biology and life sciences forum

MDPI

Proceeding Paper

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

Ana Coelho Marques [1,2,*], Cláudia Campos Pessoa [1,2], Diana Daccak [1,2], Inês Carmo Luís [1,2], Ana Rita F. Coelho [1,2], João Caleiro [1], Paula Scotti Campos [2,3], Ana Sofia Almeida [2,4], Manuela Simões [1,2], Maria Graça Brito [1,2], José Carlos Kullberg [1,2], Maria Fernanda Pessoa [1,2], Fernando Reboredo [1,2], José C. Ramalho [2,5], José Manuel N. Semedo [2,3], Paula Marques [6], Maria Manuela Silva [2,7], Paulo Legoinha [1,2], Isabel Pais [2,3] and Fernando C. Lidon [1,2]

[1] Earth Sciences Department, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal; c.pessoa@campus.fct.unl.pt (C.C.P.); d.daccak@campus.fct.unl.pt (D.D.); idc.rodrigues@campus.fct.unl.pt (I.C.L.); arf.coelho@campus.fct.unl.pt (A.R.F.C.); jc.caleiro@campus.fct.unl.pt (J.C.); mmsr@fct.unl.pt (M.S.); mgb@fct.unl.pt (M.G.B.); jck@fct.unl.pt (J.C.K.); mfgp@fct.unl.pt (M.F.P.); fhr@fct.unl.pt (F.R.); pal@fct.unl.pt (P.L.); fjl@fct.unl.pt (F.C.L.)
[2] GeoBioTec Research Center, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal; paula.scotti@iniav.pt (P.S.C.); sofia.almeida@iniav.pt (A.S.A.); cochichor@mail.telepac.pt (J.C.R.); jose.semedo@iniav.pt (J.M.N.S.); abreusilva.manuela@gmail.com (M.M.S.); isabel.pais@iniav.pt (I.P.)
[3] Instituto Nacional de Investigação Agrária e Veterinária, I.P. (INIAV), Avenida da República, Quinta do Marquês, 2780-157 Oeiras, Portugal
[4] Instituto Nacional de Investigação Agrária e Veterinária, I.P. (INIAV), Estrada de Gil Vaz 6, 7351-901 Elvas, Portugal
[5] PlantStress & Biodiversity Lab., Centro de Estudos Florestais (CEF), Instituto Superior Agronomia (ISA), Universidade de Lisboa (ULisboa), Quinta do Marquês, Av. República, 2784-505 Oeiras and Tapada da Ajuda, 1349-017 Lisboa, Portugal
[6] Centro Operativo e Tecnológico do Arroz (COTArroz), 2120-014 Salvaterra de Magos, Portugal; p.marques@cotarroz.pt
[7] ESEAG-COAF, Avenida do Campo Grande 376, 1749-024 Lisboa, Portugal
* Correspondence: amc.marques@campus.fct.unl.pt; Tel.: +351-212-948-573
† Presented at the 1st International Electronic Conference on Agronomy, 3–17 May 2021; Available online: https://sciforum.net/conference/IECAG2021.

check for updates

Citation: Marques, A.C.; Pessoa, C.C.; Daccak, D.; Luís, I.C.; Coelho, A.R.F.; Caleiro, J.; Campos, P.S.; Almeida, A.S.; Simões, M.; Brito, M.G.; et al. Precision Agriculture as Input for the Rice Grain (*Oryza sativa* L.) Biofortification with Selenium. *Biol. Life Sci. Forum* **2021**, *3*, 37. https://doi.org/10.3390/IECAG2021-10019

Academic Editor: Youssef Rouphael

Published: 11 May 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract: Using two rice genotypes as a test system (OP1505 and OP1509), the aim of this study was to develop an agronomic workflow for Se biofortification through foliar fertilization (with sodium selenate and sodium selenite). During the biofortification process, the state of the culture (slope, surface drainage, water lines and normalized differences vegetation index—NDVI), using an Unmanned Aerial Vehicles synchronized by global positioning system (GPS) was further assessed. It was found that after sowing, the water-drainage pattern became profoundly altered, following the artificial pattern, created by grooves between plots. NDVI values, compared to the control, did not show significant differences. These data were correlated with physiological monitoring during biofortification. Furthermore, it was found by eco-physiological data obtained through leaf gas exchanges, that the application of 300 g Se ha^{-1} did not show any toxicity effects in the biofortified plants. In the context of innovation, it was concluded that the application of precision agriculture techniques in conjunction with leaf-gas exchange measurements allow for an efficient monitoring of the experimental field conditions and the development of the rice cycle during the implementation of the biofortification workflow.

