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EFFICIENCY AND SUITABILITY OF NON-INVASIVE MEASUREMENTS FOR POTATO PLANTS GROWN IN GREENHOUSE

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Abstract

Potato is the most important tuber crop worldwide occupying the fourth place after wheat, maize and rice. Many techniques have been developed to facilitate the monitoring of canopy growth. Normalized Difference Vegetation Index (NDVI) and chlorophyll content (SPAD 502) were found to be good indicators for predicting nitrogen deficits and detecting early stress by drought. The experiences were carried in the Laboratory of crop technology and good agricultural practice greenhouse from National Institute of Research and Development for Potato and Sugar Beet Brasov, Romania, during the years 2019-2020. The aim of this study was to observe the behavior of a potato variety using different soil substrates in the greenhouse and identifying the effectiveness of non-invasive measures to determine plant stress. SPAD device detect the distribution of chlorophyll in different growth stages, registering average values on variants between 37.0 and 45.5 units in 2019 and between 34.0 and 39.2 units in 2020. Vegetation indices registered higher values in 2019 compared to 2020, when the values ranged between 73.0 and 78.2.

Key words*: image classification, conservatory, crop, parameters, remote sensing.*

INTRODUCTION

Potato (*Solanum tuberosum* L.) is considered the fourth, after wheat, corn and rice, most important food in the world. It is cultivated on an area of about 19 million ha and the annual registered production is around 325 million tons. Developing countries produce more than half of the world's total potato production (FAO, 2016). Its productivity is limited as a consequence of climate changes such as drought and heat (ICPP, 2007). Potato depends on a regular supply of water and nitrogen (N) to ensure high quality yield performance (Bélanger et al., 2001; Levy et al., 2013). Water stress in the plant leads to stomatal closure, reduction of transpiration and water transport through the plant (Saravia et al., 2015).

In recent years the growth and yield of potato crop have been greatly influenced by abiotic stresses. Periods of high temperature and drought are becoming more frequent in different regions of Romania. Currently, there are a number of non-invasive methods that determine the chlorophyll concentration at leaf or plant level. Using remote sensing instruments it is possible to monitor changes in crop health over the course of a growing season (Richardson et al., 2004). Optimal nutrient management is critical to obtain a high tuber yield and good quality of potato. Improper nutrient application may lead to lower yield or environmental pollution (Li et al., 2012). Photosynthesis is a complex process that takes place in all the green organs of the plant, especially in the leaves (Beukema & van der Zaag, 1990). Being the most important metabolic event on Earth, it is also the most important process to understand in order to maximize potato production (Tekalign & Hammes, 2005).

Reflectance represents the characteristic of the component of the terrestrial environment to reflect a part of the incident solar radiation in the direction of the remote sensing sensor, depending on their physical and chemical properties (Gâf et al., 2015; Popescu et al., 2019). Past research has shown a close link between leaf chlorophyll concentration and leaf nitrogen (N) content in agricultural crops such as rice, maize, and wheat because the majority of leaf N is contained within the chlorophyll molecules (Peterson et al., 1993; Percival et al., 2008).

Normalized Difference Vegetation Index (NDVI) and chlorophyll content (SPAD) can be good indicators for predicting nitrogen deficits (Borhan et al., 2004; Bagheri et al., 2013) and detecting early stress by drought. Reduced water uptake also decreases the nutrient absorption rate (He & Dijkstra, 2004). Physiological parameters such as chlorophyll content (SPAD) and the Normalized Difference Vegetation Index (NDVI) are related with N nutrition and have been reported to indicate plant fitness under stress and could be useful indicators for selection of superior genotypes in breeding and genetic improvement programs aiming to enhance stress tolerance (Anithakumari et al., 2012; Cabello et al., 2013). The normalized difference vegetation index (NDVI) is commonly used to research the vegetation growth and distinguish vegetation from non-vegetation with eliminating most of the radiation errors, but it is prone to saturation (Miller et al., 1990). The sources of variation are related to the environment (soil type, climatic conditions, foliage diseases, intensity of light), variety (very early varieties show higher variations of chlorophyll than late ones, even if were planted on the same date), culture management (irrigation, residues from the previous crop) (Goffart et al., 2008).

