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Absorption and Accumulation of Heavy Metals by *Atriplex* under Phosphoric Fertilizers (Phosphate rock, Organophosphate and TSP)

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ABSTRACT

This work aims to measure the impact of heavy metals contained in phosphate applied on plants. Thus, we applied three different phosphate fertilizers on sylvopastoral plants of the genus Atriplex family Chenopodiaceae. In addition to a reference TSP fertilizer, phosphate rock (DO20) we used organophosphate with an optimal dose of 200ppm of P2O5. The contents of metallic elements were measured by atomic absorption spectrophotometry, at soil level and in leaf tissue of tested plants. In general, spectral analysis by AAS showed a high bioaccumulation of toxic heavy metals, exceeding in most cases, the standards for all species. We concluded in this work that the studied species responded differently to metallic pollution. We also concluded that a natural fertilizer gave relatively less depressed view results recorded on one side and that it is not issue from a polluting industry on the other side.

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INTRODUCTION

The phosphates are almost used in their totality in the agricultural sector, where 85% are used like fertilizers and 5% as additives for the animal fodder. Whereas, in other sectors (detergent industry, pharmaceutical, metallic...) the used quantities don't pass the 10% [1, 2]. Indeed, to maintain the present level of the agricultural world production, it is necessary to assure a permanent addition of nutritive elements to the soils and the cultures [3, 4]. To replace the nutritive elements absorbed by the plants and therefore to improve the soil fertility, the phosphoric fertilization is then a key element, from which the development of agriculture can perpetuate itself [5].

However, the phosphates contain tracers of heavy metals, of which most frequent are zinc (Zn), the copper (Cu), the cadmium (Cd), lead (Pb), the nickel (Nor) and mercury (Hg) [6]. No negligible quantities of these elements will transit, probably, toward the fertilized soils [7, 8]. The variations of the levels of these heavy metals can have important repercussions on the ecosystem, because they can be transferred to the plant or animal commodities [9, 10]. It is therefore indispensable to control the contributions of the agricultural input in order to supervise the quantities of the metallic elements that risk to pass in transit and to contaminate the whole ecosystem.

In this perspective, our global objective consisted to evaluate the contamination risks of the steppic agro-system by heavy metals when various phosphoric fertilizers are brought. The used fertilizers are: a natural phosphoric fertilizer (the DO_{20}) under its mineral and organo-mineral shape and a commercial fertilizer (the TSP) which is considered as a reference fertilizer.

MATERIAL AND METHODS

Experimental site:

The test took place in a pastoral nursery in a semi-arid region of the South Tebessa city situated in the northeast of Algerian (Figure 01). The area is steppic plain dominated by xero-halophytes bushes and

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characterized by a graduated and shallow chalky soil. The physical and chemical characteristics of this soil are shown in the Table 01.

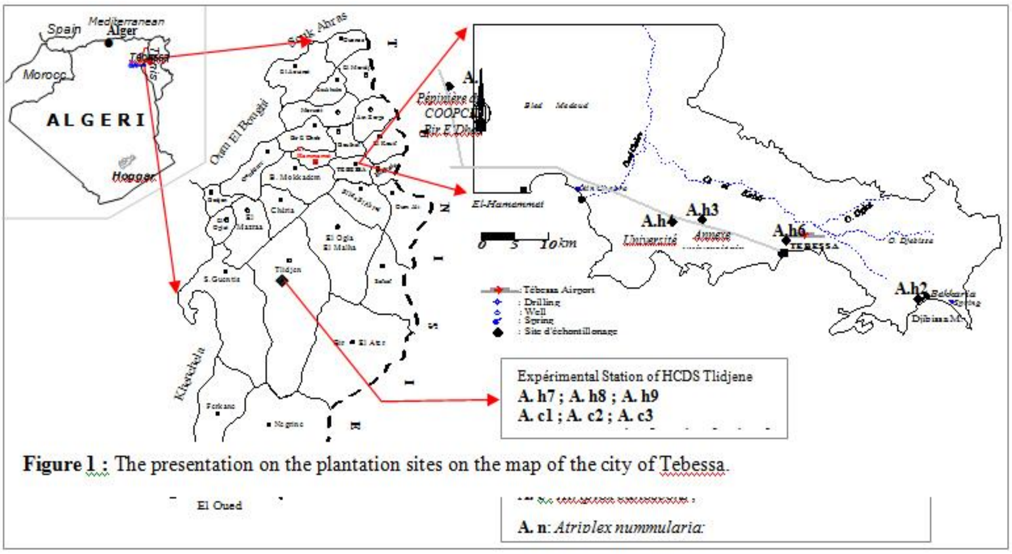

Fig. 1: The presentation on the plantation sites on the map of the city of Tebessa.