Keywords: leaf gas exchanges; photosynthesis; precision agriculture; rice genotypes; selenium biofortification

1. Introduction

To enhance productivity, agriculture is incorporating several next-generation technologies linked to smart farming [1]. Precision agriculture involves acquisition and data processing related, not only to the field (water surface drainage, elevation and slope), but also to the plant health at multiple growth levels (the presence of pests and weeds, the content of chlorophyll in plants and some climatic conditions) [1,2].

Although an essential element in the human diet, Se content in plants is very low [3]. Staple foods, namely rice, have a low content of Se [4], yet through agronomic biofortification it is possible to overcome this limitation, therefore improving its intake by humans [5]. The application of sodium selenate and sodium selenite is a well-known method used to increase Se concentration in food crops, such as rice [6]. Considering the high relevance of rice as a staple food in humans societies, this work aimed to use next-generation technologies (i.e., remote sensing) for monitoring the efficiency of a workflow for rice biofortification with Se.

2. Materials and Methods

2.1. Experimental Fields

The trial was conducted from 4 June to 23 October of 2019. Field trials were carried out at the Rice Technological Center (COTArroz) located in the middle of the Lezíria Ribatejana, Portugal. Two new advanced rice lines (OP1505 and OP1509) of the breeding program carried out by the Instituto Nacional de Investigação Agrária e Veterinária (INIAV, Elvas, Portugal) were used. During this period, the average maximum and minimum air temperatures were 35 °C and 22 °C, respectively. The average rainfall was 0.49 mm, with a daily maximum of 24 mm and an accumulation of 0.5 mm. Biofortification was carried out via the foliar application of sodium selenate and sodium selenite (three replicates per genotype). The experimental design was performed in randomized blocks and using a factorial arrangement (2 concentrations, 2 forms selenium, 2 genotypes, 4 replicates in a total of 32 plots). The plot size for each replication was (8 m × 1.2 m = 9.6 m^2). The agronomic management of trials, namely the application of control weeds, nitrogen fertilizers, diseases, insect pests and water irrigation were monitor. Selenium applications occurred at the end of booting (500 g Se ha^{-1}), anthesis and at the milky grain stages (300 g Se ha^{-1}, for the last two cases).

In OP1505, foliar fertilizations with Se occurred on 26 August and 10 and 25 September, whereas in OP1509, the applications were made on 21 August, 3 and 18 September. Grain harvest occurred on 23 October 2019 for both genotypes. The analysis occurred in whole flour, and only the husk was removed in these grains.

2.2. Precision Agriculture—Characterize the Experimental Fields Production and Monitor the State of the Culture

The experimental field was flown over twice with Unmanned Aerial Vehicle (equipped with altimetric measurement sensors) synchronized by GPS, as described by Coelho et al. [7]. The first flight was performed before implementation of the biofortification workflow for morphological characterization (slopes, surface drainage and water lines) of the experimental field (on 18 July 2019), while the second was performed to characterize the vegetation index (NDVI), on 25 June 2019 (for monitoring the differences in vigor between plants).

2.3. Leaf Gas Exchange Measurements and Analysis of Selenium Contents

Leaf-gas exchange parameters, determined in the field trials, using six randomized leaves per treatment, on 17 September, 2 and 15 October, followed the methods described by [8]. Selenium content in the whole flour was determined using an XRF analyzer (model XL3t 950 He GOLDD +) under a helium atmosphere, previously calibrated with reference standards provided by the Thermo Fisher Scientific [9]. After this, for each sample, measurements were carried out in triplicate with emission radiation for 180 s. For data analysis, the software NITON Data Transfer (XL 3t-36653) was used.

2.4. Statistical Analysis

A statistical analysis of the data was performed with the IBM SPSS Statistics 20 program, through a one-way analysis of variance and the Tukey's test for mean comparison. A value of $p \leq 0.05$ was considered to be significant.

