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Application of Multispectral Images to Monitor the Productive Cicle of Vines Fortified with Zinc †

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

1 Earth Sciences Department, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal;
2 GeoBioTec Research Center, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal;
3 ESEAG / Grupo Universidade Lusófona, Lisboa, Portugal;
4 INIAV, Instituto Nacional de Investigação Agrária e Veterinária, Oeiras, Portugal
5 PlantStress & Biodiversity Lab, Centro de Estudos Florestais, Instituto Superior Agronomia, Universidade de Lisboa, Oeiras, Portugal;
* Correspondence: d.daccak@campus.fct.unl.pt
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Abstract: In a context of an exponential growing population and resource limitations, precision agriculture techniques can improve efficiency in the agricultural sector. This can be achieved by monitorization and quick detection of changes in crops, resulting in smart resource use, waste reduction and maximization of production. In a field located in Palmela (Portugal), three foliar sprays of ZnO and $ZnSO_4$ were performed in *Vitis vinifera* variety Fernão Pires, for production of biofortified single-vine wine. Field characterization was performed with soil sampling and UAVs (with altimetric measurement sensors), synchronized by GPS. Vegetations indexes, and characterization of drainage capacity and slopes were then interpolated with mineral content, monitored with X-Ray Fluorescence analysis. Morphologically, the experimental parcel had a slight slope (maximum of 1.10 m) with irrigation and nutrient availability in soil requiring special attention (i.e., just 1/3 of the parcel had higher capacity to water drainage). NDVI values reflected better physiological values in N-NE region. Zinc increases in leaf's were directly proportional with the applied concentrations in vines sprayed with $ZnSO_4$ and ZnO, in the concentration of 60% (900 g ha^{-1}) revealed a greater vigor. In conclusion, the use of smart farm techniques and its crossing with analytical procedures, allows the characterization and monitoring of vines, and a higher potential for optimization of wine production.

Keywords: Biofortification; Grapes; NDVI; Precision Agriculture; Remote Sensing; *Vitis Vinifera*; Zinc

1. Introduction

At a nutritional level, Zn deficits represents a serious health problem, affecting one third of the world's population [1, 2]. This micronutrient is one of the most abundant trace elements of the human organism, with average values of about 1.5 - 2.5 g in adults [2]. Also, it has important physiological functions, in the immune system, sensory capacity, neurobehavioral development, reproductive health, growth, and physical development [3].

To prevent nutritional deficiencies alternatives have emerged, namely agronomic biofortification, to increase mineral density at responsive growth stages of crop plants, through soil and/or foliar applications [4, 5]. Moreover, foliar spraying seems to be more efficient in the capture and allocation of nutrients than soil application [5].

Countries having a Mediterranean climate are prone to Zn deficiency in crops [6]. In plants Zn performs important roles linked to plant development, reproduction and signaling, due to its structural, catalytic and activating functions, and also as a cofactor for some enzymes [7]. Besides, its deficiency is the most common cause of yield reductions in numerous crops [8].

For a sustainable agriculture, it is necessary to resort to new technologies to monitor activities related to control and decision-making, namely through images obtained with cameras coupled to Unmanned Aerial Vehicle (UAVs), which allow to acquire information about crop water stress, the photochemical reflectance index, and the vegetation indices [9]. Through normalized difference vegetation index (NDVI), it is further possible to obtain information about crops productivity, because it measures photosynthetic activity, correlating positively with chlorophyll content and, therefore, with nitrogen levels in plants [10].

The wine industry contributes for Portugal`s agricultural sector, and in 2018, over 176800 ha were destined to wine production [11]. According to [12], Portugal holds the 11^{th} position in the world rank of wine producers, with a production of 6.1 mhl.

In this study, UAV`s were used for characterization of a vineyard where a Zn workflow was being carried out, namely morphologic parameters such as slopes and related aptitude for surface water drainage. Furthermore, the assessment of physiologic response of vineyards after spraying with $ZnSO_4$ and ZnO, was performed to monitor the impact of the workflow on plants, which was then correlated with Zn concentration in leaf´s.

