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A case study on minerals interaction in the soil and Se enrichment in Rice (*Oryza sativa* L.)

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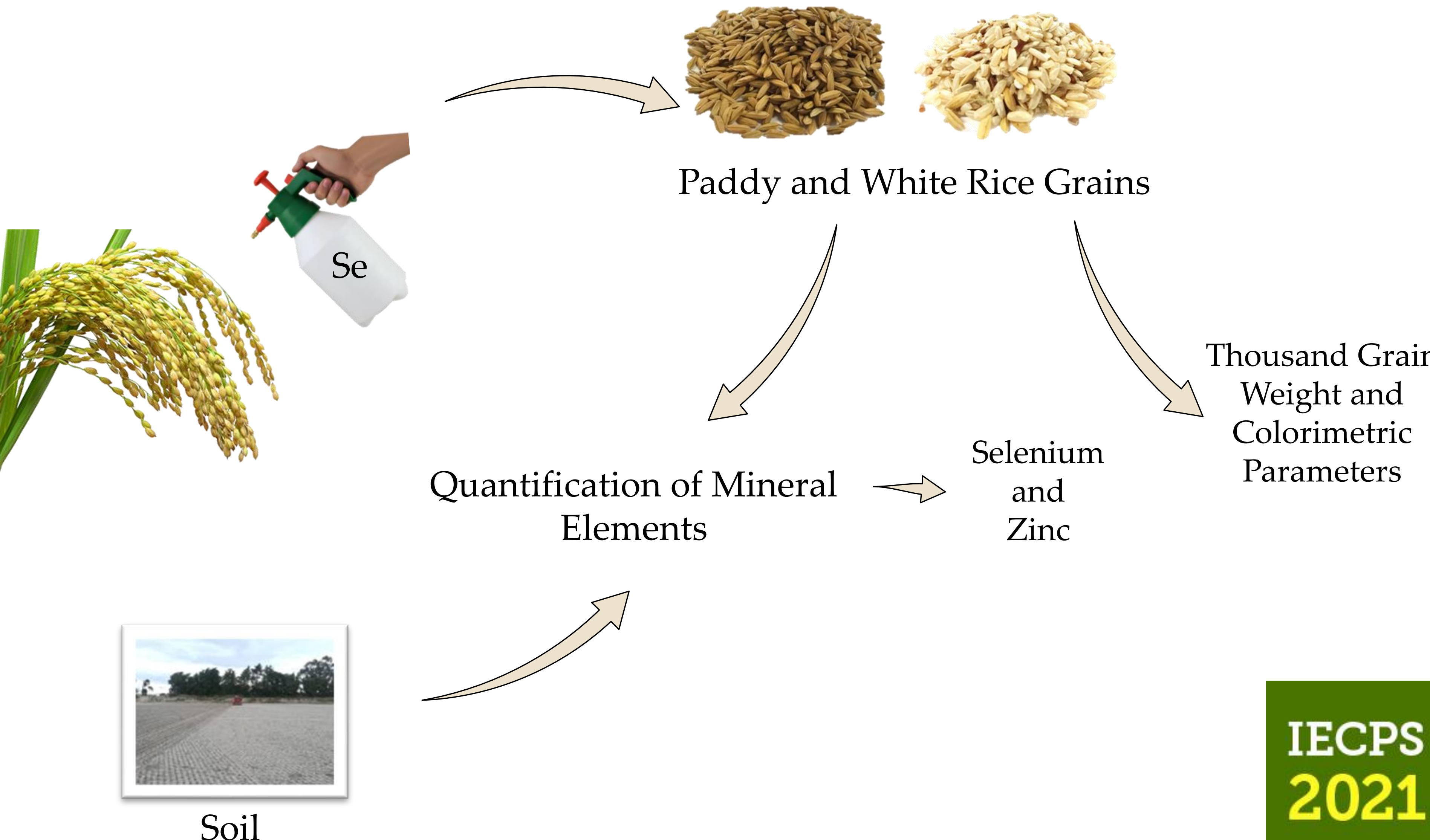

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Abstract: Selenium plays an important role in regulating soil-plant ecosystem functions. Is an essential element with antioxidative activity however its presence in plants is scarce. In this context, a technical itinerary was implemented in the rice variety (Ariete) through foliar pulverization with two selenium concentrations (50 and 75g $Se.ha^{-1}$) of sodium selenate (Na_2SeO_4) and sodium selenite (Na_2SeO_3). Regarding the interaction of Se with other nutrients namely Zn the contents were analyzed in paddy and white grains . It was found that in the white grains there was an antagonistic relationship with the element Zn: an increase of Se in the grain, 29.9 to 77.9 g $Se.ha^{-1}$, and a decrease of Zn content from 16.6 to 9.01 g $Se.ha^{-1}$.

