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Posters

Effects of Soil Tillage and Fertilization on the Arsenic Uptake in Durum Wheat

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Introduction

The increasing heavy metal contamination with concentrations of trace elements, especially arsenic, is a serious problem due to their toxicity and carcinogenicity. Arsenic accumulation in plants is slowly increasing in various parts of the world through anthropogenic activities and the industrial effluents that are released in soil and water. Although Arsenic is not an essential element for plant growth, it can be adsorbed and accumulated in plant tissues, including those of vegetables, fruits and grains, therefore it represents a potential risk to human health due to its toxicity. Worldwide, durum wheat (*Triticum durum* Desf.) kernels are used for the production of staple foods, such as pasta and bread, thus, in a wheat-based diet a large amount of Arsenic could enter in the food chain and cause human health issues. It is well known that arsenic accumulation in agricultural plants is related to the availability of Arsenic in the soil, the physiology of plants and several soil factors, mainly pH, moisture, microbial community and nutrient dynamics. Several methods have been adopted to reduce the concentration of Arsenic in the contaminated sites, but generally all these methods are costly and low efficient. A proper use of soils in agricultural cropping systems could represent a suitable way to reduce the risks of food contamination, however few studies have investigated the effects of agronomical practices on Arsenic accumulation in agricultural plants and their products. This study hypothesized that the soil tillage and fertilization practices could affect Arsenic accumulation in durum wheat. The main objective of this study was to evaluate how soil tillage (plowing, ripping and spading) and fertilization source (mineral and organic) affect Arsenic accumulation on durum wheat.

Materials and Methods

The field trial was realized at the “Nello Lupori” experimental farm of the University of Tuscia located in Viterbo (Central Italy - 45°25'N, 12°04'E, Alt. 310 m a.s.l.). The experimental site is located in a volcanic area with a high concentration of Arsenic in the soil due to deep-rising fluids of the active geothermal systems. The average soil characteristics in the 0 - 30 soil layer are: 63% sand, 22% silt and 15% clay. Moreover, the total organic carbon and nitrogen are 1,07% and 0.12%, respectively, while the pH is 7.1. The climate of the area is Mediterranean typical of Central Italy, with cold, wet winters and hot, dry summers. The weather conditions, measured in an automating weather station located near the field experiment, were similar to that observed in the long term period (30-year).
The experimental treatments were: (i) two fertilization type [mineral fertilizers; organic fertilizer (composted urban organic waste)]; (ii) three tillage method at a depth of 30 cm [plowing tillage, subsoiling tillage, spading tillage]. The experiment was conducted in a complete randomized block design with three replications. The plot size was 50 m^2 (10 x 5 m).
The experiment was carried out in a field where the previous year was cultivated sorghum crop. After the sorghum harvesting, residues were finely chopped and uniformly distributed in the soil surface. In September, the soil was tilled following the above-mentioned treatments and, then, it was harrowed in order to break soil clods for the seed bed preparation. The organic fertilizer (15 t ha^{-1}) was distributed in one application before the harrowing. Mineral fertilizers were applied according to the practices adopted in the study area by distributing the phosphorus (80 kg ha^{-1}) before the harrowing, and the nitrogen at the beginning of tilling stage (20 kg ha^{-1}), at the end of the tilling stage (30 kg ha^{-1}) and at the beginning of stem elongation (50 kg ha^{-1}). Durum wheat var. Antalis was sown on November 29th, 2018 and harvested

on June 25th, 2019. Yield and yield characteristics, straw, roots and leaves of durum wheat were collected from a 1 m^2 quadrant randomly placed in the middle of each plot. Arsenic content in all plant samples was determined by an atomic absorption spectrophotometer. The Arsenic concentration was expressed as milligrams per kilo of dry weight (mg kg^{-1} of D.M.).
Data obtained from the experimental trials were statistically analyzed by analysis of variance (ANOVA) using JMP statistical software package version 4. Fisher's protected least significant differences (LSD) test at the 0.05 probability level ($P < 0.05$) to compare the effects was used.

