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MONITORING VEGETATION GROWTH OF OIL ROSE (*ROSA DAMASCENA* MILL.) BY HYPERSPECTRAL SENSING

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Abstract

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In this study, traceability of the oil rose growth during vegetation period was investigated using hyperspectral detection method under the field conditions. The study was conducted in the Rose Garden at Suleyman Demirel University. Five pieces of 5 years old rose rootstocks (3 replications from each plant) were selected for the purpose of measuring and sampling. The study lasted for 33 weeks and the traditional growing activities were applied to the selected plants. Under the field conditions a spectral reflections were measured at wavelengths of between 325-1075 nm by using ASD FieldSpec HandHeld spectroradiometer and plant probe. Chlorophyll analysis was performed on selected samples. Spectral reflectance measurements and chlorophyll content were compared by Stepwise Multiple Linear Regression Analysis method, and predicting models were established. Results showed that (i) for hyperspectral sensing purpose the vegetation process of the oil rose should be divided into four major periods as growth, harvest, decline and the formation of new leaves, (ii) hyperspectral applications and reflectance values measured in the field might be used to predict chlorophyll a, chlorophyll b and chlorophyll a + b content in the oil rose, (iii) the physiological decline affecting harvest yield during vegetative growth might be identified in all periods by spectral reflectance values.

Key words: ASD HandHeld, chlorophyll, oil rose (*Rosa damascena* Mill.), visible near-infrared reflectance spectroscopy

Introduction

Hyperspectral sensing is still in the process of development. One of the application areas of these techniques is the use of the spectroradiometer measurements. The fundamental basis of the method is objects having a unique reflection (reflectance/radiance) in the electromagnetic areas. The advantageous of these techniques are identifying the reflectance radiometrically, recording the reflectance value digitally, and analyzing many numbers statistically. Reflectance values are the objects' unique spectral signatures. Reflectance characteristics vary according to chemical structure, which gives such properties to objects as color, texture, brightness, and appearance.

Plants display different absorption and reflectance properties at different wavelengths. Of the visible bands, the blue band is absorbed by chlorophyll and carotenid pigments, and the red band is absorbed by only chlorophyll pigment, and the reflectance occurs only at the green band. The absorbed energy is mostly used for photosynthesis. Photosynthesis takes place in the chloroplasts, which intensify on the outer surface of the plant cells. For this reason, the wavelengths of energy absorbed in different parts of the plant cell vary (Merzlyak et al., 2003; Başayiğit et al., 2008; Albayrak et al., 2009).

Lack of nutrients in the plant causes chlorosis on leaves, water deficits, flowers' color change, and abnormal formations producing other physiological problems. These abnormal developments, at the same time, indicate that physiological characteristics of leaves do not process healthily. Deterioration of physiological units in plants, resulting from deficiency or excess of plant nutrients, and resulting chloro-

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sis, directly affect the spectral reflectance characteristics of plants (Gedik, 2006).

All nutrient deficiencies arise in the form of chlorophyll reduction or deformation. Chlorophyll development is determined with the increase of reflectance occurring in the visible (400-700 nm) and infrared (700-1100 nm) bands. The most abundant nutrients in the structure of chlorophyll are N and Mg. Therefore, N and Mg deficiencies cause very high increases in the reflectance values, and this increase is determined to be up to 90% (Silva and Beyl, 2005; Başayiğit and Albayrak, 2007). Reflectance characteristics are directly related to leaf chlorophyll content and mineral content (Jacquemoud and Ustin, 2001; Başayiğit et al., 2008). This fact has led to the findings that nutrient element deficiencies can be identified by spectral methods, plant growth can be observed and physiological disorders can be identified.

Oil rose, with current production potential and export, is an important agricultural resource. Turkey is the most important country in the world engaged in the production of oil rose, and Isparta, and its districts are the first rank in the economically cultivation of oil rose. Isparta province produces more than 70% oil rose of Turkey, and the rest is performed in the districts of Afyonkarahisar and Burdur provinces bordering to Isparta (Demirözer, 2008).

Oil rose has delicately physiological properties. The time between bud formation and the harvest of rose flower is very short. All kinds of diseases that may occur in this short term, e.g. nutrient deficiency and other stress factors cause physiological problems in the growth of the plant, and thus, ultimately reduce the rose flower and oil yield. For this reason, any negativity arising from habitat or other factors have an impact on the quantity of rose flower and quality of rose oil, and thus high economic losses may occur when compared to other agricultural products.