Table 01: Physicochemical characteristics of the soil [12].

Parameter	*Values*	*Analysis Method*
pH (eau)	8.062	pH meter
P total	5.01	Olsen
Cu (ppm)	9.305	Spectrophotometer of atomic absorption
Zn (ppm)	50.68	
Mn (ppm)	124.85	
Cd (ppm)	2.677	
Cr (ppm)	35.861	
Ni (ppm)	17.55	
Assimilated P	0.02	Olsen
Organic matter (%)	1.67	% Dry matter

Used fertilizers:

Three phosphoric fertilizer shapes have been used: the Triple Super Phosphate (TSP) with 46% of P_2O_5 that served as a fertilizer reference; the DO_{20} that is a natural fertilizer (Rock phosphate) with 20% of P_2O_5. The chemical characteristics are shown in Table 02. The DO_{20} has been brought under two aspects: a grind raw mineral aspect and an organo-mineral aspect (OP) (mixed with the sheep manure with equal parts). The quantity of the phosphoric fertilizers brought to the plants is equivalent to a dose of 200 ppm of P by Kg of soil, considered as an optimal concentration [11].

Table 02: Chemical analysis of the natural phosphate (DO_{20}) [13].

Parameters	*Values* (%)	Parameters	*Values* (ppm)
CaO	41.14	Cl	248
P_2O_5	20.87	Cd	31
F	2.56	Mn	59
S_iO_2	4.92	Pb	15
Al_2O_3	1.31	Sn	1.426
Fe_2O_3	0.64	As	10
Na_2O	0.90	Co	/
K_2O	0.14	Zn	315
MgO	5.83	Cu	5
CO_2	15.49	Organic C	0.25%
S	0.84	H_2O	0.69%

DO_{20} = Djebel Onk phosphate with 20% of P_2O_5 (national phosphoric resource).

Plants:

The tested plants (Figure 02) are fodder bushes belonging to three halophytes species of *Atriplex* kind: *A. halimus*, *A. canescens* and *A. nummularia* coming respectively from the North Africa [14], the North America [15, 16] and Australia [17]. They are implanted since 6 years under the natural conditions of the area.

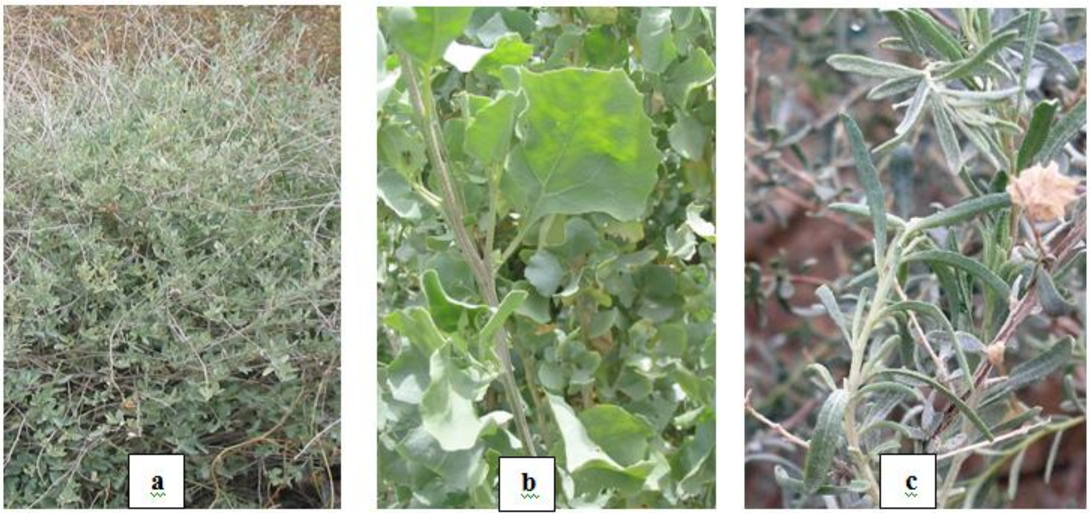

Fig. 2: Photos of studied species: Atriplex: a- A. halimus, b- A. nummularia, c- A. canescens.