3. Results

The water lines observed in the experimental field are associated with intermediate elevation zones (Figure 1a). The direction of the estimated water lines suggests that if surface drainage exists, it should follow the trend of the estimated water lines for WSE (Figure 1a). After seedling, the drainage pattern was profoundly altered, following the artificial pattern created by the existing furrows between plots. After the calculation of slopes, each plot of land surface for the drainage zones were differentiate into classes in a map (Figure 1b). As expected, given the location and soft morphology of the land, as well as the crop typology, the experimental field presented slopes of lower than 5%, for the entirety of the cultivation area, being therefore considered suitable for rice cultivation, given the estimated potential for infiltration of surface water. The field (Figure 1b) showed moderate drainage capabilities, thus promoting runoff (5–20% slop). The field showed areas ranging between 0–5% and with more than 20% slope. Regarding NDVI values, relative to the control, there were no significant changes (Figure 1c). Relative to the control, for OP1505, the highest value was observed in rice plants treated with selenate (showed greater vigor, 0.820), while in OP1509 with the selenite treatment, the highest value was found (0.788) on 21 August.

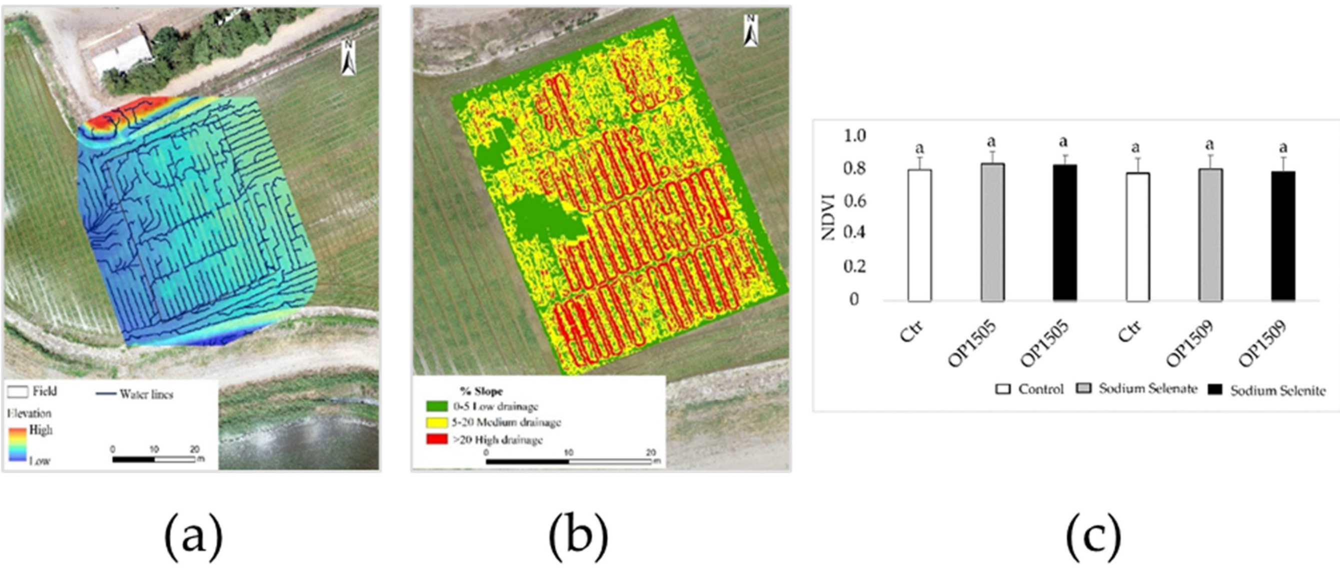

Figure 1. Orthophotomaps of: (**a**) water lines, slope/surface drainage; (**b**) Information collected at 18 June 2019 and mean values of normalized vegetation index (NDVI) ± standard deviation; (**c**) Information collected at 25 June 2019. Obtained from images obtained with UAVs (n = 12), from *O. sativa* OP1505 and OP1509 submitted to foliar fertilization with sodium selenate and sodium selenite. *a* reveals the absence of significant differences among treatments of each genotype.