Oil roses bud between the last week of April and first week of May, and the buds blossom after about 10-15 days. The first harvest of oil rose start, depending on weather conditions, between the last week of May and first week of June and continues to average 25-30 days. The highest level of oil yield occur when the rose completely blossom (Kıneci, 2005).

Oil rose should be healthy from beginning of the blooming period in order to keep yield and harvest at maximum in the rose flower production. For this reason, it is mandatory to monitor growth period of oil rose, and early intervene of the adverse conditions relating to growth. This requirement has led to research on the use of Spectroradiometric methods that can be applied in field.

The objective of the study was to investigate whether oil rose display the growth problems, that will affect the harvest yield in the pre-blooming period, can be determined by hyperspectral detection systems. For this purpose, chlorophyll pigment content was associated with the spectral reflectance curves, so that it was studied to identify the early stage chlorosis that was undetectable by the human eye.

Materials and Methods

The study was conducted in Suleyman Demirel University, Faculty of Agriculture and Rose Garden, Department of Soil Science and Plant Nutrition, Laboratory of Remote Sensing and GIS. The rose garden, selected as the study area, is located on 36 283407 m east and 4190629 m north longitudes, has an altitude of 1000 meters. The garden, in the slope of straight and nearly straight, was an alluvial bottomland. Garden soils are defined as a Farm Series clay loam, and classified as Typic Xerefluvent according to the US soil taxonomy (Akgül and Başayiğit, 2005). The region is located in the transition zone between the Mediterranean and Central Anatolian climates and affected by both climates (Akten, 2008).

In this study, the plants of parcels, where yield and harvest are optimum, were used considering the data records of Rose Garden. Normal growing activities were applied to selected plants. From the beginning of May to the end of September, ammonium nitrate, monopotassium phosphate, and potassium sulfate fertilizing were made with drip irrigation within every 10 days. To fight with rose rust, scale insects and aphids, the Mastercop, Supracide+Biozyme, Antrocol+Basudin, Antrocol+Bayleton+Basudin sprayings were respectively performed on the dates of 16.03.2010, 16.04.2010, 04.06.2010, 06.16.2010. Five pieces of 5 years old rose rootstocks were selected for measurements. The study was initiated in March when the leaves of selected plants reaches 1.5 cm, and continued until November. Every week, phenological observations were noted. All observations were recorded, photographed and archived. Three paralleled sampling were taken from each rose rootstock throughout 33 weeks.

Leaves were sampled with petiole and upper parts on the blooming shoots exposed to full sunlight (Kaçar and İnal, 2008). While choosing the leaves, attention was paid that there was not dust, pesticide residues and other pollutants on the leaves and problem with biological or mechanical detrimental effect (Dedeoğlu, 2011). Leaf samples were placed into the light-proof locked sample pouches, and then taken to the laboratory in a cooler box for chlorophyll analysis. The same day chlorophyll analysis was performed on the fresh leaves. Chlorophyll a, chlorophyll b, chlorophyll a + b quantities were determined according to Arnon (1949).

Spectral reflectance was measured by ASD FieldSpec HandHeld spectroradiometer. Plant probe was used for reflectance measurements. The probe was located on leaf lam-

ina of the upper part of the leaves in a position that would see the light source and then the reflectance measurements were taken from vein gaps. Measurements were performed between 325-1075 nm (1 nm interval 750 bands) wavelengths by calibrating, once every 10 reading, by spektralon made of plaster block, which was a white reference.

By using the Minitab statistical package software, specified reflectance values were linked with chlorophyll values obtained from laboratory analysis according to Stepwise Multiple Linear Regression analysis method, which is a multiple comparison test. With the reduction of variables (wavelength), at maximum 6 wavelengths, and the highest R^2 valued prediction models were formed using different wavelengths combinations.

Results and Discussion

The change of chlorophyll content during vegetation process: "Chlorophyll Curve" was created from the data obtained from the results of the weekly-performed laboratory analysis. Weekly change of chlorophyll content during vegetation period was given in Figure 1. Chlorophyll content varied in line with season, agricultural activities and the period of plant growth.