Statistical analysis:

The data have been treated by the variance analysis and the averages have been compared by Newman-Keuls test (p <0.05). The correlations between the studied parameters have been deducted from a global correlation matrix. These statistical analyses have been made using statistical software (Statistica version 6, 2002).

RESULTS AND DISCUSSIONS

The results showed a very variable content of heavy metals in the leaves of the studied plants. Indeed, we observed the lowest values in *A. halimus* and the most elevated values in *A. canescens*. However, *A. nummularia* was characterized by intermediate rates. It is important to signal that these contents are affected positively by the phosphoric fertilization, particularly in *A. halimus* and *A. canescens*. Whereas *A. nummularia* doesn't react to the fertilizers, except in the case of the cadmium.

Table 03: The rate of transfer of heavy metals from soil to plant

Rate of transfer	*A. halimus*	*A. nummularia*	*A. canescens*
Cu	10,55	21,88	23,40
Zn	5,16	3,64	4,14
Mn	0.58	0.33	0.57
Cd	3.8	6.11	3.15
Cr	15,55	16,66	25,18
Ni	4,5	20,0	17,6

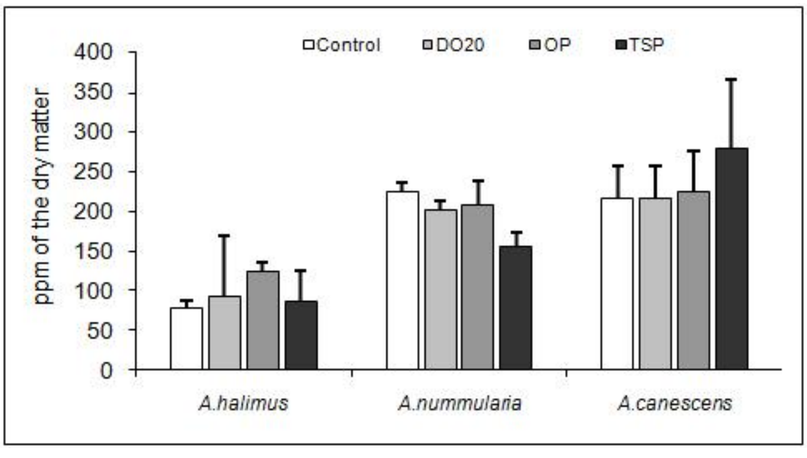

Fig. 3: Variation of the content in Cu of three Atriplex species under phosphoric fertilizers

Figure 03 presents the contents of *Atriplexes* leaves in copper that appears in the norms [18] (under the toxicity threshold). The studied species showed a faculty and a variability to accumulate the Cu in their tissues (soil doesn't contain 9.3 ppm anymore). Concerning the fertilizers, the treated plants are affected slightly and present some values upper or under than the control plants particularly those belonging to *A. halimus* and *A. canescens*.

Contrary to the Cu, the leaf content in Zn is in most cases, inversely influenced by the phosphoric fertilization (Figure 04). According to certain author [19], the phosphoric fertilizers could decrease the bio-availability of the Zn in soil, by creating the insoluble phosphate of the zinc.