Keywords: Rice; Soil; Selenium; Zinc

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Introduction

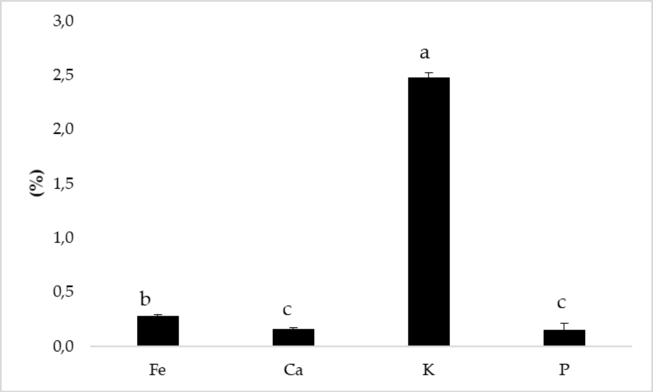
Selenium (Se) is an essential micronutrient to many species, however, its presence in plants is scarce [Garcia-Bañuelos et al., 2011]. Since 1930, studies have been conducted to understand the relationship between Se concentrations in soil and plant uptake [Fordyce, 2013]. Selenium content in plants is correlated with the bioavailability of the micronutrient in the soil [White, 2016]. Considering that plants absorb from the soil, the main Se species in the form of selenate (SeO_4^{2-}) and selenite (SeO_3^{2-}), strategies for enriching the rice grain (*Oryza sativa* L.) with Se have been applied [Lidon et al., 2018]. According to a nutritional perspective, in addition to Se, any crop should maximize the uptake of essential mineral elements and decrease the accumulation of contaminants in the edible parts [Zhou et al., 2020]. However, there are antagonistic relationships that it is important to consider as in the case of Zn. It is important on the one hand to enrich the rice grain and on the other to ensure that the quality parameters are not negatively affected because rice quality parameters directly influence its commercial value [Burestan et al., 2020].

This work aimed to correlate mineral interactions in the paddy rice field soil as well as to characterize the interactions between Se and Zn content in rice grains considering the quality parameters.

Results

1) <u>Characterization of Rice Field</u>

Considering the importance and the contribution of soil to the enrichment of Se in the rice grains, rice paddy soils were analysed. The results shows that pH range 5.86 with electrical soil conductivity of 0.223 dS/m and 1.32 of organic matter. Soil analysis showed significantly different levels of Fe, Ca, K, P, S, Mg and high levels of Pb and As, while Se remained below 1 ppm (Figure 1).



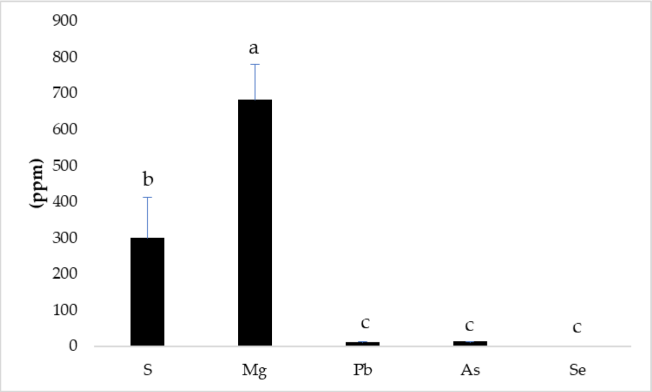


Figure 1. Soil analysis at 0 – 30 cm deep. Average values (% or ppm) ± standard deviation (*n* = 16) of Fe, Ca, K, P, S, Mg, Pb, As and Se contents in the soil samples of rice paddy field trial. Letters *a*, *b* and *c* indicate significant differences among different elements on each graph ($P \leq 0.05$).