Vegetation process of oil rose was divided into four major periods taking into account the phenological observations and chlorophyll content: (i) The first of these periods was "a growth period". Growth of plant leaf and budding of rose flowers occur together during this period covering the dates of 18.03.2010-28.05.2010. During this period, the reduction of chlorophyll was observed against rust disease coming with rain. The disease declined due to pest control and the decrease in rainfall amount in the following days, and thus, the increase in chlorophyll content was determined. In fact, spectral reflectance curves showed the proportional change in the chlorophyll pigment; (ii) The second period was "a harvest season". Rose flower has been harvested during the dates of 28.05.2010-24.06.2010. Chlorophyll value and the reflectance curves showed linearity during harvesting. Chlorophyll content reached at a maximum value during harvest period, and the lowest spectral reflectance curves were observed in this period; (iii) The third period was "a decline period" covering the dates of 24.06.2010-26.08.2010 in which the chlorophyll content tended to decrease. During this period, the growth of leaves stopped. Therefore, the chlorophyll content decreased and spectral reflectance curves proportionately increased later during this period; (iv) The fourth period was "a new leaf formation period" covering the dates of 26.08.2010-26 .10.2010. During this period, recently formed leaves started to grow. However, with the influence of climate, vegetation period ended and paling and shedding of leaves started. The spectral reflectance curves obtained during this period indicated that plant growth stopped after a certain level.

The first period of vegetation formed wavy curves, the second period formed straight curves, the third period formed concave decreasing curves, and the last period formed convex increasing curves. Disease factors in the leaves, climate, and agricultural activities had a significant effect on the formation of curves; however, the typical feature of the curve was to show chlorophyll development belonging physiological periods of the plant (Figure 1). Another point of attention was that the chlorophyll content started to increase since the formation of the rose buds, and the formation of flowers reached the highest value at the end of the period.

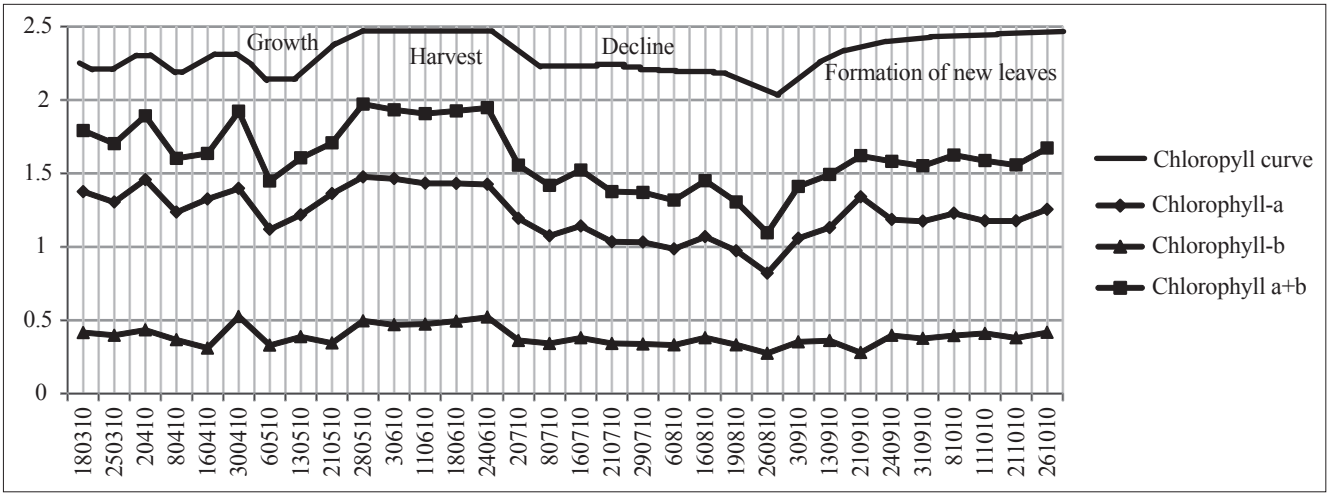

Fig. 1. The chlorophyll content of *Rosa damascena* Mill.during vegetation period

Chlorophyll content reached the highest value in blooming period and maintained this level until the end of harvest. The plant, keeping chlorophyll content at the highest level during blooming period, used all of its energy for blooming metabolism. Comparing chlorophyll content of the plant with its morphological characteristics, showed that growth decline in flowers, and significant increases in the reflectance values were occured when the values dropped below 1.118 mg g^{-1} for chlorophyll a, 0.330 mg g^{-1} for chlorophyll b and 1.448 mg g^{-1} for chlorophyll a+b.