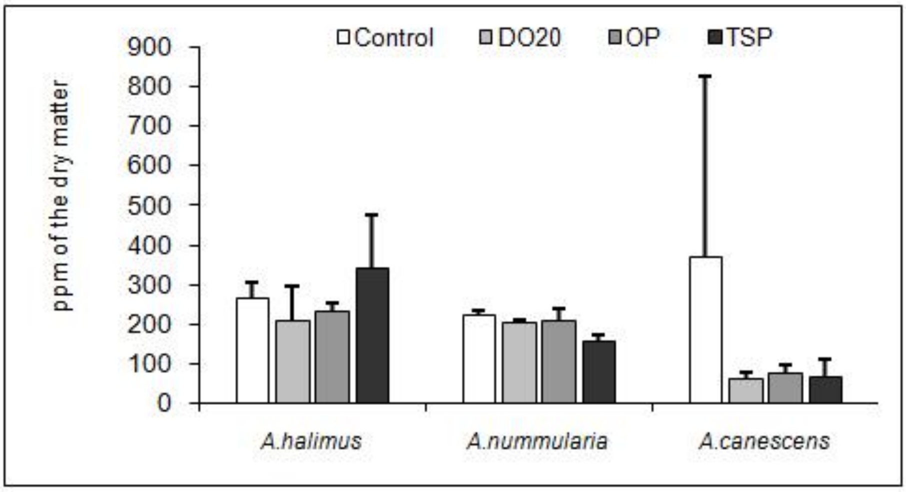

Fig. 4: Variation of the content in Zn of three Atriplex species under phosphoric fertilizers.

The rates of the manganese (Figure 05) varied simultaneously with those of the copper according to the phosphoric fertilization; however it rests in the norms [20, 21] and without reaching rates of transfers (soil-plant) superior than 1 (Table 3.).

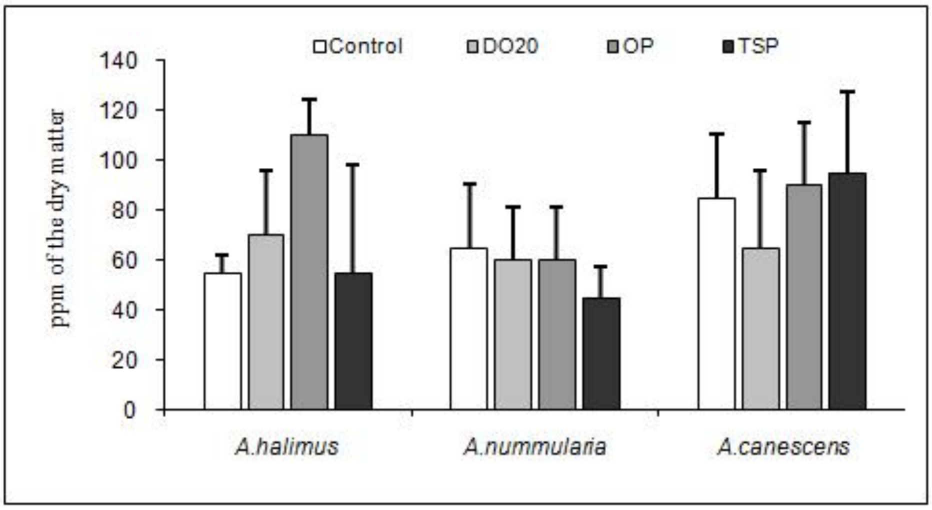

Fig. 5: Variation of the Content in Mn of three Atriplex species under phosphoric fertilizers.

Concerning the strictly toxic heavy metals (Cd, Cr and Ni), the content of the leaves in cadmium (Figure 06) shows clearly that all the fertilized plants present values higher than the control plants and the norms [22, 23]. Several authors reported that the phosphates are responsible for the increase level of the cadmium in the soil and its bio-availability is elevated for the plants [7, 9, 24, and 25].

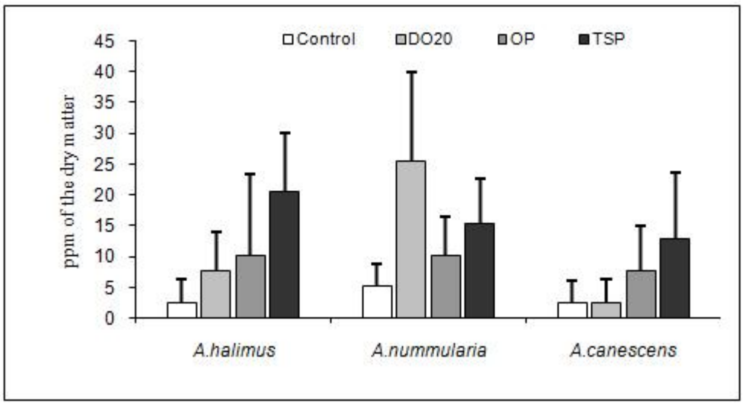

Fig. 6: Variation of the content in Cd of three Atriplex species under phosphoric fertilizers.

