by the spreading of raw wastewater for 100 years. They determined the different phases involved in the retention of MTEs. The existence of endogenous and exogenous MTEs means that they are distributed in different horizons and phases of the soil. Thus, a horizon rich in organic matter can adsorb a huge amount of ETM (Hall *etal.,* 2002). So the plant which uses soil's organic matter will also extract the associated ETMs. This will increase the amount of MTEsextracted from the soil by the plant. In conclusion, these results can be explained by a stabilization of metals over time, ie their evolution towards non-extractable forms as suggested by Emmerich*et al.* (1982) or by the re-adsorption of some of the metals extracted in the previous steps on the remaining phases and / or by the incomplete destruction of the metal bearing phases in the previous steps (Nirel and Morel, 1990; Cornu and Clozel, 2000). In other words, the extraction of the different ETMs will depend of many factors (origin and mobility of the ETM, saturation or not of the sites, phase involved in their retention) which explain the different contents of ETM in the different profiles of the soil (Dere*et al.,* 2006). These results also show that in the case of *Cyperusesculentus* it is the Cd that is the most phyto vailable since it has been the most extracted and it could also be the most mobile.

It is followed by Zn, Cu and Pb. Pb is therefore the least extracted element by *Cyperusesculentus.* All the percentages (except that of Cd) show that the extraction of metals by *Cyperusesculentus* in highly polluted soil is not very important compared to the initial concentration of ETM in highly polluted soil. Similar results were obtained by Kirpishchikova *et al.* (2009) in the treatment of polluted soils by three plants despite fourteen months of cultivation. This result suggests that *Cyperusesculentus* would be very tolerant to metal pollution in highly polluted and hyperaccumulative soil of MTEs. The addition of chelating agents or complexing agents can significantly increase the yield of phytoremediation (Rock, 2003; Anderson, 2000).

The yields of a phytoremediation are very variable and difficult to compare because they depend on the experimental conditions, the plant, the number of crops, the nature of the soil, the level and nature of pollution, etc. and can not be generalized to all cases. In the low polluted soil *Cyperusesculentus* adopts another behavior. In fact, the extracted Cu and Zn contents of 51.26% and 110.96%, respectively, increased compared to 34.67% and 44.27% in the highly polluted soil. This observation shows that the Cu and Zn extraction capacity by *Cyperusesculentus* depends on the degree of soil pollution. However, for the Pb, its extraction is stronger in the highly polluted soil that little polluted. This can be explained by the fact that Pb is more mobile and therefore more phytovailable in highly polluted soil than in polluted soil. These results therefore highlight the ability of *Cyperusesculentus* to extract metals. ETM extraction by *Cyperusesculentus* shows first its tolerance and resistance to the presence of these pollutants and then its ability to phytoaccumulated and / or phytoextracted these pollutantsthrough its vegetative parts.

With regard to the plant species *Daturainnoxia*, the extraction of Zn (41%) is the most important by *Daturainnoxia* in highly polluted soil. Kirpishchikova *et al.* (2009) found that Willow extracts more Zn than Pb and Cu. Zn is followed by Cd, Cu and Pb. The Zn element therefore appears as the most phytovailable. The effectiveness of the treatment in the highly polluted soil by *Daturainnoxia* is 41% for Zn; 16.24% for Cu, 35.27% for Cd and 6.34% for Pb. The contents taken by *Daturainnoxia*inlow polluted soil increase. However, Zn content (232.71%)is still the highest. These results therefore show that in the case of *Daturainnoxia*, the more the concentrations of ETM increase the more its extraction capacity decreases. In the case of *Ricinuscommunis*, the contents extracted in the low polluted soil are 4%, 512.7% and 260.53% respectively for Pb, Cu and Zn. In highly polluted soil they are also 2.46%, 60.8% and 136%. In low polluted soil, *Daturainnoxia* extracts more Pb than *Cyperusesculentus* and *Ricinuscommunis.*

Table 2. Pb, Cd, Cu and Zn contents (%) accumulated by *Cyperusesculentus*, *Daturainnoxia* and *Ricinuscommunis* grown on low and highly polluted soils.

