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Evaluation of Spectral Reflectance of Seven Iranian Rice Varieties Canopies

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ABSTRACT

Rice cultivated areas and yield information is indispensable for sustainable management and economic policy making for this strategic food crop. Introduction of high spectral and special resolution satellite data has enabled production of such information in a timely and accurate manner. Knowledge of the spectral reflectance of various land covers is a prerequisite for their identification and study. Evaluation of the spectral reflectance of plants using field spectroradiometry provides the possibility to identify and map different rice varieties especially while using hyperspectral remote sensing. This paper reports the results of the first attempt to evaluate spectral signatures of seven north Iranian rice varieties (Fajr, Hybrid, Khazar, Nemat, Neda, Shiroudi and Tarom plots) in the experimental station of the Iranian Rice Research Institute (main station in Amol, Mazanderan Province). Measurements were carried out using a field spectroradiometer in the range of 350-2,500 nm under natural light and environmental conditions. In order to eliminate erroneous data and also experimental errors in spectral reflectance curves, all curves were individually quality controlled. A set of important vegetation indices sensitive to canopy chlorophyll content, photosynthesis intensity, nitrogen and water content were employed to enhance probable differences in spectral reflectance among various rice varieties. Analysis of variance and Tukey's paired test were then used to compare rice varieties. Using *Datt* and *PRI1* indices, significant differences (α= 0.01) were found among rice varieties reflectances in 19 out of 21 cases. This promises the possibility of accurate mapping of rice varieties cultivated areas based on hyperspectral remotely sensed data.

Keywords: Endemic north Iranian rice varieties, Field spectroradiometry, Spectral signatures, Vegetation index.

INTRODUCTION

Rice (*Oryza sativa* L.) is only second to wheat in the Iranian diet and is considered a strategic crop. Therefore, investments on rice production quality and quantity improvement are of utmost significance to reach economical independence and sustainable agriculture for which basic information on rice fields' area and distribution is indispensable (Tabatabaee and Borgheie, 2006; Mousanejad *et al.*, 2010). Changes in rice fields' area together with the number of different rice varieties mandate the utilization of precise tools to map rice fields and to classify rice varieties. The rapid progress of remote sensing techniques along with improvements in spectral and spatial resolutions of the data has made it possible to perform regular and recurrent studies over large areas in a timely and accurate manner. A number of studies

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have focused on the feasibility of using satellite data for the determination of rice fields' distribution (Kamthonkiat, *et al.,* 2005; Xiao *et al.,* 2006; Serra *et al.,* 2007; Khajeddin and Pourmanafi, 2007). Ansari Amoli and Alimohammadi (2007) reached an overall accuracy of 78-95% using *MODIS* data for land use classification in the north of Iran. Rama Rao (2008) also reported an 87.8% overall accuracy for rice varieties land use classification using Hyperon hyperspectral data.

Knowledge of spectral reflectance of land covers is essential for their study and recognition. Field spectroradiometry enables us to directly evaluate spectral reflectance of land covers. Nowadays, on one hand, the nondestructive evaluation of the spectral reflectance of plants has provided us with invaluable information on plant characteristics and, on the other hand, the spectral signatures of features obtained so are used as end members in hyperspectral classifications (Kneubuehler *et al.,* 1998). Over the past decade, a considerable number of studies on the spectral characteristics of vegetation cover, especially crop species, have been performed. This is considered the first step to analyze high spectral resolution remotely sensed data. Spectral characteristics of plants at various wavelengths are governed by leaf inter and intra cellular structure, biochemical contents such as chlorophyll, carotenoid, nitrogen, and water content (Asner, 1998; Jacquemoud and Ustin, 2000; Schaepman *et al.,* 2005; Stimson *et al.,* 2005). Each of these variables is specifically important at a specific wavelength. Many studies have so far tried to determine appropriate wavelengths for effective evaluation of each feature (Lee *et al.,* 2008; Zhu *et al.,* 2008). For example, the upper end of red and the lower end of infrared (690-740nm) known as the red edge region is extremely sensitive to changes in chlorophyll content (Filella and Peñuelas, 1994; Azong Cho and Skidmore, 2006). As spectral reflectance at each wavelength is influenced by a number of variables such as content and formulation of biochemicals as well as cellular structure and environmental factors, spectral ratioing and development of vegetation indices using appropriate wavelengths have been found to effectively reflect these changes. This will also eliminate unfavorable environmental and non-environmental effects such as scattering of adjacent features. Quite a few studies on definition, development, and application of appropriate vegetation indices in relation with biochemical compounds in plant canopy have been carried out (Blackburn, 1998; Datt; 1999; Lovelockand Robinson; 2002; Le Maire *et al.,* 2004; Clevers *et al.,* 2005; Malenovsky *et al.,* 2005).