The contents of the plants in chromium in the three plant species (Figure 07) pass extensively the norms [26]. The phosphoric fertilization amplifies these rates, without being the principal cause, because the rate of the chromium in the control plants is upper than the norms. It seems that, in addition to the increased content of the Cr in the soil (17.55 ppm in table 01), the elevated bio-accumulator character of the plants can explain these values. Although the studied species of *Atriplex* don't show any sign of toxicity for the Cr, these rates can be very dangerous for the rest of the ecosystem (fodder nature of the studied plants).

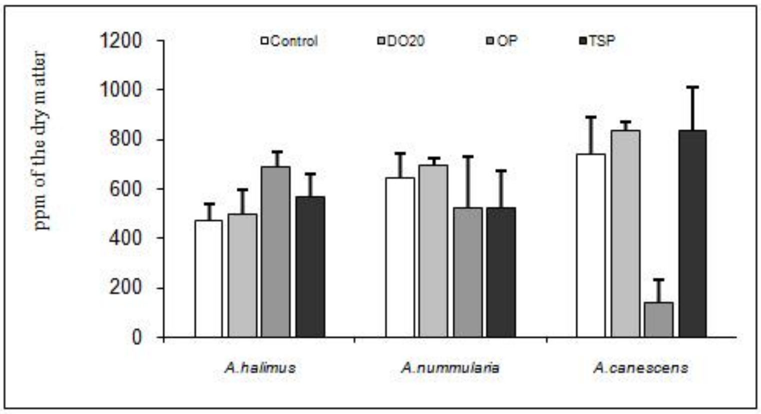

Fig. 7: Variation of the content in Cr of three Atriplex species under phosphoric fertilizers.

The nickel concentration in the leaves appears much related to the phosphates addition (Figure 08). Indeed, the tissues of the treated *A. halimus* and *A. canescens* are more charged in Ni than in the control plants. *A. halimus* presents a content of Cr in its leaves clearly upper than the norms. However in the two other species, the contents of Cr pass amply the tolerable threshold, noting that the content of the soil in this element is normal.

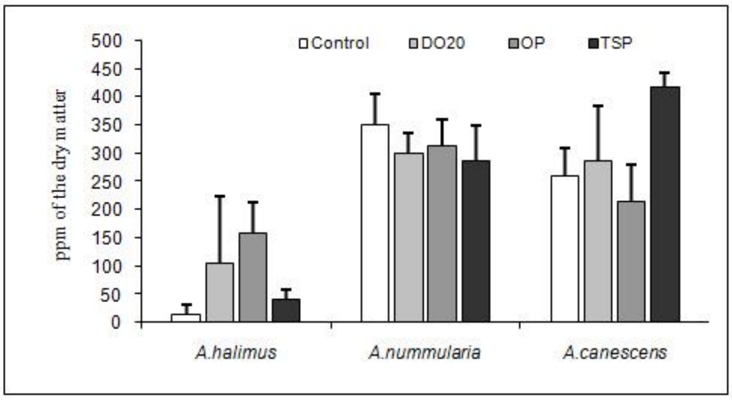

Fig. 8: Variation of the Content in Ni of three Atriplex species under phosphoric fertilizers.

General conclusion:

Considering the conditions of our experimentation, we can conclude that the *Atriplexes* are characterized by an hyper-bioaccumulation of some heavy metals, particularly those considered most toxic (Cd, Cr and Ni). The last character varied greatly between the studied species, where *A. canesence* accumulates more Cu and Cr, *A. halimus* accumulates more Zn and Cd, whereas *A. nummularia* is characterized by intermediate rates.

The phosphoric fertilization appears secondaly implied in this phenomenon (except the case of Cd) and even less for the natural phosphates.

The use of *Atriplexes* as fodder is probably accompanied by a high risk of contamination of the food chain, because of the high registered contents of heavy metals in their leaves.

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