	Cyperusesculentus		*Datura innoxia*		*Ricinuscommunis*	
	Lowpolluted	Highlypolluted	Lowpolluted	Highlypolluted	Lowpolluted	Highlypolluted
Pb	0.025	10.63	5.16	6.34	4	2.46
Cd	-	120	-	35.27	-	0.25
Cu	51.26	34.67	106.68	16.24	512.7	60.8
Zn	110.96	44.27	232.71	41	260.53	136

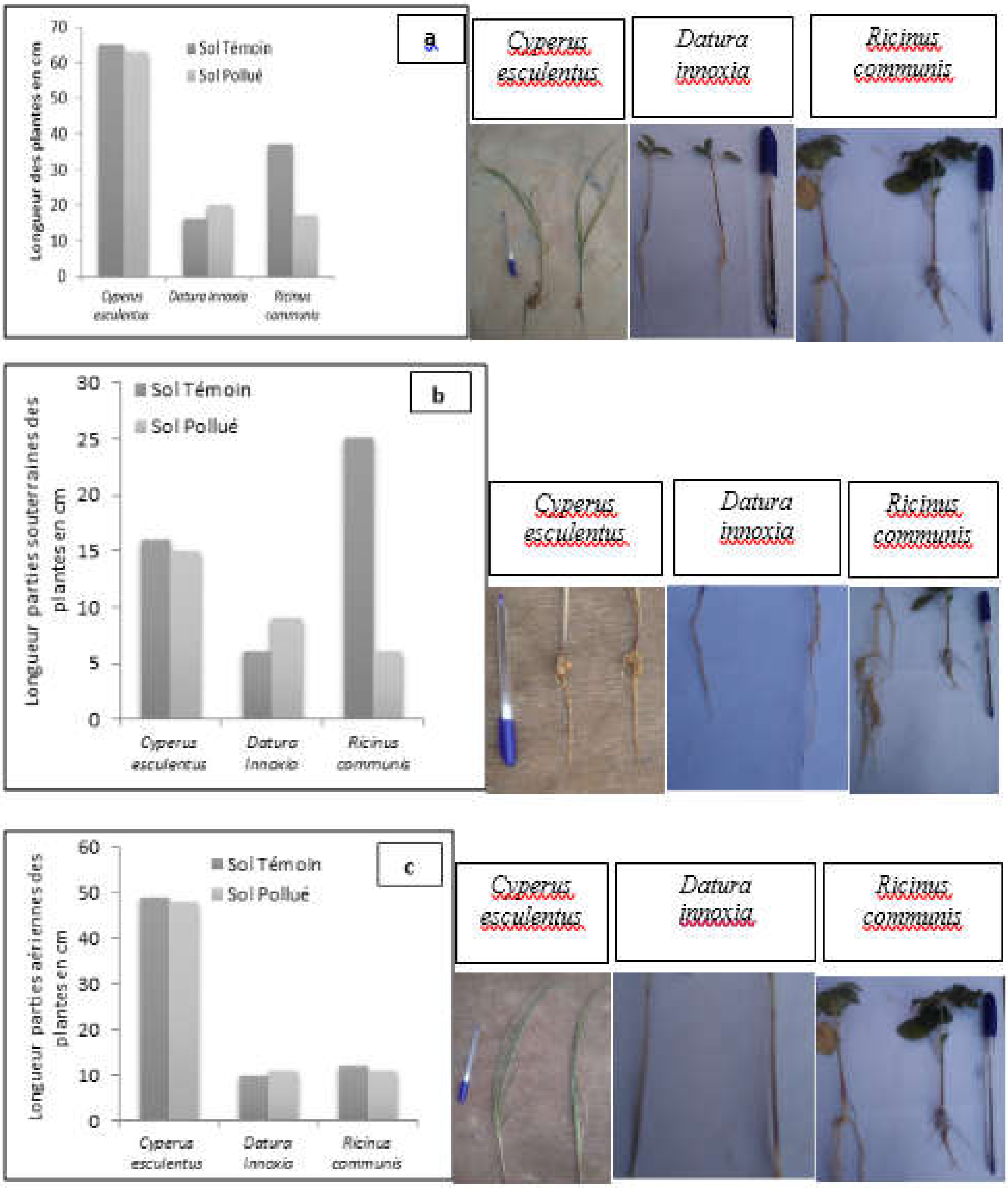

Figure 2. Whole length of the plant (a), length of the underground part (b) and length of the aerial part (c) of the plants in the control and polluted soils.Pics: from left to right, the plants in the control soil and in the polluted soil.

To extract Cu and Zn, *Ricinuscommunis*is very well. In highly polluted soil, *Cyperusesculentus* extract more Pb and Cd. Cu and Zn are better extracted by *Ricinuscommunis*.

Development of plant species

Figure 1 shows the development of *Cyperusesculentus*, *Daturainnoxia* and *Ricinuscommunis* after one (1) month of culture in control and polluted soils.

In polluted soil, it appears that apart from *Ricinuscommunis* for roots all plants have adapted to pollution. In other words, they have been tolerant to pollution. They grew as well as the plants in the control soil. Regarding *Cyperusesculentus* and *Daturainnoxia*, they showed similar development to the control. However, *Ricinuscommunis* in the control soil exhibits more than the same root development in the polluted soil. These results suggest that *Ricinuscommunis* did not fit well as

Cyperusesculentus and *Daturainnoxia* in polluted soil that developed similarly to the same species in the control soil. This shows that *Ricinuscommunis* is less hyper accumulative than *Cyperusesculentus* and *Daturainnoxia*. The aerial and root parts of *Cyperusesculentus* are the longest. On the other hand, the length of the aerial part of *Daturainnoxia and Ricinuscommunis* are similar. From all these results, it is clear that *Datura innoxia* grown in polluted soil has developed much more than the two other plants. It is followed by *Cyperusesculentus* and *Ricinuscommunis*. In sum, despite the high concentrations of MTEs(Pb 125 mg / kg; Cd 0.5817 mg / kg; Cu 208.4805 mg / kg and Zn 139.8387 mg / kg) exceeding the regular standards of Baize, (1993-2005) and Bowen, (1979), the three plant species except *Ricinuscommunis* developed well on polluted soil. They showed no signs of intolerance or symptoms of toxicity. On the contrary, they showed a similar development to a control that we did (growing plants on unpolluted soil removed from all sources of pollution). The development of the root systems of *Cyperusesculentus* and *Daturainnoxia* indicates that they are good subjects for phytoremediation. Indeed, in addition to its depolluting power the plant must have a good development and a good architecture of the root system.

Conclusion

This experimental study phytoremediation in two soils polluted by the ETMs shows that *Cyperusesculentus, Daturainnoxia* and *Ricinuscommunis* are good species that could decontaminate polluted soil by several metals. Indeed, at the end of this study, we suggest, *Daturainnoxia* for the extraction of Pb and *Ricinuscommunis* for the extraction of Cu and Zn in soil slightly polluted by the ETM. To clean-up highly polluted soil by the ETM, we strongly recommend the plant species *Cyperusesculentus* for the extraction of Pb and Cd and *Ricinuscommunis* for the extraction of Cu and Zn. Among the three plant species, the decontamination capacity of *Ricinuscommunis*seems to be greater than the decontamination capacity of the two other (*Daturainnoxia* and *Cyperusesculentus*). No matter the pollution degree of soil, *Ricinuscommunis* can extract metals. On the other hand, *Cyperusesculentus* is very efficient for the depollution of very polluted soil. In future studies, it would be interesting to follow the speciation of these metals after and during phytoremediation and to take in account the mobility of MTEs in soils.

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