SPAD values are changing at every foliar level and the measurements carried out on the middle foliar level provide the closest correlation with average SPAD values of the leaf canopy (Víga et al., 2012). There for are recommended to make assessment at different foliar to determine the average SPAD value of the potato leaf canopy. The most important limitation is that factors other than available N (variety, growing season, location) can affect plant growth and chlorophyll development and thus the SPAD values obtained (Minotti et al., 1994). The device has a function similar to that of a farmer who evaluates the crop by color, only that it determines the measurements objectively with accuracy and precision, not subjectively like the farmer (Gianquinto et al., 2004).

Using SPAD 502 for the monitoring of leaf chlorophyll during the vegetation period, the existence of a possible nitrogen deficiency can be signaled quite early, which can be corrected without decreasing the production (Shapiro et al., 2006).

Most traits are evaluated on individual plants or even on certain organs of individual plants. Also, the measurements depend on the environmental conditions during the measurements. That is why more integrated methods would be needed, both in time and space (Jarvis, 1995).

MATERIALS AND METHODS

The experiment was carried out in the Laboratory of crop technology and good agricultural practice greenhouse from National Institute of Research and Development for Potato and Sugar Beet Brasov (NIRDPSB), Romania, located at 45°40'26"N 25°32'30"E and took place between 2019-2020.

Studied potato variety was Castrum (genitors: Christian x Dura), with followed characteristics (Hermeziu et al., 2015).

Morphological: the plant is tall with semi-upright port. The leaf present intermediary opening, strong presence of leaflets, light green color. The flowers are white with medium to low frequency, with corolla medium to little. The tubers are round-oval with yellow skin and pale yellow flesh. The sprouts are ovoid, with red purple strong anthocyanin coloration and low pubescence of base.

Physiological: Castrum variety belongs to the group of middle varieties with a vegetation period of 110-120 days.

Observations were performed weekly between 8.08-26.09.2019 and 19.06-27.08.2020.

All variants were supplied with water in the amount of 900 ml/pot weekly.

Potato tubers were harvest in 10.10.2019 and 14.09.2020.

SPAD 502 Plus (Chlorophyll Meter) determinations: 3 readings on each plant. For interpretation of chlorophyll results is used the formula of nitrogen index (Schepers et al., 1996; Richardson et al., 2002): N index = readings average/control average x 100%.

Reflectance or the Normalized Difference Vegetation Index (NDVI) was taken using two types of wavelengths (red and infrared). NDVI was calculated following the formula: NDVI = (ρNIR - ρRed)/ (ρNIR + ρRed) (Rouse et al., 1975).

In order to study also the effect of fertilization on the physiological traits, tubers were planted in greenhouse in pots filled with field soil from different levels. The experimental variants were: V1 control - pots with soil from horizon 20-30 cm + 20-10 horizon and 10-0 horizon; V2 - pots with 10cm of perlite and soil from field (same 3 horizon) and V3 - pots with 10 cm of perlite and soil from field (same 3 horizon) and 10 cm of compost.
The data obtained were statistically processed using the SPSS program (test Duncan and analysis of variance).

RESULTS AND DISCUSSIONS

SPAD values registred in greenhouse

For all measurements performed in 2019, the SPAD values were below the limit of 50 units, the highest average value being obtained in September 5 (48.33 units) for variant V3. This variant maintaining the highest values on the entire study period. In 2020, the highest values were obtained at the beginning of the vegetation period in all variants. In the V1 variant, as the foliage developed, the number of SPAD units decreased, while in V3 the regression was slower, at the last measurement (August 27) was registered a value of 42.2 units, with a significant difference of 19.4 units from V1 (Figures 1a, 1b).