2. Materials and Methods

2.1. Experimental Field

The experimental field is located in the region of Palmela, Portugal, with the coordinates N 38º 35′41.467″ O 8º 50′44.535″ W and corresponds to a vineyard with Fernão Pires variety. It was performed a Zn biofortification workflow with two types of treatments: $ZnSO_4$ and ZnO with concentrations of 0%, 10%, 30% and 60% (corresponding to 0, 150, 450 and 900 g ha^{-1}). Foliar spraying was performed with three applications along the reproductive cycle, between 16 of June and 6 of August. Harvest was carried out at 17^{th} of September.

2.2. Fiel morphology and NDVI

Acquisition of multispectral and altimetry images was performed through an Unmanned Aerial Vehicle (UAV), equipped with an RGB camera attached (to obtain the orthophotomap and altimetry model), and a multispetral camera (Parrot Sequoia), to attain images corresponding to the near infrared (NIR) region and the Red-Edge of the electromagnetic spectrum [13]. The design of maps was elaborated through the Agisoft Photoscan and ArcMap (Agisoft, 2018; ESRI, 2019), namely: orthomosaic, models elevation systems, slope maps and vegetation indexes.

2.3. Quantification of Zn in grape leaf´s

Accumulation of Zn in randomized grape leaf`s was analyzed after three foliar sprays, using a XRF analyzer (model XL3t 950 He GOLDD+), under He atmosphere [14]. The grape leaf`s were cut, dried (at 60 °C, until constant weight), grounded and processed into pellets.

3. Results

Morphologically, the terrain where the workflow took place is almost flat (Figure 1A), presenting a maximum variation of 1.10 m in the area of sprayed vineyard, implying a soft inclination. Regarding surface drainage conditions (Figure 1B), only 1/3 of the total land area reflected aptitude for infiltration of surface waters. Furthermore, NDVI index values indicated a better physiological response in the N-NE zone (Figure 1C).

