Società Italiana di Agronomia
50° Convegno Nazionale

Evoluzione dei sistemi agronomici in risposta alle sfide globali
Udine, 15-17 settembre 2021

Vis-NIR-SWIR Spectroscopy to Predict Safety of Spinach

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Introduction

- The overuse of N fertilizers pursues a higher nitrate content in plant tissue of leafy vegetables, such as spinach
- Vis-NIR-SWIR reflectance spectroscopy could result in a rapid and non-destructive assessment of nitrate levels in plant tissues

OBJECTIVE: identify the most significant spectrum wavelengths for the nitrate content estimation to obtain specific vegetation indices directly applicable in the open field

Materials and Methods

The study was conducted in controlled conditions, in 2019.

- 5 experimental treatments
  N_0: 0 kg ha^{-1} **N_75**: 75 kg ha^{-1} **N_150**: 150 kg ha^{-1} **N_200**: 200 kg ha^{-1} **N_250**: 250 kg ha^{-1} of ammonium nitrate
- 9 replications (pots) → 45 pots

Growth and analytical determinations:
- Aerial dry plants biomass weight (DW)
- Leaf chlorophyll and carotenoid contents (Chla, Chlb, and Car)
- Leaf reflectance (350-2500 nm)
- Leaf nitrate content

- Spectral data pre-processing included: (i) the first derivative, (ii) the standard normal variate (SNV), and (iii) Savitzky-Golay (SG) treatments
- Spectral data were split into training (n=32) and testing (n=13) datasets and used to create and validate a partial least squares regression (PLSR) model
- *Statistical devices*:
  ParLeS software
  R software

Results

•N fertilization significantly affected both DW and nitrate content, while no differences were recorded in terms of pigments content

•N_150 represented the best N dose to obtain higher yields while the highest nitrate content was recorded at the highest N dose (N_250)

Table 1: Leaves DW (g plant^{-1}), leaf nitrate content (mg Kg^{-1} FW), SPAD, Chla and Chlb (μg g^{-1} FW), and Car (μg g^{-1} FW) as recorded in spinach subjected to different N fertilization rates (n=45).

Treatments	DW	Nitrate content	SPAD	Chla	Chlb	Car
N_0	1.94	2536.3	44.1	1523.7	709.8	389.1
N_75	2.45	3965.4	47.0	1417.8	648.8	364.8
N_150	2.72	4582.7	48.3	1730.1	792.1	439.8
N_200	2.18	4060.3	49.3	1431.8	665.2	367.6
N_250	1.72	4859.8	46.2	1513.4	714.3	388.1
p-value	*0.01*	*<0.01*	*0.05*	*0.60*	*0.61*	*0.60*
SED	*0.29*	*305.6*	*1.7*	*212.4*	*95.9*	*51.0*

•The validation results of the PLSR model indicated that a good correlation exists between the predicted and observed values for nitrate content (R^2 = 0.698)

•Relevant wavelengths were selected based on the variable importance of projection (VIP) in the PLSR model and fell almost uniformly in the Vis (blue-violet and red), NIR and SWIR regions

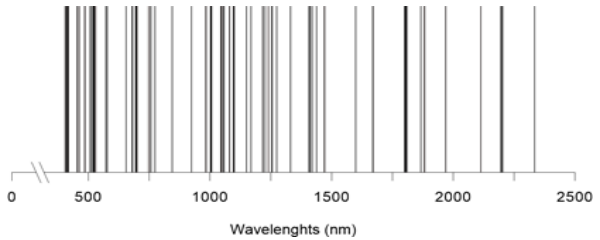

Figure 1: Indication of the wavelenghts falling into the top 100 for VIP (Variable Importance in the Projection) scoring to PLSR model.

- Vis bands are mainly related to Chl and N content in leaves and so, could indicate also the nitrate in vegetable tissues
- The wavebands comprised between 1000 and 1400 nm could be related to N-H stretching
- The wavelengths over 1800 nm could indicate that the discrimination of spinach by nitrate content is related to lipids, proteins and N-H combinations.

•The newly developed PLSR model, built based on the selected wavelengths, significantly enhance the predictive ability of nitrate content in spinach leaves (R^2 = 0.863)

Conclusions

Despite the highest limit of this study was represented by the number of observations, which must be significantly increased, some preliminary considerations can be made. Starting from an adequate selection of wavelengths, the identification of new vegetation indices could be possible and could represent a valid solution for the development of digital tools exploitable in practical applications.

Acknowledgments: This study was supported by the AgriDigit program, "Tecnologie digitali integrate per il rafforzamento sostenibile di produzioni e trasformazioni agroalimentari (AgroFiliere)" (DM 36503.7305.2018 of 20/12/2018).