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EFFECT OF NITROGEN APPLICATION ON THE SPECTRAL SIGNATURE OF POTATO PLANTS USING ONE WAY ANOVA STATISTICAL TEST

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ABSTRACT

This study aimed to investigate the effect of nitrogen application on the spectral characteristics of potato plants growing in clay soil. An experiment in Lizometers at Arid Land Agriculture and Research Institute, Faculty of agriculture, Ain Shams University, Egypt was conducted to monitor the effect of four different nitrogen application (50, 100, 150 and 200 %) as a percentage from the recommended rate for the potato crop nitrogen needs. The spectral signatures of potato plants were measured three times during the growing season (30, 55 and 80 days after sowing) by ASD hand held spectroradiometer. Potato leaf total nitrogen was determined in laboratory by taking leaf samples, which exist in the field of view of the spectroradiometer. One- Way ANOVA was carried out on both the nitrogen content in leaf and spectral reflectance values for the Near-infrared region. In clay soil, significant differences in reflectance pattern between various levels of nitrogen treatments more enhanced at 55 and 80 days after planting than that after 30 days after planting.

INTRODUCTION

Potato is considered one of the important vegetable crops in the most countries of the world. The potato crop ranks fourth in economic importance after Wheat, Maize and Rice and also the first alternative for grain crops and is used for human consumption, animal feed and as a source of starch, carbohydrates and alcohol. In Egypt, potato is considered as one of the most important and economic vegetable crops. It can be grow in almost any season and in most of country, except during very hot months in summer. Spectral reflectance in the visible and near infrared region (400–2500 nm) has been identified as a popular method to sense localized factors relating to the soil and crop. Results from spectral reflectance measurements have been widely used in arable research to evaluate such factors as crop nitrogen, crop density, weed detection, and soil properties. However, despite this research activity, spectral reflectance techniques are still not widely used for commercial applications. The majority of agricultural studies use measurements in the visible (400–700nm wavelength) and near infra red (700–2500nm wavelength) region of the electromagnetic spectrum. Recent researches concluded that wavelengths in this region could potentially detect many physiological and biological functions of crops and soil and therefore offer potential for applications in agriculture, including measurements of crop chlorophyll, crop green area, crop density and soil properties. Many of these studies use the large differences in the spectral characteristics of the soil and crop, especially at the '**red edge'** [*the point where the electromagnetic spectrum changes from visual to near infrared at a wavelength of approximately 700nm]*. The principle is that the majority of the red light is absorbed by the chlorophyll in the canopy and therefore little is reflected, in contrast a high proportion of the near infra red light is reflected. As canopy green area increases, due to either increasing crop density or chlorophyll content, the percentage of red reflectance decreases whilst the near infrared reflectance increases. Depending on the canopy and soil type, the position of the red edge can also change **(Moses and Andrew, 2006; Onisimo and Andrew, 2007).** Similarly, different soil types and different crops can also have small spectral characteristic differences **(Farifteh *et al.*, 2007; Piekarczyk J., 2001; Van der Meer, 2004; Ye *et al.*, 2008; Bodo and Schmidhalter, 2008).**