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Results

2) Analysis of Selenium and Zinc Contents

Selenium accumulation in paddy rice grains increased in both treatments (Table 1). Regarding the control, it was in the treatment with sodium selenite that the increase was more significant, from 22.1 ppm (control) up to 58.0 ppm. In the same treatment but in the white rice grains the contents increased from 29.9 ppm to 77.9 ppm. Selenium spraying resulted in higher Se contents compared to the control, however, promote the progressive decrease of the Zn contents in white rice grains (i.e., the contents decrease from 16.6 to 9.01 ppm).

Table 1. Average values (ppm) ± standard deviation (n = 4) of Se and Zn in the paddy and white rice grains of *Oryza sativa* L., variety Ariete at harvesting. Letters *a* and *b* indicate significant differences among treatments ($P \leq 0.05$).

Treatments (g Se.ha^{-1})	Paddy		White Rice	
	Se	**Zn**	**Se**	**Zn**
Control	22.1 ± 0.01ab	10.4 ± 4.02a	29.9 ± 7.20b	16.6 ± 0.75a
	Na_2SeO_4			
50	27.4 ± 0.10b	3.89 ± 0.76a	31.7 ± 3.15b	8.63 ± 0.19b
75	47.6 ± 0.02ab	10.3 ± 2.77a	35.6 ± 2.39b	7.59 ± 0.99ab
	Na_2SeO_3			
50	53.7 ± 2.27a	8.17 ± 2.05a	37.1 ± 2.43b	8.87 ± 0.80ab
75	58.0 ± 1.96a	11.5 ± 1.23a	77.9 ± 1.97a	9.01 ± 1.28ab

Results

3) Grain Weight and Colorimetric Analysis

The grain weight did not showed significant differences in paddy rice grains regarding the different forms of Se applied (Figure 2). However, in white rice grains, the sodium selenate enrichement showed a little bit increase of weight in both treatments (50 and 75 g $Se.ha^{-1}$).

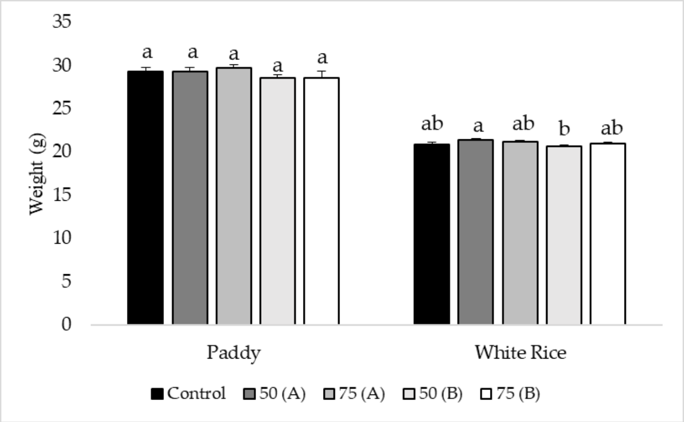

Figure 2. Average (g) ± standard deviation (n = 4) of 1000-grain weight of paddy and white rice grains of *Oryza sativa* L. variety Ariete at harvesting. Letter A and B represent sodium selenate and sodium selenite treatments, respectively. Letters *a* and *b* indicate significant differences among treatments ($P \leq 0.05$).

Results

3) Grain Weight and Colorimetric Analysis

In paddy (Figure 3A) and white rice grains (Figure 3B), regarding to the control, are not significant differences can be observed. Both grains showed two peaks at 550 and 650 nm which corresponds to green to yellow and yellow to red transitions. These peaks are more pronounced in white grains because it is associated with industrial processing.

