Interdisciplinary study of trace-elements distribution and their uptake by flax plants. Chemical speciation in agricultural soil and microscopical analysis of plant tissues

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INTRODUCTION

Flax seeds are widely used in animal food because of their high content in Omega 3 . A number of heavy metals (trace-elements, TEs) are essential as micronutrients; however, they become highly toxic at supraoptimal concentrations. For instance, in field conditions, they can accumulate in the plants at high quantities which are incompatible with their introduction in the food chain. In order to control this risk and evaluate the uptake of TEs, it is necessary to assess the contents of various chemical species of TEs in the soil and in the plants (total content and the contents of each organ).

We were mainly interested in evaluating the presence of the following elements: Cu, Cd, Ni, Pb and Zn in soils on which flax plants were grown. Two situations have been compared: the first one corresponds to fields into which some sludge of water-treatment were brought in agronomic doses, similar to integrated cultural practices (Gamaches-en-Vexin, Normandy, France) and the second corresponds to fields plot irrigated by waste water over a long period which led to an accumulation of TEs in the soil (Herblay, Paris Region, France).

We are currently performing TEs extraction from both soil types and plants by using two different methods: a sequential and a total extraction (mainly assisted by microwaves). The data will be compared and presented. Our aim is to study all these extractions (Table 1) which one of each have a different agronomic interpretation and to correlate them to the different results of our experiments.

METHODS

Several methods are used to extract and determine the availability of TEs in fractions of the soil. We chose four single extractions (HF, Aqua Regia, EDTA, Ultrapure water) and an optimised sequential extraction inspired from the BCR Programm.

RESULTS AND DISCUSSION

The data obtained by EDTA are stable, nevertheless we could have expected a reduction thanks to the absorption of the bioavailable TEs through the plants. This stability may be due to a TEs redistribution in the soil during growth.

Though the total content variation be poorly significative between the beginning and the end of growing, the flax seeds accumulate TEs (hence the usefulness to determine the partial content of TEs by sequential extraction in order to understand the transfer mechanisms). The soil-plant transfer coefficient is calculated like the ratio of the concentration of TEs in the flax seed to the soil one (Table 2).

Table 1. Copper contents (mg/kg fine dry soil) of the most contaminated profile of Gamaches and Herblay plot versus the cultural steps and the extraction type. Assay of 2002.

	Gamaches plot			Herblay plot		
Extractant	Sowing	Flowering	Maturation	Sowing	Flowering	Maturation
Ultrapure Water	2.0	1.6	0.6	5.4	3.2	1.7
EDTA	2.8	2.7	2.7	61.1	62.5	60.6
Aqua regia	8.9	9.1	8.1	201.0	192.7	184.3
HF	13.0	12.1	8.9	211.2	200.0	190.4
HF µwave assisted	13.1	12.3	8.9	213.3	200.2	195.5

Table 2. Coefficient of transfer of Cu, Zn, Ni, Cd and Pb through seeds flax in plot of Herblay according to its TEs content (mg/kg).

Content in soil and seed	**Cu**	**Zn**	**Ni**	**Cd**	**Pb**
Soil (sowing)	211	564	38	2.86	381
Seed	20	99	0.792	0.792	0.41
Coefficient of Transfer	0.099	0.175	0.021	0.277	0.001

In addition, the content and localization of TEs in flax plants as well as their possible effects on the tissue organization are presented. At the maturation step, we observe a widening of the xylemian (X) tissue as well as mature fiber beam (F) presenting an important thickening of the cellular wall (Figure 1).

Following these observations, we do not notice any difference concerning the anatomic organisation of Oliver and Astral varieties. Therefore, the fiber beams appear to be for most cases, more numerous in the Oliver variety than in the Astral variety.

CONCLUSIONS

The TEs total contents does not reflect their mobility. The sequential extraction allows us to determine TEs-soil associations and remains a way to understand the mechanisms of soil-plant transfer. Oxides and organic matter bound fractions constitute an important source of TEs. Cd, Zn and Cu are three metals potentially available for the oleaginous flax crop. The precision of this procedure is generally good, the limiting factor being the inherent heterogeneity of the soil.

During 2003, complementary measurements will be made to confirm these first results:

- for the soil: speciation in solid phase by Extended X-ray Absorption Fine Structure analysis in parallel of the sequential chemical extractions,
- for the plant : Electron Energy Loss Spectroscopy to localize TEs in tissue of the different organs, and phytochelatines, polysaccharides extractions (compound may be bound in TEs) and analysis.

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