Xue *et al.* (2004) determined the best indices and Wang *et al.* (2008) reported the most appropriate wavelengths to study spectral reflectance of rice canopy. Coefficient of determination (R^2) between *VI* (R_{810}/R_{560}) and nitrogen content and that between reflectance at 550nm and nitrogen content have been found to be 0.85 and 0.91 by Xue *et al.* (2004) and Inoue *et al.* (1998), respectively, indicating high sensitivity of this index to nitrogen content variations. Shen *et al.* (2000) also reported a similar coefficient of determination between *VI* (R_{810}/R_{560}) and nitrogen content in rice (R^2= 0.85) and Muller *et al*. (2008) found a significant relationship between the same variables (R^2= 0.85).

Ansari Amoli and Alimohammadi (2007) obtained an accuracy of 95% for rice class in their study on a regional land use determination using *MODIS NDVI*. This index has also provided acceptable results in biomass monitoring and evapotranspiration in rice fields as compared with other land uses (Akbari *et al*., 2007).

The objectives of this research were to obtain spectral signatures of a number of important rice varieties endemic to the north of Iran including Fajr, Hybrid, Khazar, Nemat, Neda, Shiroudi and Tarom before harvest and also to study the spectral differences of these varieties at different wavelengths as related to changes in chlorophyll content, photosynthesis intensity, nitrogen, water contents and structure in plant canopy using vegetation indices.

MATERIALS AND METHODS

Study Area

The study was carried out at the experimental station of the Iranian Rice Research Institute located in Mazandaran Province (main station in Amol, Figure 1). The studied plots included Fajr, Hybrid, Khazar, Nemat, Neda, Shiroudi and Tarom varieties.

Tarom, originally from Mazandaran, is considered to be one of the best and highest quality rice varieties. Khazar originated from Gilan but is also cultivated in Mazandaran due to its high yield and adaptation to Mazandaran climate. Grain texture is chalky and the color is dark cream resembling various Sadri types especially Tarom. Hybrid, a modified variety, has an increased 20–25% yield as compared with the original varieties. Endemic varieties of Neda and Nemat are also high yielding ones.

Field Spectroradiometer

An ASD FieldSpec® spectroradiometer with a spectral range of 350-2,500 nm was used in this study. It included the following parts:

Spectroradiometer that measures 35×29×13 cm in size including three detectors at 350–1,000 nm, 1,001–1,800 nm and 1,801–2,500 nm with different sensitivity to temperature and humidity variations.

Fiber optic sensor having a view field of 25 degrees able to sense an 18 cm circle if located at nadir at 40 cm elevation. To facilitate aiming at the target surface, a pistol grip is connected to the spectroradiometer using a 1.2 m cable.

A notebook PC equipped with RS^3 software for data acquisition.

Spectralon® panel (a thermoplastic resin) in the form of a compact disk (Figures 2 and 3).

Sample Spectroradiometry

On the average, 10–12 pure and

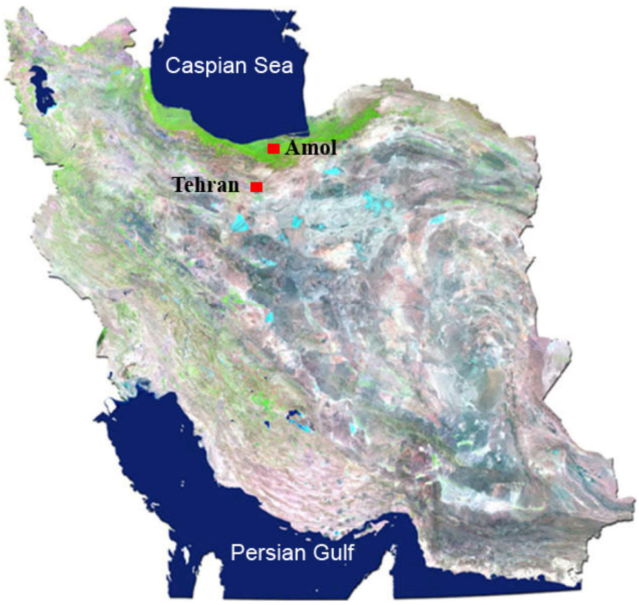

Figure 1. Location of the study area in the northern part of Iran on a mosaic of satellite images. (Green color shows the forests and other vegetations.)