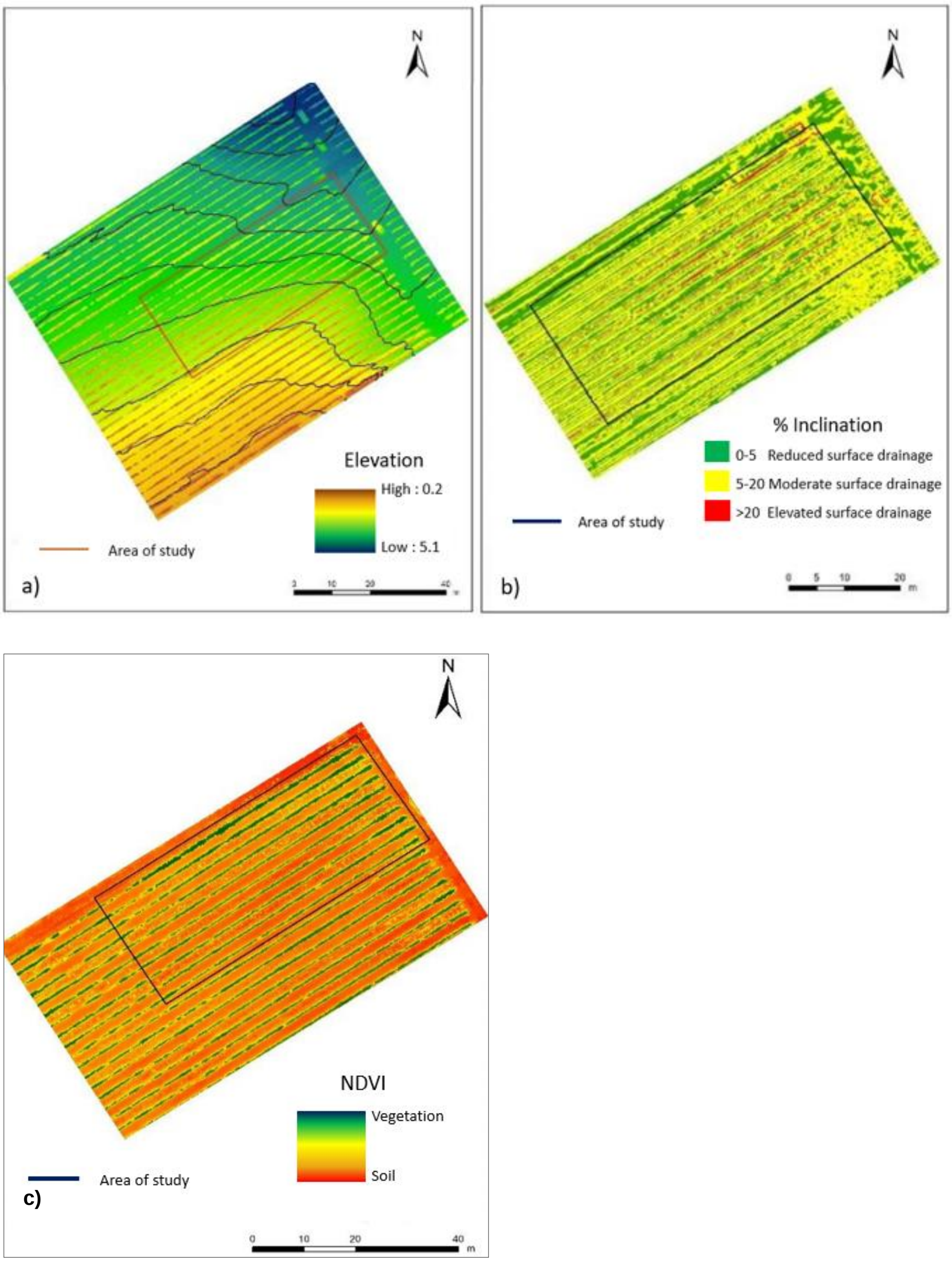

Figure 1. Digital elevation model (A), digital map of slopes (B), and NDVI model (C), from the experimental field acquired at 27th June 2018 (after three foliar sprays).

Zinc\`s mineral content in leaf\`s after three foliar applications with $ZnSO_4$ and ZnO, were directly proportional with the applied concentrations (Figure 2). Rows sprayed with higher concentrations of Zn for each treatment (OZn60 and SZn60) presented higher mineral content, and all sprayed rows showed higher concentration of Zn in leaves in comparison to the control. Also, rows sprayed with ZnO presented greater vigor in comparison to rows sprayed with $ZnSO_4$. Less vigor was observed for rows SZn30 and SZn10, where values were inferior to the control.