Measuring the amount of energy reflected at known wavelengths enables some information to be obtained about the characteristics of the contacted body. For most agricultural studies, the spectral reflectance of two bands at least, typically either side of the 'red edge' are measured enabling a ratio to be calculated. Many forms of ratio, usually termed vegetation indices, have been used. These are usually correlated against a property relating to agricultural studies e.g. canopy characteristics, soil properties. When a small number of wavelength bands are measured data analysis is relatively simple. For example if reflectance values each side of the red edge are used to calculate the normalised difference vegetation index (NDVI), its value would increase with increasing green cover. However LAI prediction from remotely sensed data faces two major difficulties: (1) vegetation indices approach a saturation level asymptotically when LAI exceeds 2 to 5, depending on the type of vegetation index; (2) there is no unique relationship between LAI and a vegetation index of choice, but rather a family of relationships, each is a function of chlorophyll content and/or other canopy characteristics. (**Driss *et al.*, 2004; Guyot *et al.*, 1988; Broge & Leblanc, 2000)** this only holds true until canopy closure when the crop has a leaf area index (LAI) of up to three **(Dampney *et al.*, 1998; Danson & Rowland, 2000)**, where LAI is defined as the ratio between total leaf area, one side only, per unit area of ground. Depending on the cereal type and variety **(Hgca, 1998)** this generally occurs between growth stages **(Zadoks *et al.*, 1974)** GS 30 (early stem elongation) to GS 39 (flag leaf all visible). In attempting to overcome these limitations, instruments capable of measuring a range of wavelengths are used. Such instruments produce large amounts of data from a single measurement and can potentially provide more information relevant to the soil or crop than a simple vegetation index **(Dehua *et al.*, 2007)**. For Example such data can be used to calculate the shift in the red edge **(Moses and Andrew, 2006; Onisimo and Andrew, 2007; Shafri *et al.*, 2006**). However, the interpretation of this hyperspectral data can be complicated by the inter-relationships between wavelength variables **(Riding & Bryson, 2000)** and many statistical techniques have been utilised to analyse such data. For example, neural networks **(Goel, *et al.*, 2005; Mutanga and Skidmore, 2004; Ye *et al.*, 2008)**; partial least-squares analysis **(Hansen and Schjoerring, 2003)**; fuzzy logic **(Hemming & Rath, 2001)**; principle component analysis **(Nielsen *et al.*, 2000)** and stepwise multiple linear regression **(Hummel *et al.*, 2001)** have all been used. This Study aimed to monitor the effect of nitrogen application rate on potato crop grown in to clay soil during different growth stages of the growing season

MATERIALS AND METHODS

This study were carried out at Arid Land Agriculture and Research Institute, Faculty of Agriculture, Ain Shams University located at Shubra Al Khaimah, Qaliubiya Governorate, Egypt. A randomized experiment containing six replicates in Lizometers was conducted to monitor the effect of different nitrogen application rates on potato crop. Treatments included four nitrogen application 50%, 100%, 150% and 200% from the recommended rate of 150 kg N fad^{-1}. Each sampling plot consisted of two rows (one meter long and 0.5 meter width) with a density of six plants Lizometer. Potato tubers were sown on 28 October 2010 under the open field condition in clay soil. Phosphorus, Potassium micro elements fertilizers were supplied in adequate amounts according to the general nutrient status of the field as determined by soil samples: 24 kg ha^{-1} P_2O_5 and 125 kg ha^{-1} K_2O. Table (1) shows the 100 % Fertilization program as adapted for the experiment during the growing season. Irrigation was adapted for both the concentration of salts through fertilization so the concentration of fertilizers did not negatively affect the plants and the quantity for the water requirement of potato. Therefore, no water stress occurred. Spectral data was collected during three growth periods: 1) the rapid growing period, 2) the full coverage period (the middle stage when the canopy reached almost 100% ground cover), and 3) the senescent period (the late stage when the leaves became senescent). These growing periods corresponded to the spectral sampling dates of December 1st and 25th - 2010 and January 15th, 2011.

A full range spectroradiometer (from 350 nm to 2500 nm) manufactured by Analytical Spectral Devices™ (ASD, FieldSpec® FR) was used to collect potato canopy spectral data. The sensor's field of view was 25°. Data were collected on cloudless days from 10 am to 2 pm in order to minimize external effects from the atmospheric conditions and changes in solar position. The spectroradiometer was held at nadir angle at 50 cm above the canopy, resulting in a 22.17 cm diameter field of view over the canopy. Spectral reflectance was calculated as the ratio of measured radiance to the radiance from a white standard reference panel (Labsphere spectralon panel). Immediately after the white standard radiance measurement, five spectra of the potato canopy were obtained. All of the measurements were made with the sensor located directly over the center of the canopy. The mean of the five spectra was then determined to provide a single spectral value.

Plant samples were taken in manner to represent the spectral measurements so plant leaves in the field of view were taken for laboratory analysis. A dried sample of 0.1 g was taken in 500 ml Kejldahl flask, then added 10 ml of conc. H_2SO_4 and digested until colorless solution appeared. The content was cooled down and diluted to about 25 ml with distilled water. Total nitrogen was determined in solution according to Kejldahl method **A.O.A.C., (1990)**.

Table (1): amounts and forms of different fertilizers add through the growing season.