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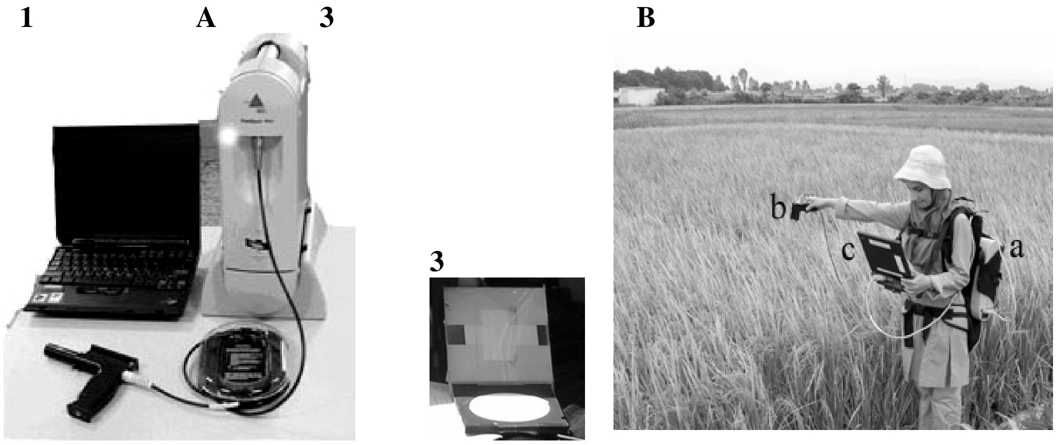

Figure 2. (A) Set up of the Spectroradiometry device including: (1) Spectroradiometer; (2) Pistol grip; (3) Notebook PC, (4) Spectralon panel and (B) Field measurement