Results

The yield, straw and harvest index (HI) of wheat were significantly affected by both soil tillage and fertilization source. Wheat grain yield varied from 322 to 135 g m^{-2} of DM and tended to be higher in subsoiling and spading soil tillage than a plowing and on mineral than organic fertilizers, except in subsoiling tillage where no differences were observed between the fertilizer sources (Fig. 1).
Reduced tillage practices, as subsoiling and spading, could have enhanced water availability in the soil for the crop, especially in May when durum wheat needs a large amount of water for filling the spikes. It is known that mineral fertilization has positive effects on grain yield of durum wheat, especially if split based on the crop needs. The straw data followed a similar trend to that described in seed yield.
The Arsenic accumulated into durum wheat plants was mainly distributed in the roots, followed by leaves, then kernels and stems (Tab. 1), however, there were significant differences among the treatments. Indeed, in whole plants, it was the highest in plow treatments under mineral fertilization source (0.735 mg kg^{-1} of DM).

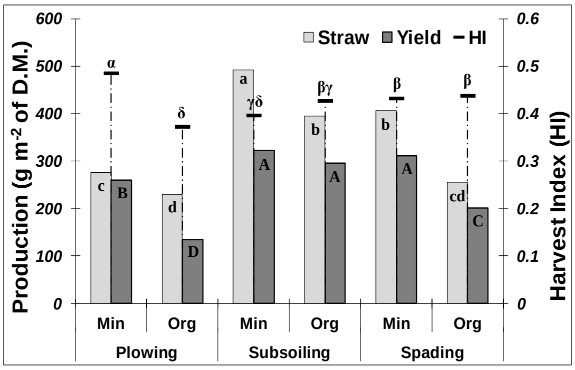

Figure 1. Durum wheat production and harvest index (HI). Values belonging to the same parameter with different letters are statistically different according to LSD (P < 0.05).

Table 1. Arsenic accumulation in durum wheat. Values belonging to the same parameter with different letters are statistically different according to LSD (P < 0.05).

		Arsenic accumulation (mg kg^{-1} of DM)				
		Roots	Stems	Leaves	Kernel	Whole plant
Plowing	Mineral	0.531 a	0.025 a	0.162 a	0.016 b	0.735 a
	Organic	0.439 a	0.025 a	0.103 b	0.015 b	0.583 b
Subsoiling	Mineral	0.370 b	0.026 a	0.035 c	0.030 a	0.461 c
	Organic	0.374 b	0.018 b	0.045 c	0.033 a	0.470 c
Spading	Mineral	0.162 c	0.016 b	0.034 c	0.035 a	0.247 d
	Organic	0.291 c	0.021 ab	0.049 c	0.019 b	0.380 d
Distribution (%)		75.4 A	4.6 C	14.9 B	5.1 C	

The data highlights that adoption of subsoiling or spading soil tillage determined a reduction of Arsenic accumulation in the whole plant of durum wheat (on average -29% and -52%, respectively). Few differences were detected on the fertilizer sources in agreement to Stazi et al. (2018), even if it looks that the adoption of organic fertilizers contributes to the mitigating of the accumulation of Arsenic in the durum wheat plants. Although spading showed high values of Arsenic content in the kernels, the values are abundantly lower compared the recommended thresholds suggested by the European Food Safety Authority regarding dietary exposure.

Conclusions

This study demonstrated that the adoption of sustainable agronomical practices, such as reduced tillage and organic fertilization, could contribute to reduce the Arsenic uptake in durum wheat in contaminated soil and thus help the reducing the risks for human health.

Literature

Stazi S.R., Mancinelli R., Marabottini R., Allevato E., Radicetti E., Campiglia E., Marinari S., 2018. Influence of organic management on As bioavailability: Soil quality and tomato As uptake. Chemosphere 211: 352-359.