Days After Planting	Ammonium Nitrate	Phosphoric acid	Potassium sulfate	Magnesium sulfate	Calcium Chloride	Micro nutrients mix
	g / Lizometer* - Fertilization					
20	25	2.5	6.25	2.5	--	1.25
30	25	2.5	6.25	2.5	--	1.25
40	25	2.5	6.25	3.75	6.25	1.25
50	12.5	2.5	6.25	3.75	6.25	1.25
60	12.5	--	12.5	2.5	6.25	1.25
70	12.5	--	12.5	2.5	6.25	1.25
80	12.5	--	12.5	2.5	6.25	1.25

*: Each Lizometer = m^3

RESULTS AND DISCUSSION

Plant analysis data

Tables 2 shows NPK levels in potato plant leaf under different nitrogen application rates (50, 100, 150 and 200% from the recommended rates) grown in clay soil. Data indicate that there is a significant increase in potato leafs total nitrogen with increasing amount of nitrogen fertilizer added to the plant.

Table (2) NPK content in potato leaves 30, 55 and 80 days after planting

Treatment	N (ppm)	P (ppm)	K (ppm)
		30 days	
50%	5.04	0.788	3.54
100%	5.6	0.921	5.81
150%	6.89	0.725	7.2
200%	7.38	0.685	6.04
		55 days	
50%	4.51	0.521	6.73
100%	5.88	0.587	6.05
150%	6.68	0.575	5.48
200%	9.18	0.673	6.32
		80 days	
50%	4.48	0.554	5.6
100%	5.53	0.556	7.11
150%	6.37	0.653	6.41
200%	7.84	0.547	6.91

Stastical analysis for NPK

One-way analysis of variance (ANOVA) was carried out to test the difference between nitrogen treatments. Results show that all treatments are significantly different from each other (Fig. 1).

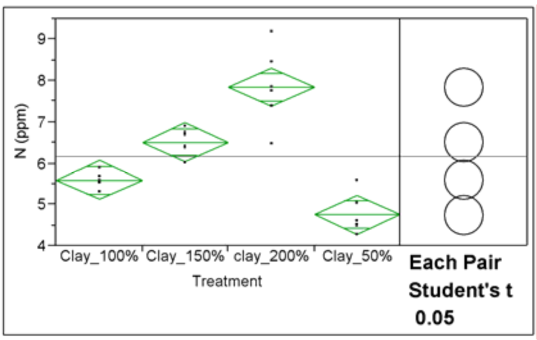

Fig.(1): One Way ANOVA for clay soil treatments.

Hyperspectral data analysis

The average spectral curve for potato after 30, 55 and 80 day after planting was calculated and the four treatments were compared as the following figures show.

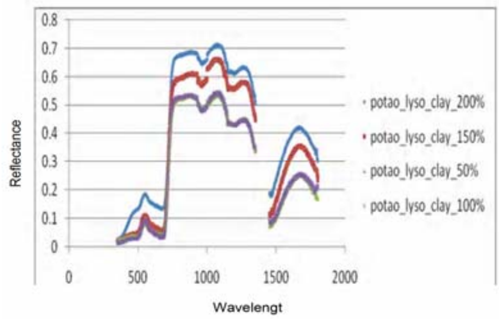

Fig. (2): Spectral curves for potato in clay soil 30 days after planting

At the beginning of the growing season nitrogen deficiency (50%) were not noticed because of clay soil organic matter supply the plant by its requirement of nitrogen. High nitrogen application (150 and 200 %) leads plant assimilation to be increased and transformed into chlorophyll, which reflects more in the region of infrared Fig. (1). In the med and late stages, plant needs more nitrogen in the same time soil supply finishes so plant spectral response in relation to nitrogen supply (50, 100, 150 and 200%) was significant clear. More nitrogen more vigor plant, more reflectance in the NIR region Fig.(2 & 3).