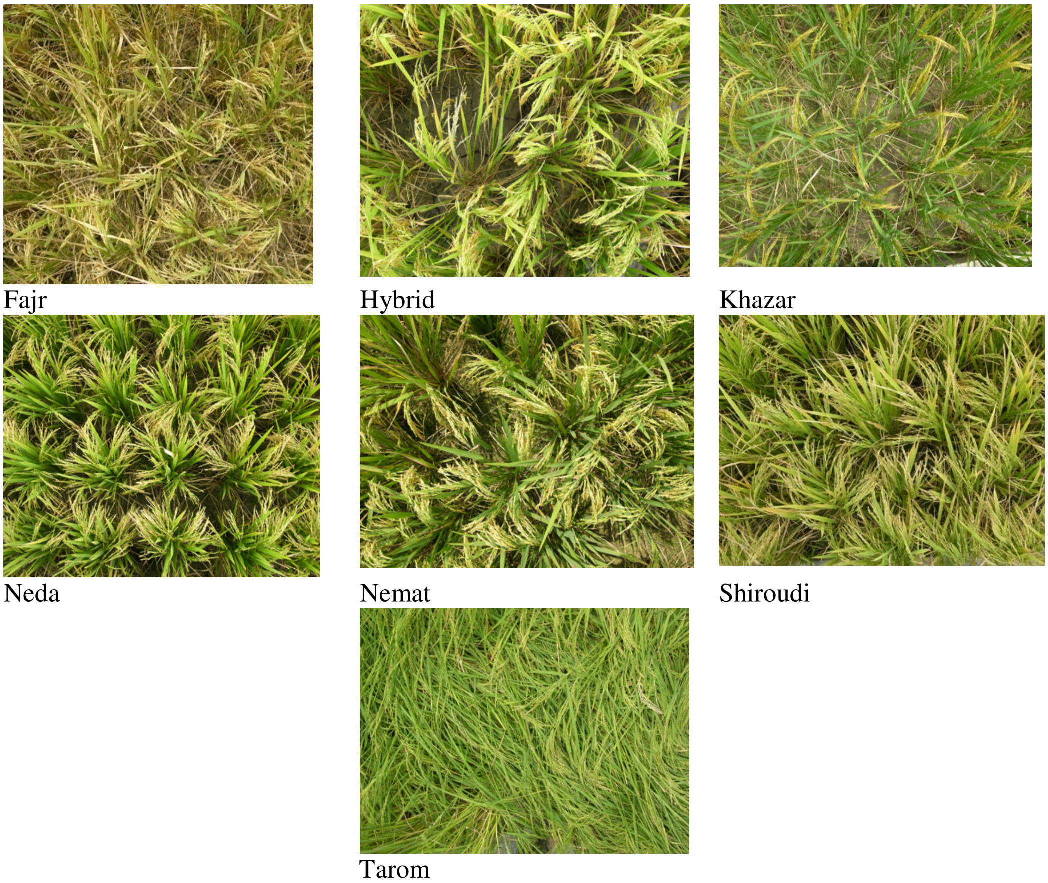

Figure 3. Canopy of the studied rice varieties

homogenous samples of each rice variety were taken to obtain each spectral signature. Samples were randomly collected in plots with the same irrigation and fertilization regimes, soil properties and phonological stage. Normal unstressed canopy sampling locations were determined based on expert opinion. Measurements were performed at 90 cm above the canopy. Totally, 76 samples with more than 95% canopy cover were taken for the seven rice varieties on 20 August 2007, between 10:00 and 13:00 local time, under direct sunlight of a clear sky and stable condition of the atmosphere. Measurements in natural environment could be affected by climatic conditions such as humidity, temperature, and wind, resulting in changes in recorded reflectance. To minimize such effects, each sample was recorded 100 times in less than a minute. These spectrums covering a spectral range of 350–2,500 nm were automatically averaged and displayed on the notebook screen before being saved to the computer. The spectrometer was optimized prior to every new target reading in order to adjust the sensitivity of the instrument detectors according to the specific illumination conditions at the time of measurement and to subtract any electrical current generated by thermal electrons (dark current). Because of slight changes in atmospheric conditions, optimization and white reflectance using a spectralon panel was redone (Pfitzner *et al*., 2006; Milton and Rollin, 2006). The time lag between the optimization and spectral measurements was only about five minutes.

Data Pre-processing

After spectral measurements, all obtained spectrums were visually evaluated using the RS^3 software. Air water vapor brings about errors in the three ranges of spectral wavelength in the vicinity of short wave infrared (Figure 4). In order to accurately determine the wavelength ranges, average and standard deviations of reflectance were calculated for each sample and each wavelength and those greater than two standard deviations than the average were removed as error (Yoder and Pettigrew–Crosby 1995).

Vegetation Indices

Although spectral differences of some vegetation species could be visually recognized, such differences between similar species and varieties are not so appreciable. Instrumental errors and environmental factors may differ from measurement to measurement and can result in problems in spectral separation so that spectral differences between samples could not be easily estimated using conventional statistical methods. On the other hand, plant spectral reflectance at each wavelength is affected by a good number of variables including biochemicals such as chlorophyll,