Statistical information belonging to samples

Leaf samples taken from plants throughout 33 weeks and the chlorophyll content of these samples were determined to vary between 0.63-1.76 ppm for chlorophyll a, 0.09-1.49 ppm for chlorophyll b and 0.11-2.30 for chlorophyll a+b. According to the results of chlorophyll analysis in the leaf samples, the lowest chlorophyll content was found in the samples made on 28.05.2010, and the highest chlorophyll content was found in the samples made on 26.08.2010 and this change was determined by reflectance graphics (Figure 2). The standard deviation belonging to the samples was calculated as 0.21 for chlorophyll a, 0.12 for chlorophyll b and 0.30 for chlorophyll a + b. Statistical information belonging to the chlorophyll content was given in Table 1.

Predicting models

Vegetation predicting models of oil rose were presented in Table 2. The predicting was considered adequate in models where R^2 was above 0.90. According to this, predicting model was created by using three bands for chlorophyll b in the first period while predicting model was able to be created by using six bands for chlorophyll a+b in the second period. The predicting was made from five bands for the second period chlorophyll a with the highest R^2 value of 0.99 while the predicting could be made from four bands for the third period chlorophyll b with the lowest value above 0.90.

Wavelengths, the number of wavelengths, wavelength ranges and the distribution in line with bands used for four different periods were presented in Table 3. According to this, the wavelengths, which were selected from forecasting models in which R^2 value was above 0.90, intensified in the ranges of 350-400 nm and 1000-1050. In the measurements performed before blooming, R^2 value was determined to be 0.95 in the forecasting models created with the reflectance values taken from wavelengths between 373-407 nm. In the literature, it was stated that chlorophyll development was able to be determined with the increase of reflectance in the visible band (400-700 nm) and infrared band (700-1100 nm) (Jacquemoud and Ustin, 2001; Silva and Beyl, 2005;

Table 1
The descriptive statistical data of chlorophyll content

	Chlorophyll-a	*Chlorophyll-b*	*Chlorophyll a+b*
Sd.	0.21	0.12	0.3
Variance	0.04	0.01	0.09
Max	1.76	1.49	2.3
Min	0.63	0.09	0.11
Kurtosis	-0.27	46.94	3.62
Skewness	0.19	5.1	-0.67

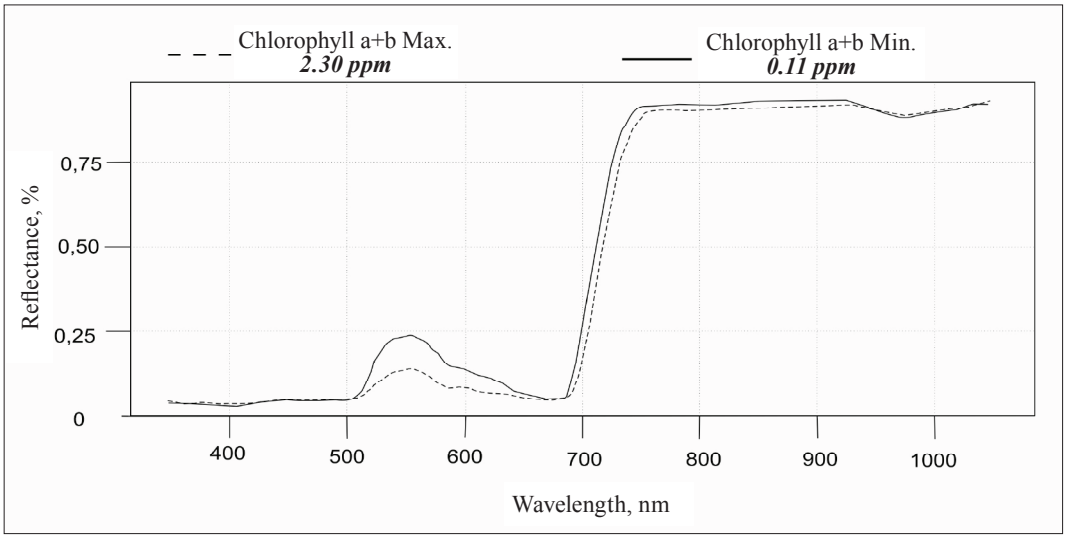

Fig. 2. The reflectance curves of chlorophyll content on 28 May 2010 and 26 August 2010 dates

Table 2
The chlorophyll prediction models for vegetation periods of *Rosa damascena* Mill. nm: *Nanometer*

