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Precision Agriculture as input for the Rice Grain (*Oryza sativa* L.) Biofortification with Selenium

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Abstract: With population growth worldwide, the production of quality and quantity food is increasingly pressing. As such, it becomes essential to develop new agricultural technologies to increase productivity. Under this assumption, an agronomic workflow for Se biofortification of two genotypes resulting from genetic breeding (OP1505 and OP1509) were selected for evaluation through foliar fertilization with sodium selenate (Na2SeO4) and sodium selenite (Na2SeO3) with different concentrations (300 and 500 g Se.ha−1). Aiming to characterize, through precision agriculture, the experimental fields production and monitor the state of the culture (slope, surface drainage, water lines and normalized differences vegetation index - NDVI), an Unmanned Aerial Vehicles (UAVs) synchronized by global positioning system (GPS) was used. It was found that after sown, the water drainage pattern became profoundly altered, following the artificial pattern, created by the grooves between plots. NDVI values, compared to the control, did not show significant differences. These data were correlated with physiological monitoring during biofortification. In fact, as shown by the eco-physiological data obtained through leaf gas exchanges, the application of 300 g Se.ha−1 did not show any toxicity effects in the biofortified plants. In a context of innovation, it was concluded that the use of precision agriculture techniques in conjunction with leaf gas exchanges measurements allowed an efficient monitoring of the field conditions and culture to implement a rice biofortification itinerary.

Keywords: Leaf gas exchanges; Photosynthesis; Precision agriculture; Rice genotypes; Selenium biofortification

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Materials and Methods

- Biofortification Itinerary – Foliar application with Selenium (sodium selenate and sodium selenite);
- Characterize the experimental fields;
  Monitor the state of the culture (Orthophotomaps and NDVI);
- Leaf Gas Exchange Measurements (net photosynthesis - Pn, stomatal conductance to water vapor - gs, transpiration rates- E , and variation in the instantaneous water use efficiency - iWUE);
- Analysis of Selenium contents (XRF analyzer);
- Data analysis.

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Results and Discussion

The water lines observed in the experimental field are associated with intermediate elevation zones (Figure 1). After seeding, the drainage pattern is profoundly altered following the artificial pattern created by the existing furrows between plots. The field has moderate drainage capabilities therefore promoting runoff (5 - 20 % slope). The field also has areas with 0 - 5 % and more than 20% slope.

Regarding NDVI values there were no significant changes (Figure 1c) regarding control. In OP1505 the highest value was in the plants where selenate would be applied showed greater vigor (0.820) while in OP1509 where the selenite treatment was to be applied (0.788), compared to the control.

