Can NDVI index be used for yield prediction in *Solanum tuberosum* L. plants biofortified with calcium?

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Abstract: Remote sensing technology (namely, through UAVs) have been used to monitor potato crops. As such, this study aims to analysis the relationship between the NDVI index model and yield productivity in *Solanum tuberosum* L. plants from Agria variety submitted to Ca biofortification process with two different concentrations (12 and 24 kg/ha) of $CaCl_2$ or Ca-EDTA. The NDVI values were collected six days after the six foliar application and compared to Ca increase in potato tubers (at harvest) and total yield. The results highlight the fact that 24 kg/ha $CaCl_2$ presented the lowest NDVI index, however, did not show the lowest yield. Moreover, that same treatment presented the highest Ca biofortification index in tubers. Also, seems that NDVI index can be used in decision-making and improve crop management strategies considering being an indicator to detect plant growth or vigor, however in this research it's not sufficient for yield prediction.

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- Remote sensing technology has been increasingly used to monitor potato crops recently, namely through UAVs (Unmanned aerial vehicle).

- The normalized difference vegetation index (NDVI) is one of the most used, being valuable to assess growth or vigor in plants, as well as to provide information's and insights regarding nutrient efficiency and infestations.

- In fact, NDVI can estimates primary productivity of different crops, namely potato crops.

This study aims to analysis the relationship between the NDVI index model and yield productivity in *Solanum tuberosum* L. plants from Agria variety submitted to Ca biofortification process with two different concentrations (12 and 24 kg/ha) of $CaCl_2$ or Ca-EDTA.
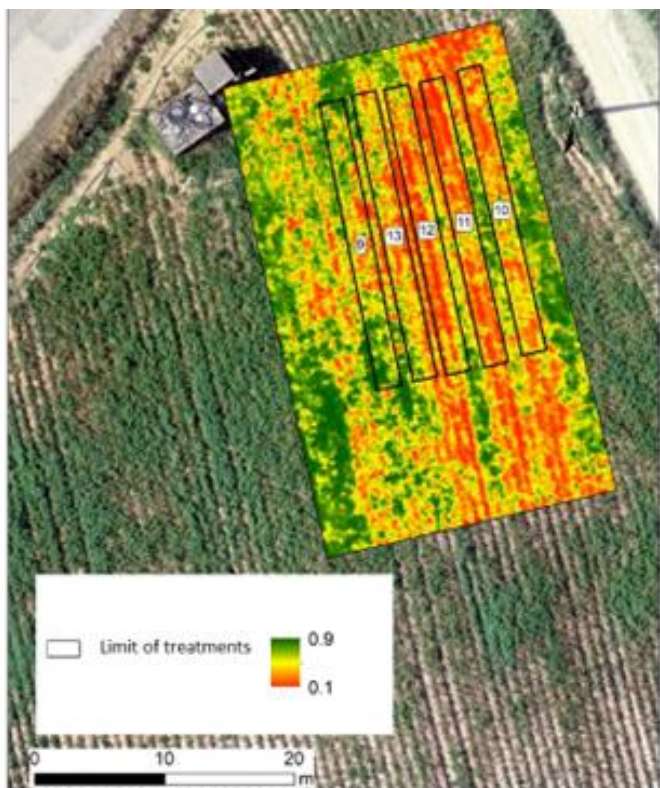
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Results

Figure 1. NDVI model of *Solanum tuberosum* L. plants (Agria variety) carried out six days after the 6th foliar application with calcium (calcium chloride or Ca-EDTA).

Table 1. Minimum, maximum, and average of NDVI (± SD) of the different treatments in *Solanum tuberosum* L. plants (Agria variety), six days after the 6th foliar application with calcium.

Code	Treatment	Minimum NDVI	Maximum NDVI	Average NDVI
9	Ctr	0.17	0.88	0.65 ± 0.16
10	12 kg/ha $CaCl_2$	0.13	0.85	0.50 ± 0.15
11	24 kg/ha $CaCl_2$	0.11	0.82	0.40 ± 0.15
12	12 kg/ha Ca-EDTA	0.12	0.83	0.44 ± 0.17
13	24 kg/ha Ca-EDTA	0.18	0.85	0.54 ± 0.17

Considering both **Figure 1** and **Table 1** it's possible to verified that Ca biofortification treatment had effects in the decrease of the foliage of plants. In fact, 24 kg/ha $CaCl_2$ treatment presented the lowest average NDVI index (**Table 1**), as well as the minimum and maximum NDVI, followed by 12B treatment. Also, Ctr present the highest average and maximum NDVI index. Indeed, 24 kg/ha Ca-EDTA presented the highest minimum NDVI index, however it's important to consider that was only applied once due to toxicity symptoms in *Solanum tuberosum* L. plants.
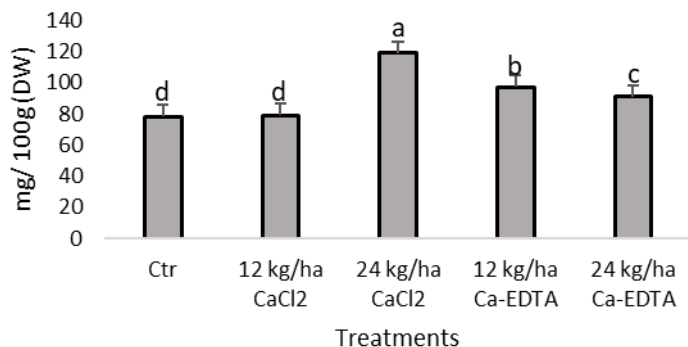
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Results

Figure 2. Calcium content (*n*=4 ±EP) (mg/100g considering the dry weight) in tubers of *Solanum tuberosum* L. (Agria variety) at harvest. Different letters (a,b,c and d) indicates significant differences between treatments.

Calcium content in tubers at harvest was carried out in tubers with skin (full tuber) (**Figure 2**). Additionally, 12 kg/ha Ca-EDTA presented the second highest Ca content in tubers, being the second treatment, which presented the lowest NDVI index. Moreover, there were a biofortification index in of 52.7 % relative to 24 kg/ha $CaCl_2$ and of 24.4 % considering 12 kg/ha Ca-EDTA treatment.

Table 2. Total yield (kg) of *Solanum tuberosum* L. (Agria variety) at harvest.

Treatment	Total Yield (Kg)
Ctr	75.4
12 kg/ha $CaCl_2$	81.5
24 kg/ha $CaCl_2$	64.1
12 kg/ha Ca-EDTA	28.9
24 kg/ha Ca-EDTA	40.3

Considering **Table 2**, it's possible to verified that 12 kg/ha Ca-EDTA treatment was the one which presented the lowest yield compared to the remain treatments. The 12 kg/ha $CaCl_2$ treatment increase the total yield compared to control plants, indicating that $CaCl_2$ applied with that concentration had beneficial effects which leads to yield increase, however, didn't show the highest NDVI index.

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Conclusions

- Our study revealed that 24 kg/ ha $CaCl_2$ presented the lowest NDVI index, however, did not show the lowest yield at harvest.

- The 12 kg/ha $CaCl_2$ led to an increase in total yield compared to control plants, indicating a positive effect of this concentration in promoting yield enhancement, despite didn't showing a higher NDVI index or even a significant increase in Ca content in tubers.

- These findings indicate that NDVI index alone may not be sufficient for accurately predicting yield in *Solanum tuberosum* L., despite being a valuable indicator for detecting plant growth, vigor or even plant stresses. Also suggest that the relationship between NDVI index, Ca content and yield is complex.

Acknowledgments