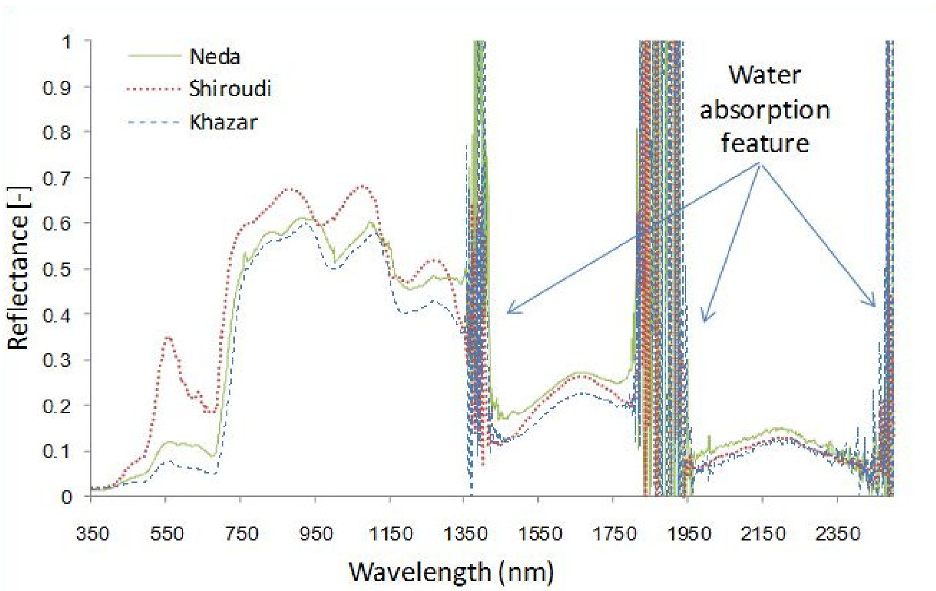

Figure 4. Spectral reflectance of Neda, Shiroudi and Khazar varieties prior to error elimination in the water absorbance wavelengths

nitrogen, carotenoid, and xanthophylls as well as leaf water, intra and inter cellular structure, and photosynthesis performance. Therefore, employment of vegetation indices calculated from wavelengths sensitive to the mentioned factors can help to determine reasons for differences between species. A considerable number of studies has been carried out on development and definition of appropriate indices to assess pigments concentrations (Gamon *et al.,* 1992; Gitelson *et al.,* 2003; Barry *et al.,* 2008; Kimura *et al.,* 2004), leaf water (Wang *et al.*, 2008), leaf area index (Vaesen *et al.*, 2001), nitrogen content (Lee *et al.*, 2008; Zhu *et al.*, 2008) and other factors affecting vegetation spectral reflectance. Based on the available literature, a number of indices having good statistical relationships with the above mentioned factors have been selected for the present study (Table1). Red edge wavelengths and visible chlorophyll absorbance wavelengths are frequently used in chlorophyll content sensitive indices. These wavelengths (550, 664, 710, 720, 756, 810 nm) have shown good relationships with chlorophyll content and nitrogen, a structural element of chlorophyll. In addition, the 1,122 nm wavelength corresponding to lignin spectral absorbance is also sensitive to nitrogen content as this element is present in lignin structure (Inoue *et al.*, 2008). In *Datt* index (Datt, 1999), the selection of the 680 nm wavelength is based on the maximum spectral absorbance of chlorophyll a, the 710 nm wavelength is based on the maximum spectral absorbance of total chlorophyll (a+b) and that of 850 nm is based on the minimum spectral absorbance of either pigment and leaf water. Evaluating the contribution of scattering in spectral reflectance at different wavelengths, this index has shown better relationships with chlorophyll. Spectral reflectance at 970 nm is sensitive to leaf water (Peñuelas and Inoue, 1999; Gloser and Gloser, 2007). Wavelengths employed in photochemical reflectance indices (PRIs) generally indicate spectral absorbance of factors affecting photosynthesis and xanthophylls pigments. The logic behind wavelengths used in SIPI (Structure Insensitive Pigment Index) is the changes in carotenoid content as related to that of chlorophyll due to the sensitivity of

Table 1. Vegetation indices used in the study.

Vegetation index	Equation	Sensitivity	Reference
Normalized Difference Vegetation Index (NDVI)	$(R_{755}+R_{664})/(R_{755}-R_{664})$	Chlorophyll	Rouse *et al.* (1974)
Datt	$(R_{850}-R_{710})/(R_{850}-R_{680})$	Chlorophyll	Datt (1999)
Normalized Difference Spectral Indices (NDSI)	$NDSI\ [410,550]= (R_{550}-R_{410})/(R_{550}+R_{410})$ $NDSI\ [1050,1122]= (R_{1050}-R_{1122})/(R_{1050}+R_{1122})$ $NDSI\ [940,1122]= (R_{940}-R_{1122})/(R_{940}+R_{1122})$	Chlorophyll (b) Nitrogen Nitrogen	Inoue *et al.* (2008)
Water index (WI)	R_{900}/R_{970}	Leaf water	Peñuelas *et al.* (1996)
Vegetation Index (VI)	R_{810}/R_{560}	Nitrogen	Inoue *et al.* (2008)
Green Ratio Index (GRI)	R_{830}/R_{550}	Nitrogen	Inoue *et al.* (2008)
Structure Insensitive Pigment Index (SIPI)	$(R_{800}-R_{445})/(R_{800}-R_{680})$	Chlorophyll/Carotenoid	Peñuelas *et al.* (1995)
Soil-Adjusted Vegetation Index (SAVI)	$1.5(R_{830}-R_{660})/(R_{830}-R_{660}+0.5)$	minimize soil background and LAI variation in crops	Huete (1998)
Photochemical Reflectance Index (PRI)	$1.5(R_{830}-R_{660})/(R_{830}-R_{660}+0.5)$ $PRI2=(R_{531}-R_{570})/(R_{531}+R_{570})$ $PRI3=(R_{539}-R_{570})/(R_{539}+R_{570})$	Photosynthesis	Gamon, *et al.* (1992)

R: Reflectance.