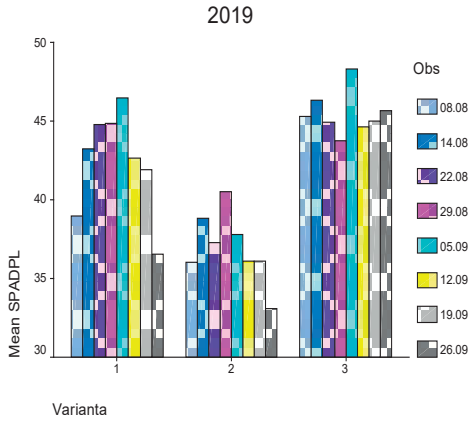

Figure 1a. SPAD value registered in 2019

At the level of 2019, V3 registered the highest values throughout, while variants V1 and V2 fluctuated, so that the higher value registred at V1 was in the middle of the vegetation period, in 22, (44.8) respectively August 29 (44.9), while at V2 the highest value was recorded on August 29 (40.5) and then the lowest values of all measurements from all variants were recorded (Table 1).

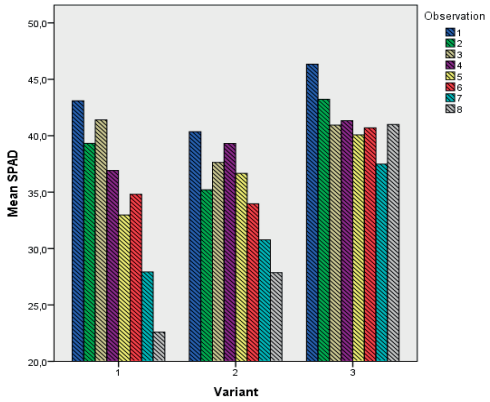

Figure 1b. SPAD value registered in 2020

Table 1. Comparison of SPAD values of potato plants grown in greenhouse (8.08-26.09.2019)

Variant	SPAD average value/plant								
	Vegetation period	08.08	14.08	22.08	29.08	5.09	12.09	19.09	26.09
V1	42.4b	39.0b	43.3a	44.8a	44.9a	46.5a	42.6a	41.9a	36.5b
V2	37.0c	36.0b	38.8b	37.3b	40.5a	37.8b	36.1b	36.1b	33.1b
V3	45.5a	45.3a	46.3a	44.9a	43.8a	48.3a	44.6a	45.0a	45.7a
Mean	41.6	40.1	42.8	42.3	43.5	44.2	41.1	41.0	38.4
Sig.	.000	.025	.002	.001	.110	.000	.000	.000	.000

Table 2. Comparison of SPAD values of potato plants grown in greenhouse (19.06- 27.08.2020)

Variant	SPAD average value/plant								
	Vegetation period	19.06	29.06	09.07	17.07	27.07	06.08	17.08	27.08
V1	34.9b	43.1b	39.3b	41.4a	36.9b	33.0b	34.8b	27.9b	22.6b
V2	37.4a	46.3a	43.2a	40.9a	39.3a	36.7b	34.0b	30.8b	27.9b
V3	39.2a	40.4b	35.2b	37.6b	41.3a	40.1a	40.7a	37.5a	41.0a
Mean	37.2	43.3	39.2	40.0	39.2	36.6	36.5	32.1	30.5
Sig.	.000	.299	.000	.902	.002	.000	.009	.001	.000

In 2020, the highest values were also recorded in V3, with the mention that at the third measurement (July 9) the chlorophyll content of plants in V1 (41.4) and V2 (40.9) was significantly higher (Table 2).

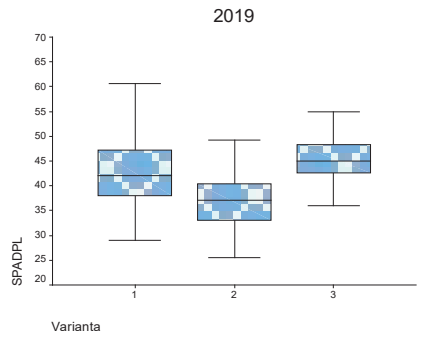

Figure 2a. Box plot regarding SPAD values in 2019

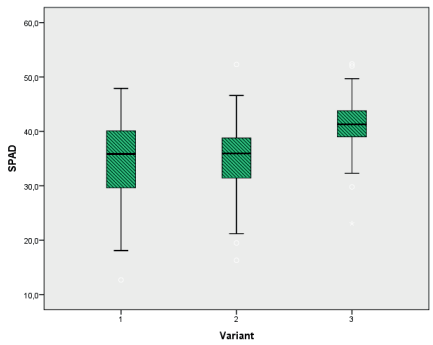

Figure 2b. Box plot regarding SPAD values in 2020

The lowest value observed in 2019 was 26 units at V2, while about 25% of the total units had values above 62. The average value recorded at V1 was 43 unit, to V2 the lowest was 38 units while at V3 this value it was around 45 units. A statistically assured difference can be observed at V3 compared to V1 and V2.