Physiological data were acquired after the second and third foliar fertilization with Se in rice (Table 1). After second fertilization, the net photosynthesis (P_n) of OP1505 values increased regardless of the form applied. A significant (and gradual) decrease in Pn, stomatal conductance to water vapor (gs) and transpiration (E) was observed in all plants as the end of their life cycle approached. In OP1509, Pn values increased in selenite treated plants. The positive effect on Pn found after application of 500 g Se ha^{-1} and 300 g Se ha^{-1} (2nd and 3rd applications) of selenite, was found to be 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 (performed on 17 September, after 2nd Se application), second and third analysis (performed on 2 and 15 October, after 3rd Se application).

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

[1] Different letters indicate significant differences between treatments (a, b, c) ant between different moments of analyses (r, s, t), for each genotype (single factor ANOVA test, $p \leq 0.05$).

At harvest, after the application of selenate and selenite, it was found that the average yields (in kg ha^{-1}) were 7296 and 6785 (for OP1505) and 7409 and 6168, respectively. In control plants, yields of 7040 and 6788 were obtained in OP1505 and OP1509, respectively.

Foliar fertilization with both forms promoted the accumulation of Se in the whole flour compared to the control (Figure 2). Genotype OP1505 showed a higher value in selenate treatment (11.9 mg kg^{-1}), while OP1509 revealed significant differences in both treatments, particularly in the selenite treatment (8.60 mg kg^{-1}), relative to the control.

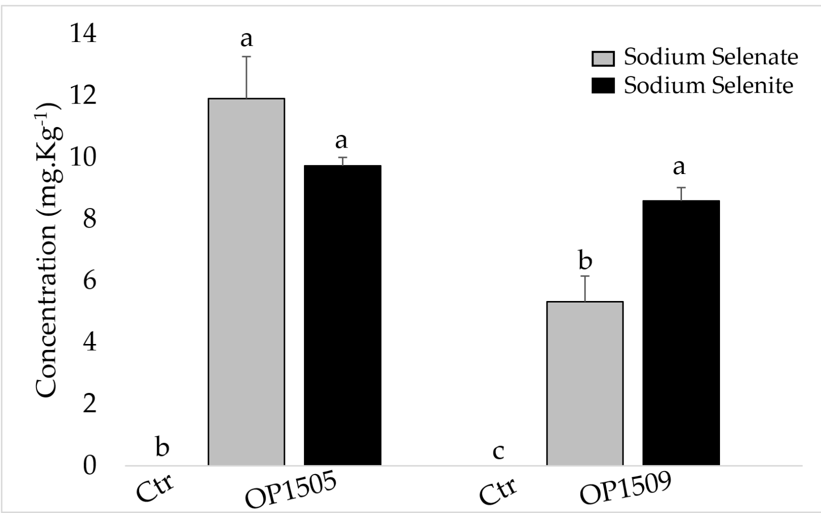

Figure 2. Mean values of Se contents ± S.D. (n = 4) of whole flour of O. *sativa* control (Ctr), genotypes OP1505 and OP1509. Different letters (a, b) indicate significant differences between treatments for each genotype (single factor ANOVA test, $p \leq 0.05$).

4. Discussion

The geomorphology of rice fields strongly affects water-surface drainage. After seedling, the drainage pattern was profoundly altered, following the artificial pattern created by the existing furrows between plots (Figure 1a). These slope maps were obtained shortly after crop implementation, and allowed for the assessment of the initial land state of the field (direct observation of land properties and acquisition an altimetry model). Slope maps were classified in slope classes to differentiate the surface drainage zones from the planar zones (that accumulates surface water). The field also had planar zones with 0–5 % slope, showing low drainage and good conditions for the accumulation of surface water and, consequently, its infiltration (Figure 1b). Moreover, it also had areas with a slope of greater than 20%, which in this case revealed opposite conditions. The vegetation index, NDVI, of spectra images was used to find the vigor of plants, thus monitoring the health of the crop [10,11]. The NDVI values were near 1 and ranged between 0.784–0.820 (in OP1505) and 0.764–0.788 (in OP1509) (Figure 1c). Accordingly, it can be highlighted that the plants have a higher photosynthetic capacity and consequently higher vigor (i.e., synthesis of photo-assimilates), which indicated that the drainage network in the experimental field did not negatively affect the vigor of plants. Therefore, data obtained showed that, at the time of image collection, the plants of both genotypes in each plot were ready for the implementation of the biofortification workflow.