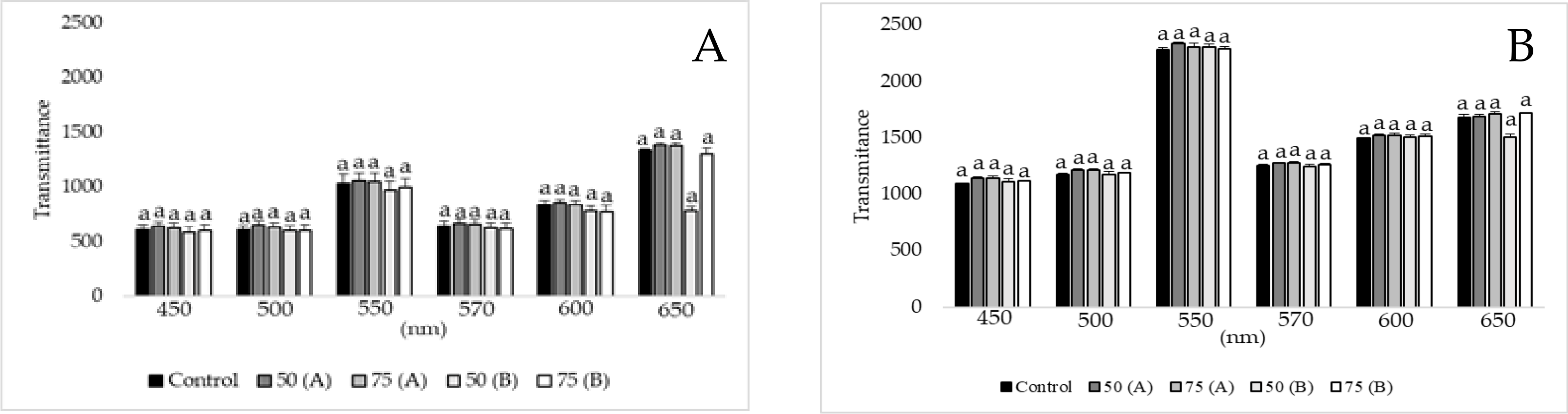

Figure 3. Average colorimetric parameters ± standard deviation (n = 4) of paddy (A) and white rice grains (B) of *Oryza sativa* L., variety Ariete at harvesting. Letter *a* indicate the absence of significant differences among treatments ($P \leq 0.05$).

Discussion

Trace elements in the soil such as Zn, Cd, Pd, Cu, As, and others are absorbed and transported to tissues aboveground level [Yang et al., 2021]. The results show that pH range from 5.5 to 6.5 which indicates that we are in the presence of suitable soil for crops management. In the soil samples, the levels of Fe, Ca, K, P, S, Mg, Pb, As, and Se are quantified (Figure 1). Studies have reported the role of Se in combating heavy metal stress in plants [Feng et al., 2021]. The reduction in heavy metal uptake can be explained because there is a reduced synthesis of heavy metal enzymes triggered by increased glutathione peroxidase synthesis [Hasanuzzaman et al., 2020]. Previously studies reported Se application in rice plants [Lidon et al., 2018]. Our study showed that for Ariete variety, both forms of Se applied promoted the enrichment, however, better results were obtained in the treatment with selenite (Table 1). As previously found that foliar application of sodium selenate is less effective than sodium selenite [Deng et al., 2017]. These results to be associated with the mobility of selenite (which is very mobile and easily absorbed by the plants) [Lyons et al., 2005]. The foliar spraying promoted the accumulation of Se, however, the Zn values decreased in white grains (Table 1) as pointed by other authors [Mangueze et al., 2018].

Discussion

Other studies suggest that Zn is metabolized and assimilated in different pathways [Sors et al., 2005]. Literature report that selenate application promotes the accumulation of Zn, Fe, and Ca [Fargasova et al., 2006]. However, in our study, selenate application showed no significant changes in paddy rice and increased Zn content in white grains (Table 1). In addition to the study of plant-soil interactions and grain mineral contents (such as antagonistic and synergistic interactions), it is important that quality parameters such as grain weight and colorimetric parameters are not affected by grain enrichment. Indeed, independent of each treatment the grain weight biggest variations were not detected (Figure 2). In studies about the enrichment of rice in selenite, the authors pointed the production of higher brown grains [Wang et al., 2013]. For each type of grain, the colorimetric parameters did not reveal significant differences which indicated that the implemented itinerary affected the visual quality of the grains. The differences between paddy and white rice grains are probably associated with industrial processes such as dehusking and whitening (Figure 3).

Conclusions

The enrichment of the rice grains with Se at concentrations ranging between 50-75 g $Se.ha^{-1}$ did not present any symptoms of toxicity. The increment of Se influences the concentration of the element Zn particularly in the white rice grains. These interactions did not significantly affect the grain weight or the colorimetric parameters. Accordingly, it is concluded that the applied itinerary showed an antagonistic relation of Se with Zn. Also, regarding the interactions between soil minerals and interactions of micronutrients in the grain, it was possible to enrich rice grains with Se without compromising the quality parameters.

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