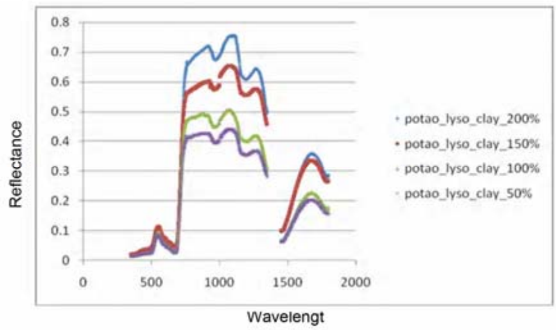

Fig. (3): Spectral curves for potato in clay soil 55 days after planting

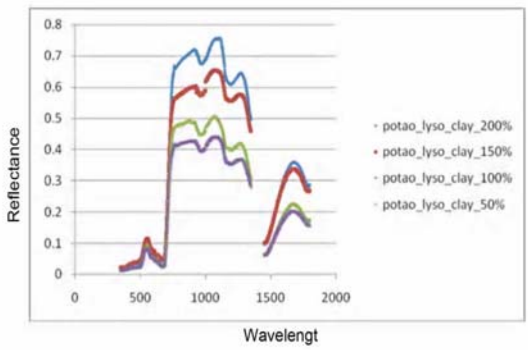

Fig. (4): Spectral curves for potato in clay soil 80 days after planting

Stastical analysis for spectral data

Results from One-Way ANOVA stastical analysis for the spectral reflectance in the Visible Near-Infra Red region emphasis that there is no significant difference between the 50% and 100% treatments after 30 days from planting (Fig. 5). In contrast to that, there is a significant difference between the 150% and 200% treatments through all season (Fig. 5, 6, 7) i.e. (30, 55 and 80 days after planting). The difference between the 50 and 100% treatments was enhanced to become significant in the later growth stages (Fig. 6, 7).

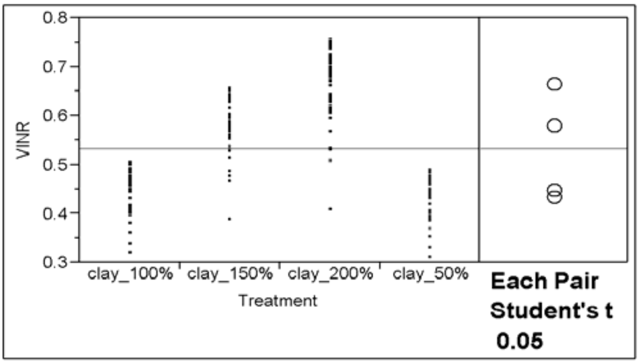

Fig. (5): One-Way ANOVA for spectral curve in the VNIR region for potato 30 day after planting.

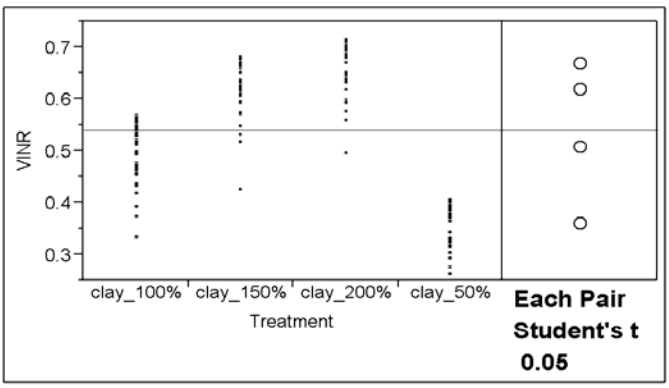

Fig. (6): One-Way ANOVA for spectral curve in the VNIR region for potato 55 day after planting.

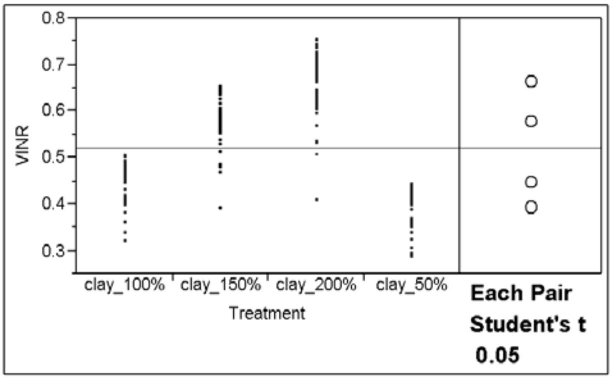

Fig. (7): One way ANOVA for spectral curve in the VNIR region for potato 80 day after planting.

In conclusion, in the visible near infrared region, the spectra from the plots with large rates of N application are significantly different from the spectra with the smaller rates of application. For the plots with larger rates of N application, reflectance decreases the most in the red region and increase in the NIR region similer to **(Kyllo, 2003; Yao *et al.*, 2008; Bodo and Schmidhalter, 2008; Dehua *et al.*, 2007)**. In clay soil, differences in reflectance pattern between various levels of nitrogen treatments more enhanced at 55 and 80 days after planting than that after 30 days of planting.

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