In 2020 the lowest value observed was 18 units at V1, while about 25% of the total units had values above 49. The average value recorded at V1 and V2 was 35 units while at V3 this value it was around 42 units. A statistically assured difference can be observed at V3 compared to V1 and V2 (Figures 2a, 2b).

The differences observed in the two experimental years regarding chlorophyll content are in accordance with the climatic conditions at the time of reading.

NDVI values registered in greenhouse

In 2019 during the development of vegetation can be observed alternating in terms of NDVI values as opposed to 2020 when there were top growth in the middle of the period in all variants, especially in V2 and V3.

Comparing the NDVI values of potato plants grown in 2019, it can be observed for the entire period, except for the values from August 8 and 22, that variant V3 registered the highest values. The average NDVI at the third measurement, on August 22, was 83.75, being influenced by climatic conditions, respectively the presence of less sunny days, with lower intensity of light radiation. The highest values were recorded at the measurements from 22 August and 12 September (85.42 at both measurements). Foliage losses, specific to the variety and different levels of fertilization made the NDVI values show significant differences (Figures 3a, 3b).

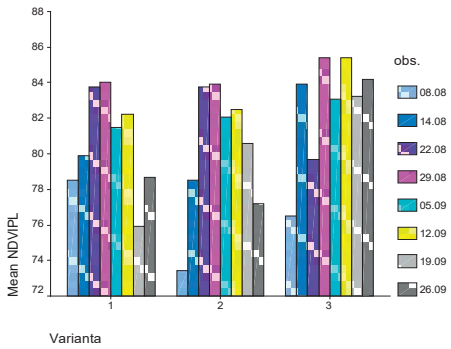

Figure 3a. NDVI value registered in 2019

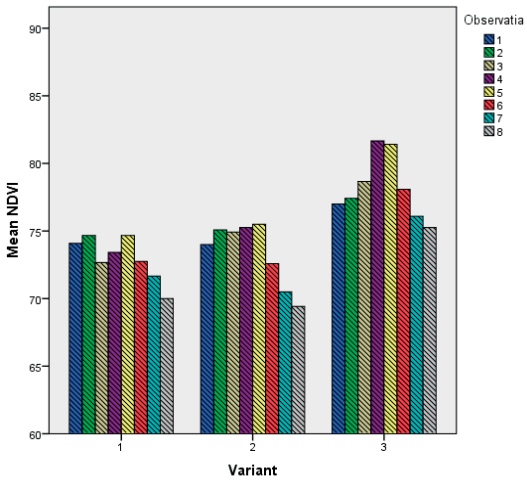

Figure 3b. NDVI value registered in 2020

Table 3. Comparison of NDVI values of potato plants grown in greenhouse (8.08-26.09.2019)

Variant	NDVI average value/plant								
	Vegetation period	08.08	14.08	22.08	29.08	5.09	12.09	19.09	26.09
V1	80.6b	78.5a	80.0a	83.8a	84.0a	81.5a	82.3b	75.9b	78.7b
V2	80.2b	73.4a	78.5a	83.8a	83.9a	82.1a	82.5b	80.6a	77.2b
V3	82.7a	76.5a	83.9a	79.7a	85.4a	83.1a	85.4a	83.3a	84.2a
Mean	81.2	76.1	80.8	82.4	84.4	82.2	83.4	79.9	80.0
Sig.	.012	.168	.148	.240	.648	.873	.042	.000	.000

Table 4. Comparison of NDVI values of potato plants grown in greenhouse (19.06-27.08.2020)