	MODEL	PREDICTION	R^2
	4/30/2010		
Chlorophyll-a	=8.844+(-5.019*386 nm)+(-1.41*373nm)+(1.537*398 nm)+(-0.386*377 nm)	y = 0.9882x + 0.0161	R^2 = 0.988
Chlorophyll-b	=5.139+(-2.497*386 nm)+(-1.145*384nm)+(0.383*407 nm)	y = 0.9583x + 0.0217	R^2 = 0.958
Chlorophyll a+b	=21.34+(-10.9381*386 nm)+(-5.0536*384nm)+(2.26*407 nm)	y = 0.9906x + 0.0138	R^2 = 0.991
	6/24/2010		
Chlorophyll-a	=-0.02709+(-0.75*351 nm)+(51.9*1047 nm)+(-71.3*1050 nm)+ (47.1*1030 nm)+(0.7*372 nm)	y = 0.840x + 0.234	R^2 = 0.998
Chlorophyll-b	=0.6944+(-0.515*351 nm)+(0.957*383 nm)+(-2.07*403 nm)+(1.49*417 nm)	y = 0.929x + 0.033	R^2 = 0.928
Chlorophyll a+b	=0.15074+(-1.31*351 nm)+(76*1047 nm)+(-105*1050 nm)+ (63.5*1030 nm)+(2.44*1030 nm)+(-1.24*367 nm)	y = 0.959x + 0.065	R^2 = 0.958
	7/16/2010		
Chlorophyll-a	=1.849+(-70.3*1027 nm)+(186*946 nm)+(-83*949 nm) +(-72*943 nm)+(24.8*1026 nm)	y = 0.9145x + 0.1295	R^2 = 0.929
Chlorophyll-b	=0.563+(-0.162*359 nm)+(0.905*711 nm)+(-19.4*1005 nm)+ (6.53*1044 nm)+(8.8*1016 nm)	y = 0.9132x + 0.0327	R^2 = 0.912
Chlorophyll a+b	=3.988+(-0.8*359 nm)+(-100.1*1038 nm)+(93*1000 nm)+ (-2.05*379 nm)+(0.62*361 nm)	y = 0.9251x + 0.1103	R^2 = 0.924
	10/8/2010		
Chlorophyll-a	=1.2966+(-0.64*367 nm)+(2.57*563 nm)+(-0.339*360 nm)+ (-0.71*366 nm)	y = 0.9361x + 0.0673	R^2 = 0.934
Chlorophyll-b	=0.18289+(-0.93*708 nm)+(-0.356*367 nm)+(2.07*566 nm)+ (-0.95*426 nm)+(0.435*403 nm)	y = 0.9458x + 0.03	R^2 = 0.942
Chlorophyll a+b	=1.50707+(-0.84*367 nm)+(3.59*563 nm)+(-0.44*360 nm)+ (-0.91*366 nm)	y = 0.9334x + 0.1178	R^2 = 0.933

Table 3
According to bands distribution of reflectance values in prediction models

	Chlorophyll-a	*Chlorophyll-b*	*Chlorophyll a+b*
350-400 nm	15	8	13
400-500 nm	0	4	1
500-600 nm	2	2	2
600-700 nm	1	2	1
700-800 nm	0	1	0
800-900 nm	0	0	0
900-1000 nm	3	0	1
1000-1050 nm	5	3	5

Başayiğit and Albayrak, 2007; Başayiğit et al., 2008). In this study, the reflectance obtained in especially 350-400 nm and 1000-1050 nm was found to be significant, and the reflectance obtained in 700-900 nm was found to be less effective on determining the chlorophyll content. However, reflectance range is required to be defined in a narrower way in order to identify carotenid and chlorophyll pigments with separately hyperspectral techniques.

Conclusion

The critical values of which growth decline started for oil rose were determined to be 1.118 mg g^{-1} for chlorophyll a, 0.330 mg g^{-1} for chlorophyll b and 1.448 mg g^{-1} for chlorophyll a + b; this change, which was observed in the decline period, was determined by the spectral reflectance. Whether chlorophyll a, chlorophyll b and total chlorophyll content are below the critical value before blooming can be determined by using hyperspectral detection, the measurements performed directly on the plant in the field, and the reflectance values of the wavelengths between 373-407 nm. Thus, it will be possible to identify, in early stage, the growth problems occurring in the vegetative period and intervene them before blooming.

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