The leaf-gas exchange analyses were performed in situ after the second and third foliar Se applications (Table 1), showing that in OP1505, regardless of the fertilization form of Se, P_n values increased in treated plants (after the 2nd application). The gs rise paralleled with significant E increases, whereas iWUE reduced, thus indicating that Se stimulates net photosynthesis. Additionally, P_n, gs and E values decreased at the end of the life cycle of all plants. Relative to the control, in the genotype OP1509, the application of selenate did not have any impact. The application of 500 and 300 g Se ha^{-1} of sodium selenite further demonstrated the consistent positive effect on P_n, higher gs and lower iWUE. These results suggest that the application of selenite shields the photosynthetic machinery until the end of the life cycle. Therefore, selenite application in this genotype promoted a positive systematic effect that determined a greater increase of Se in the grain (8.60 mg kg^{-1}) and, consequently, positive impact on grain quality. Nevertheless, it was further found that, for both rice genotypes, both forms of the Se applied promoted biofortification (Figure 2), but this data also revealed much higher values than other previously reported studies using Se in flour [12]. Moreover, other studies reported that, in rice, the foliar application of sodium selenite is more effective than sodium selenate [13]. The maximum content of Se in the whole flour of OP1509 was found with the application of selenite due to its high mobility and easy absorption by plants. [14]. Nevertheless, other studies have reported that selenate biofortification is more efficient that selenite [15]. In fact, for OP1505, the highest biofortification was achieved in selenate treatment (11.9 mg kg^{-1}) and, consequently, higher productivity was observed (7296 kg ha^{-1}). 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.

5. Conclusions

The use of drones with multispectral cameras attached allowed for the characterization of the field morphology and vigor of rice plants OP1505 and OP1509 (at least for the implementation of the biofortification workflow with sodium selenate and sodium selenite). Moreover, promoting Se biofortification with 300 g Se ha^{-1} showed the absence of inhibitory effects in the photosynthetic machinery. It was further concluded that it is possible to obtain a higher Se contents in rice grain of OP1505 and OP1509 with the foliar application of sodium selenate and sodium selenite, respectively.

Supplementary Materials: The poster presentation is available online at https://www.mdpi.com/article/10.3390/IECAG2021-10019/s1.

Author Contributions: Conceptualization, A.C.M. and F.C.L.; methodology, M.G.B., J.C.K., J.C.R., and F.C.L.; software, J.C. and M.G.B.; formal analysis, A.C.M., C.C.P., D.D., I.C.L., A.R.F.C., M.S., M.G.B., J.C.K., J.C.R. and J.M.N.S.; investigation, A.C.M., C.C.P., D.D., I.C.L., A.R.F.C.; resources, J.C.K., M.G.B., M.F.P., F.R., J.C.R., J.M.N.S., P.M.; M.M.S., P.L., I.P. and F.C.L.; writing—original draft preparation, A.C.M.; writing—review and editing, A.C.M. and F.C.L.; supervision, P.S.C., A.S.A., M.S.; project administration, F.C.L.; funding acquisition, F.C.L. All authors have read and agreed to the published version of the manuscript.