Variant	NDVI average value/plant								
	Vegetation period	19.06	29.06	09.07	17.07	27.07	06.08	17.08	27.08
V1	73.0b	74.1b	74.7a	72.7b	73.4b	74.7b	72.8b	71.7b	70.0b
V2	73.4b	74.0b	75.1a	74.9b	75.3b	75.5	72.6b	70.5b	69.4b
V3	78.2a	77.0a	77.4a	78.7a	81.7a	81.4a	78.1a	76.1a	75.3a
Mean	74.9	75.0	75.4	75.4	76.8	77.2	74.5	72.8	71.6
Sig.	.012	.943	.000	.292	.019	.092	.018	.000	.000

Tables 3-4 show NVDI results of potato plants grown in 2019 and 2020. A difference was observed both at variant level and at year level. Higher values were obtained in 2019 for all variants. Of these, the V3 recorded the highest level. The situation regarding NDVI on variants is the same in 2020, V3 had the highest NDVI value along all the time points measured.

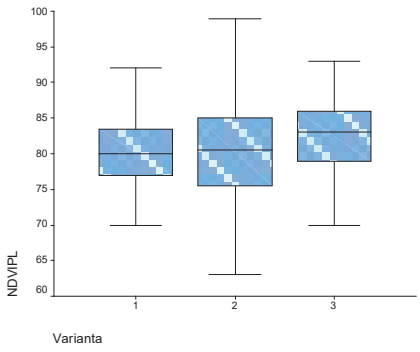

Figure 4a. Box plot regarding NDVI values in 2019

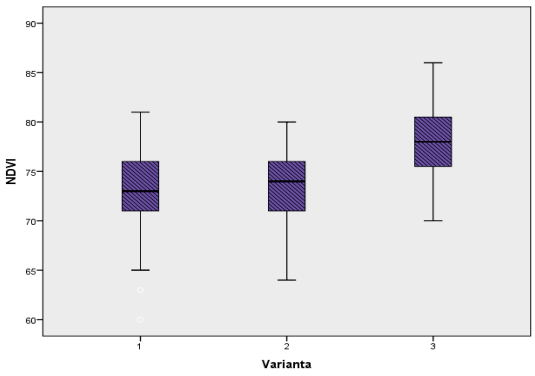

Figure 4b. Box plot regarding NDVI values in 2020

The lowest value observed in 2019 was 62 units at V2. The average value recorded at V2 was 81 units, to V1 the lowest was 80 units while at V3 this value was 83 units, without a statistically assured difference between variants.

The lowest value recorded in 2020 was for variant V2 (64 units).

The average values were different depending on the variant, the highest being recorded at V3 (77 units). The difference is statistically assured only at V3 (Figures 4a, 4b).

From these graphs it can be easily seen that the SPAD and NDVI values depends on the variant of fertilizer and on the weather conditions. Also the variety, the foliage development contributes to obtaining highest values of chlorophyll.

Tacking account of the current results it is preferable to avoid rainy days, when the humidity is high but also the dry ones because the measured values can be influenced by these unfavorable climatic conditions.

The level of fertilization, the factors that cannot be controlled even in greenhouse conditions (nebulosity, the effect of solar radiation), the much more limited agrotechnics decisively influence the potato culture.

It is preferable that at the level of the plant, from the beginning of the tubers growth, the temperatures to be moderate and the supply of water and nutrients continues. No accessibility disturbances or excess.

We subscribe to the observations of other authors (Vos, 1999; Hoel, 2003) who found that the values of chlorophyll content (SPAD) depend primarily on the variety and that during the growing season there may be variations in measurements.

It would be interesting to apply additional foliar nitrogen fertilization at the time of full flowering to varieties with lower SPAD values.

CONCLUSIONS

By this research was explored the relationship between genotype and the non-invasive measurements during a two-year experiment, with the purpose to identify ways to optimize the level of fertilization to improve a production technology. Regarding the NDVI values in both years, the variant V3 (pots with 10 cm of perlite, soil from field and 10 cm of compost) registered the highest level. Also the SPAD measurements indicated a statistically assured difference to variant V3, the chlorophyll content being in accordance with the climatic conditions at the time of readings.

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