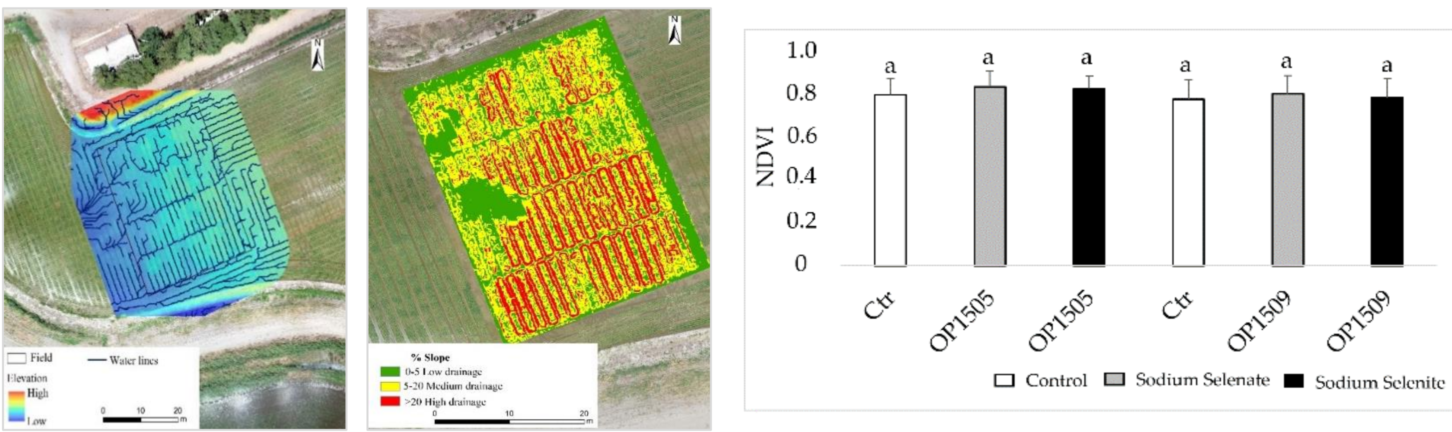

Figure 1. Orthophotomaps and mean values of normalized vegetation index (NDVI) ± standard deviation. Obtained from images of UAVs (n=12) from O. sativa OP1505 and OP1509 in the plants where testing with selenate and selenite would be implemented. Letter a revealed the absence of significant differences among treatments of each genotype. .

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Results and Discussion

Physiological data were acquired after the 2nd an 3rd leaf application of Se fertilization in rice (Table 1). In the 1st analysis at OP1505 the net photosynthesis (Pn) values increased regardless of the form applied. In OP1509 (1st analysis) Pn values increased in selenite treated plants. The positive effect on Pn of applying 500 g Se ha-1 (1st application) and 300 g Se ha^{-1} (2nd and 3rd applications) of selenite was extended in the next two evaluations along with higher gs and lower instantaneous water use efficiency (iWUE).

Table 1. Leaf gas exchange parameters - net photosynthesis (Pn), stomatal conductance to water vapor (gs), transpiration (E) rates, and as well as variation in the instantaneous water use efficiency (iWUE=Pn/E) in leaves of O. sativa (OP1505 and OP1509) at 1st analysis - after 2nd leaf application (17 September 2019); 2nd and 3rd analysis - after 3rd leaf application (2 and 15 October 2019).

Fertilization	OP1505			OP1509		
	1st Analysis	**2nd Analysis**	**3rd Analysis**	**1st Analysis**	**2nd Analysis**	**3rd Analysis**
	Pn (µmol CO_2 $m^{-2}s^{-1}$)					
Control	15.53 ± 0.75aA[1]	12.43 ± 0.64bA	5.57 ± 0.46cA	13.57 ± 0.33aB	9.61 ± 0.44bB	3.65 ± 0.17cB
Selenate	18.36 ± 0.18aA	11.04 ± 0.76bA	6.17 ± 0.44cA	13.71 ± 0.69aB	7.81 ± 1.06bB	3.11 ± 0.30cB
Selenite	19.20 ± 1.60aA	11.84 ± 0.68bA	6.48 ± 0.28cA	18.19 ± 2.08aA	12.80 ± 0.97bA	8.03 ± 0.81cA
	gs (mmol H_2O $m^{-2}s^{-1}$)					
Control	190.0 ± 22.5aB	306.4 ± 41.3aA	150.5 ± 22.3aA	173.1 ± 24.5aB	170.4 ± 18.5aB	87.9 ± 12.9aA
Selenate	332.8 ± 60.8aAB	226.1 ± 33.8abA	120.7 ± 15.5bA	339.0 ± 32.9aA	104.8 ± 17.0bB	84.7 ± 4.6bA
Selenite	418.8 ± 27.2aA	278.7 ± 78.6abA	168.0 ± 48.2bA	399.1 ± 22.9aA	276.0 ± 44.4bA	136.4 ± 15.2cA
	E (mmol H_2O $m^{-2}s^{-1}$)					
Control	2.31± 0.23aB	3.62 ± 0.44aB	1.65 ± 0.19aA	2.19 ± 0.30aC	2.49 ± 0.25aB	1.15 ± 0.55aA
Selenate	3.02 ± 0.30aB	2.85 ± 0.31aB	2.07 ± 0.38bA	3.22 ± 0.20aB	1.69 ± 0.22bB	1.70 ± 0.22bA
Selenite	5.12 ± 0.82aA	4.03 ± 0.52aB	1.81 ± 0.17aA	5.80 ± 0.57aA	4.06 ± 0.42aA	1.97 ± 0.16bA
	iWUE (mmol CO_2 $m^{-2}s^{-1}$ H_2O)					
Control	7.71 ± 0.75aA	4.12 ± 0.46bA	4.25 ± 0.63bA	8.89 ± 1.39aA	4.60 ± 0.54bA	3.87 ± 0.45bA
Selenate	6.54 ± 0.68aB	4.06 ± 0.29abA	3.50 ± 0.17bA	4.34 ± 0.18aB	4.75 ± 0.58aA	1.91 ± 0.14aA
Selenite	4.18 ± 0.42aC	3.16 ± 0.26aA	3.91 ± 0.67aA	3.14 ± 0.14aB	3.23 ± 0.14aA	4.16 ± 0.32aA

