Presence of Arsenic in Argentinian Rices. Strategies to Minimize Them

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INTRODUCTION

Arsenic (As) is a ubiquitous chemical element present in nature that is harmful to living beings; it has been classified as a carcinogen class 1 and its toxicity depends on its chemical form, resulting the inorganic forms arsenite (AsIII) and arsenate (AsV) more toxic than organic forms, such as monomethylarsonate (MMA) and dimethylarsinate (DMA). It is known that rice is one of the major contributors to the consumption of inorganic As for humans. Because of this, recently the Codex Alimentarius Commission defined as maximum values of total As and inorganic As in polished rice of 0.30 mg kg^{-1} and 0.20 mg kg^{-1} respectively. Rice is efficient in absorb high amounts of As because the anaerobic condition generated from flood increases the AsIII availability and mobility. Natural resources used for rice production in Entre Ríos (E.R.) province are characterized by low total contents of As both water (10-23 ug L^{-1}) as soil (1.4 to 5.6 mg kg^{-1}), resulting in mean values of total As in polished rice grains of 0.34 mg kg^{-1}, with large differences according to production areas and cultivated varieties. Fortunately, the largest proportion of As is in organic form. There is a geographical variation, the fields located at north of E.R. province present the greatest records of total As in rice grain. Another source of variation is genetic, with minimum values of total As of 0.22 mg kg^{-1} in the Yeruá variety and maximum of 0.54 mg kg^{-1} in the Cambá variety. In Argentina there are few studies concerning the As in agriculture, especially in flooded soils. Globally, most published works have been performed in contaminated soil with As, experiments pots or nutrient solutions. Moreover, it have documented numerous studies on possible management practices to minimize absorption and accumulation of As in rice grain, but very few of them have been conducted in real situations of commercial production fields. Considering all these antecedents, several studies were conducted in order to establish agronomic practices to reduce the concentration of As in rice under field conditions.

Effect of irrigation management and incorporation of plant residues

In a first case, in three field assays was evaluated the effect of irrigation management. The interruption of anaerobic conditions during the vegetative period, allowed significantly reduce the level of total As in unpolished rice grains from 0.60 mg kg^{-1} in continuous irrigation to 0.35 mg kg^{-1} in irrigation interrupted (Figure 1), and also the percentage of empty grains, which decreased from 16% to 13%. This practice did not affect rice yields and neither increased demand for phosphorus (P) or zinc (Zn) fertilization, elements that also reduce their availability when the soil is dried.

In a second study, we examined the effect of water management (continuous and interrupted irrigation) combined with incorporation of plant residues over yield and As absorption. The interruption of irrigation consisted drainage 15 days before entering the panicle differentiation phase, to then re-flood to maturity. This allowed obtaining very good yields (10900 kg ha^{-1}), with decrease of the concentration of DMA in unpolished rice grains (20-50 % lower than continuous irrigation). The soil aeration accelerates the decomposition of organic matter, helping As oxidation in arsenate, which is biologically inactive, and reducing the As methylation. On the other hand, the permanent flooding with the incorporation of rice stubble generated lowest yields (6280 kg ha^{-1}), caused by a decrease of the destinations and with a level of 48% incidence of empty grains. Predominance of DMA species in rice of Entre Ríos would be responsible for grains sterility. Under local conditions of soil and microbial flora, continuous irrigation promotes high availability of organic species of As and presence of physiological disorder known as "Straighthead", that produces high percentage of empty and deformed grains.

Effect of interaction of arsenic, phosphorus and zinc addition in soil

Another evaluated practice was phosphorus and zinc fertilization. The soil phosphate favors the desorption arsenate, thereby increasing their mobility and availability to plants. In E.R. province, the addition of phosphate fertilizer in many cases depresses the rice yield despite being soils with low levels of available P; a probable explanation would be the natural release of arsenic from soil. In addition, there is evidence that As can form precipitated or low solubility compounds with metals such as iron or Zn, which would reduce their availability. With the aim to evaluate the effect of interaction of As, P and Zn on yield of rice and absorption of these elements, assays were developed during two campaigns in six fields of commercial production, with addition of P, Zn and As, and in some cases, interaction with irrigation management was tested. It was observed that under natural conditions of low availability of As, the fertilizations with P and Zn did not improve yield or affected the absorption of As by rice. On the other hand, in soil with high availability of As, the yield was severely affected but, the combined addition of P and Zn allowed mitigate its toxic effect, observing in addition, a decrease of 26% of total As content in unpolished rice grains (Figure 2). This decrease in yield related to reduction in number of panicles m^{-2} and increase of empty grains. Separate applications of Zn and P had little effect on yield, low interaction with irrigation management and did not affect concentration in rice grain of As or other nutrients evaluated.

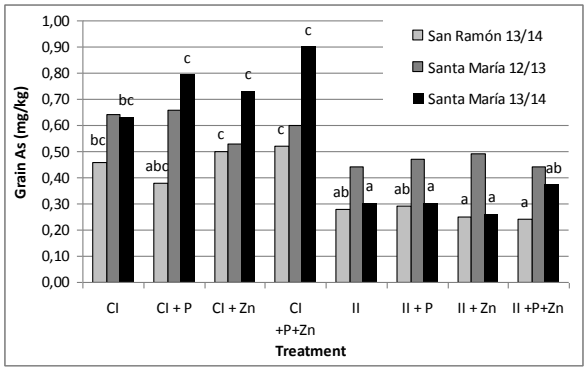

Figure 1. Concentration of total As in rice grain according to treatment and tested site. CI: continuous irrigation; II interrupted irrigation; +P, +Zn, +Zn+P: fertilization with P, Zn and P+Zn respectively.

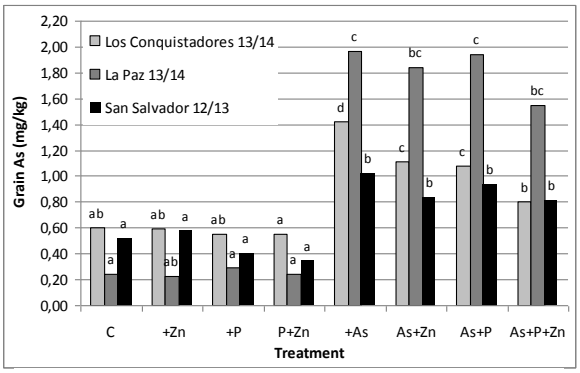

Figure 2. Concentration of total As in rice grain according to treatment and tested site. CI: continuous irrigation. C: control; +As: As addition; +P, +Zn, +Zn+P: fertilization with P, Zn and P+Zn respectively.

Conclusions

These preliminary results in the study of dynamics of As in soil-plant system under field conditions are key to assess its absorption by rice, understand the factors controlling nature of species of As in soil solution and consequently its bioavailability. In this way, it should be developed effective management strategies to reduce concentrations of As in rice grain.

For the moment and under these conditions, the drainage and drying of rice field, along with the selection of varieties of lower absorption of As, are best alternatives to reduce concentration of As in rice grains. In addition to not affecting the yield, the interruption of irrigation would favor a greater efficiency in use of water.

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