Funding: The research was funded by PDR2020, grant number 101-030671.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors give thanks to Paula Marques, Cátia Silva (COTArroz) and Orivárzea (Orizicultores do Ribatejo, S.A.) for technical assistance. We also give thanks to the Research centers (GeoBioTec) UIDB/04035/2020 and (CEF) UIDB/00239/2020 for support facilities.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Shafi, U.; Mumtaz, R.; García-Nieto, J.; Hassan, S.A.; Zaidi, S.A.; Iqbal, N. Precision agriculture techniques and practices: From considerations to applications. *Sensors* **2019**, *19*, 3796. [CrossRef] [PubMed]
2. Zhao, W.; Xu, T.; Wang, Y.; Du, W.; Shen, A. Research on vision navigation and position system of agricultural unmanned aerial vehicle. *Int. J. Comput. Integr. Manuf.* **2020**, *33*, 1185–1196. [CrossRef]
3. Garcia-Bañuelos, M.L.; Hermosillo-Cereceres, M.A.; Sanchez, E. The importance of selenium biofortification in food crops. *Curr. Nutr. Food Sci.* **2011**, *7*, 181–190. [CrossRef]
4. Reis, A.; El-Ramady, H.; Santos, E.F.; Gratão, P.L.; Schomburg, L. Overview of selenium deficiency and toxicity worldwide: Affected areas, selenium-related health issues, and case studies. In *Plant Ecophysiology*; De Kok, L.J., Hakesford, M.J., Eds.; Springer International Publishing: Cham, Switzerland, 2017; Volume 11, pp. 209–230. [CrossRef]
5. Lidon, F.; Oliveira, K.; Galhano, C.; Guerra, M.; Ribeiro, M.; Pelica, J.; Pataco, I.; Ramalho, J.; Leitão, A.; Almeida, A.; et al. Selenium biofortification of rice through foliar application with selenite and selenate. *Exp. Agric.* **2018**, *55*, 528–542. [CrossRef]
6. Longchamp, M.; Angeli, N.; Castrec-Rouelle, M. Effects on the accumulation of calcium, magnesium, iron, manganese, copper and zinc of adding the two inorganic forms of selenium to solution cultures of *Zea mays*. *Plant Physiol. Biochem.* **2016**, *98*, 128–137. [CrossRef] [PubMed]
7. Coelho, A.R.F.; Lidon, F.C.; Pessoa, C.C.; Marques, A.C.; Luís, I.C.; Caleiro, J.C.; Simões, M.; Kullberg, J.; Legoinha, P.; Brito, G.; et al. Can foliar pulverization with $CaCl_2$ and $Ca(NO_3)_2$ trigger Ca enrichment in *Solanum Tuberosum* L. tubers? *Plants* **2021**, *10*, 245. [CrossRef] [PubMed]
8. Rodrigues, W.P.; Martins, M.Q.; Fortunato, A.S.; Rodrigues, A.P.; Semedo, J.N.; Simões-Costa, M.C.; Pais, I.P.; Leitão, A.E.; Colwell, F.; Goulao, L.; et al. Long-term elevated air [CO_2] strengthens photosynthetic functioning and mitigates the impact of supra-optimal temperatures in tropical *Coffea arabica* and *Coffea canephora* species. *Glob. Chang. Biol.* **2016**, *22*, 415–431. [CrossRef] [PubMed]
9. Luís, I.; Lidon, F.; Pessoa, C.; Marques, A.; Coelho, A.; Simões, M.; Patanita, M.; Dôres, J.; Ramalho, J.; Silva, M.; et al. Zinc enrichment in two contrasting genotypes of *Triticum aestivum* L. grains: Interactions between edaphic conditions and foliar fertilizers. *Plants* **2021**, *10*, 204. [CrossRef] [PubMed]
10. Skakun, S.; Justice, C.O.; Vermote, E.; Roger, J.C. Transitioning from MODIS to VIIRS: An analysis of inter-consistency of NDVI data sets for agricultural monitoring. *Int. J. Remote Sens.* **2018**, *39*, 971–992. [CrossRef] [PubMed]
11. Daroya, R.; Ramos, M. NDVI image extraction of an agricultural land using an autonomous quadcopter with a filter-modified camera. In Proceedings of the 2017 7th IEEE International Conference on Control System, Computing and Engineering (ICCSCE), Penang, Malaysia, 24–26 November 2017; pp. 110–114. [CrossRef]
12. Zhou, X.; Yang, J.; Kronzucker, H.; Shi, W. Selenium Biofortification and Interaction With Other Elements in Plants: A Review. *Front. Plant Sci.* **2020**, *11*, 586421. [CrossRef] [PubMed]
13. Li, H.F.; McGrath, S.P.; Zhao, F.J. Selenium uptake, translocation and speciation in wheat supplied with selenate or selenite. *New Phytol.* **2008**, *178*, 92–102. [CrossRef] [PubMed]

14. Lyons, G.H.; Genc, Y.; Stangoulis, J.C.; Palmer, L.T.; Graham, R.D. Selenium distribution in wheat grain, and the effect of postharvest processing on wheat selenium content. *Biol. Trace Elem. Res.* **2005**, *103*, 155–168. [CrossRef]
15. Deng, X.; Liu, K.; Li, M.; Zhang, W.; Zhao, X.; Zhao, Z.; Liu, X. Difference of selenium uptake and distribution in the plant and selenium form in the grains of rice with foliar spray of selenite or selenate at different stages. *Field Crops Res.* **2017**, *211*, 165–171. [CrossRef]