Results and Discussion

It was found that, at harvest, the average yields (in kg ha−1) were for OP1505, 7296 and 6785 and for OP1509, 7409 and 6168 (for both genotypes, after application of selenate and selenite, respectively). Foliar fertilization with both forms promoted the accumulation of Se in the whole flour compared to the control (Figure 2). Genotype OP1505 present higher value in selenate treatment (11.9 mg.Kg-1) while OP1509 is statistically differences in both treatments, in particular selenite treatment (8.60 mg.Kg-1), compared to the control.

This result agrees with the performance of the photosynthetic machinery that suggested the application of this form for this genotype. In general, the dose 300 g Se ha-1 can be applied in both genotypes to maximize Se absorption without compromising the photosynthetic machinery.

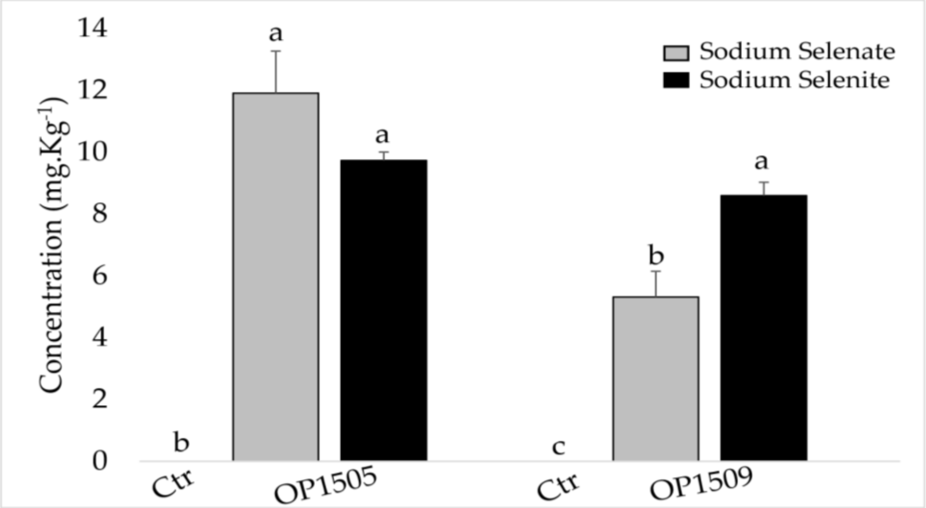

Figure 2. Mean values of Se contents ± S.D. (n = 4) of whole flour of O. sativa control (Ctr), genotypes OP1505 and OP1509. Different letters (a, b) indicate significant differences between treatments for each genotype (single factor ANOVA test, P ≤ 0.05).

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Conclusions

- The use of drones with multispectral cameras attached allowed characterizing the field morphology and vigor of rice plants OP1505 and OP1509 for the implementation of biofortification itinerary with Se forms (sodium selenate and sodium selenite).;

- Thereafter, promoting Se biofortification with 500 g Se.ha-1 revealed visual symptoms of toxicity but with 300 g Se.ha-1 inhibitions at the photosynthetic machinery could not be found.;

- It was concluded that it was possible to obtain higher Se content in rice grain of OP1505 and OP1509 with foliar application of selenate and selenite, respectively.

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