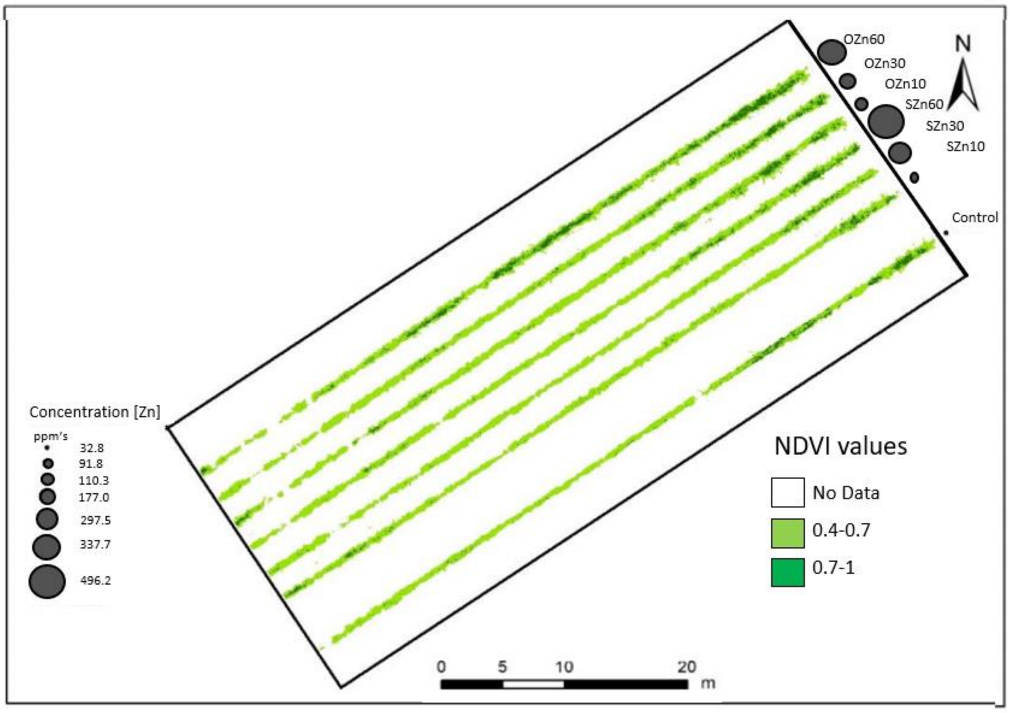

Figure 2. Representation of zinc concentration in leaf's from *Vitis vinifera*, Fernão Pires variety, and the respective vigor of plants using the NDVI vegetation index, acquired at 27th June 2018 (after three foliar sprays). Scales of [0.4-0.7[and [0.7-1.0] were used. OZn10, OZn30 and OZn60 correspond to pulverization of zinc oxide in concentrations 150, 450 and 900 g ha^{-1}, respectively. SZn10, SZn30 and SZn60 correspond to pulverization of zinc sulfate in concentrations 150, 450 and 900 g ha^{-1}, respectively. No foliar sprays were applied on control.

4. Discussion

Vineyard's development and ultimately fruit growth, depends on edaphoclimatic conditions and viticulture practices [15]. Accordingly, surface water drainage can be influenced by terrains morphology, namely since planar zones tend to accumulate this water and thus promoting it`s infiltration on soil [16]. The information attained from UAV`s, specifically regarding drainage, suggests that attention must be given to water availability for this terrain, in order to assure the necessary uptake of nutrients from soils, since poorly drained or with high salt content soils, affects grape crop`s capacity to thrive under such soil conditions [17]. However, the development of a deep root system helps grape crops to adjust to limited water supply and large productions can still be attained under rainfed conditions, but soils with high water capacity are recommended if summer rain does not occur [17]. For this terrain, irrigation throughout fruit development is no longer performed since a deep root system has been developed as this crop is composed of older vines.

On the other hand, the slight inclination of the terrain can be connected to a better physiologic response on the N-NE zone, which presents a lower elevation in comparison to the S-SW zone. Since water tends to accumulate in this zone, the predisposition to deficits in mechanisms of nutrient absorption from soil and movement of photosynthesis products to other tissues is minimized [18]. This can be linked to a prominence of higher NDVI values in the N-NE zone, implying that the applied Zn workflow did not have a negative impact on vineyards. Since NDVI values vary between – 1 and 1, with values closer to 1 indicating healthy vegetation [19, 20], this vineyard in general does not present values related to stressed vegetation.

The most common source used as Zn fertilizer is $ZnSO_4$, due to its high solubility and low cost [21], yet it was observed in sunflower plants that ZnO was also effective, enhancing the amount of Zn in all plants [22]. According to [23, 24], fertilization with sources of Zn, lead to an increase of this mineral`s concentration in leaf`s of Pistachio trees, in sweet orange and Feutrell's early mandarin plants. Furthermore, in a study with a grape variety, 'Shine Muscat', this increase was observed after Zn fertilization through foliar and soil application [25]. Data of Zn content in leaves obtained in this study, are in agreement with the other works previously mentioned, revealing an increase of Zn content in leaves after three foliar applications with both treatments ($ZnSO_4$ or ZnO), prevailing a higher rise with treatment $ZnSO_4$ (Figure 2). These increases provide better chances for Zn content in fruits to rise by translocation mechanisms.

5. Conclusions

The use of precision agriculture techniques, namely images processing from cameras coupled to UAV`s, in the vineyard submitted to the reported workflow for Zn enrichment allowed terrain characterization in terms of slopes and water drainage, to identify possible conditionings to the increase of Zn in fruits. Furthermore, NDVI enabled the assessment to different physiological responses in different zones of the vineyard, which can be related to the characteristics of the field.

The applied workflow using foliar application of Zn, did not present negative influences in the vineyard, and increases of Zn in leaf`s from Fernão Pires variety occurred with ZnO and $ZnSO_4$. In both cases, Zn content rose with the increase of concentration, which become relevant, as assimilation of Zn by leaves through foliar sprays is crucial for this mineral`s increase in fruits by translocation mechanisms, and thus needed to attain fruits with added value.

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