680 nm wavelength to chlorophyll as well as the occurrence of minimum absorbance at 445 nm at very low chlorophyll content and carotenoid absorbance. In addition, epidermis condition has little effect on absorbance at this wavelength (Peñuelas *et al.*, 1995; Zarco-Tejada *et al.*, 2005; Dechmi *et al.*, 2003). Reflectance of crops with open canopies is also greatly influenced by soil reflectance. A number of indices have, therefore, been developed to mitigate or eliminate background spectral reflectance. *SAVI* index using wavelengths at 830 and 660 nm (Huete, 1998) has been used in the present study. Spectral reflectance at wavelengths in near infra red region (970, 1,050, 1,120, and 1,222 nm) are related to water used for photosynthesis and also nitrogen as an element present in lignin and cellulose structures. Using the mentioned indices, one can evaluate spectral differences between various rice varieties with high statistical accuracy (Table1).

Statistical Analysis

The above mentioned indices were calculated using spectrum for each species after eliminating water absorbance bands. This allowed us to statistically evaluate differences between spectral reflectance of leaves in different species. One way ANOVA and paired Tukey's test were used in SAS in the present study. All comparisons were made at P< 0.05.

RESULTS

Spectral Signatures of the Studied Varieties

Every obtained spectrum from averaging 100 records was visually quality controlled. Doing so, five unusual spectra (belonging to Shiroudi, Nemat, and Fajr varieties) affected by momentary changes in environmental conditions were removed from the dataset. Standard deviations at different wavelengths were calculated for all samples and data for water absorbance wavelengths (1,341–1,411, 1,771–1,936 and 2,350–2,500 nm) were removed as they were found to have high standard deviations indicating possible experimental errors (Figure 5-b). Figure 3 exhibits a typical spectral curve before error elimination in water absorbance wavelength range and Figure 5-a presents the standard deviations calculated for one sample at different wavelengths. The average reflectance spectra obtained by repeating measurements for each variety are presented in Figure 6 as the spectral signatures. Reflectance spectra obtained in the present study for rice variety canopy indicate differences in spectral reflectance generally at visible and near-middle infrared wavelengths (Figure 6).

Statistical Analysis of the Spectral Differences of Canopies

Statistical analysis using indices employed

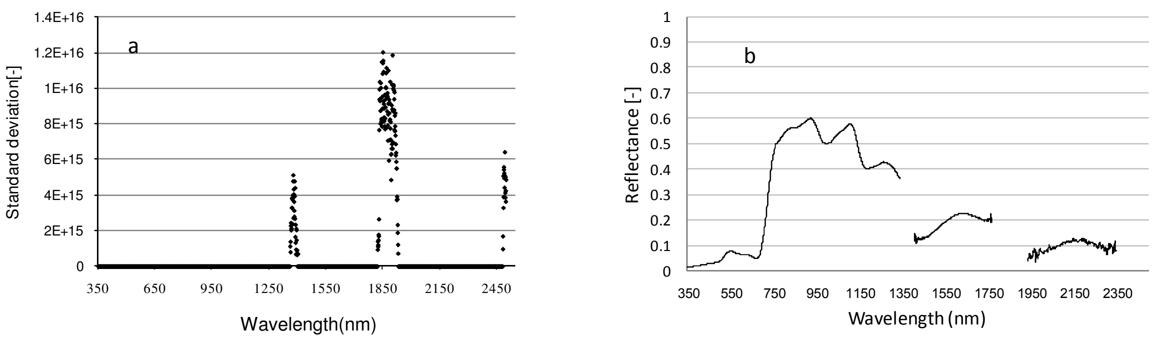

Figure 5. a, Calculated standard deviations of one spectrum for all wavelengths; b, spectral reflectance of one variety after error elimination.

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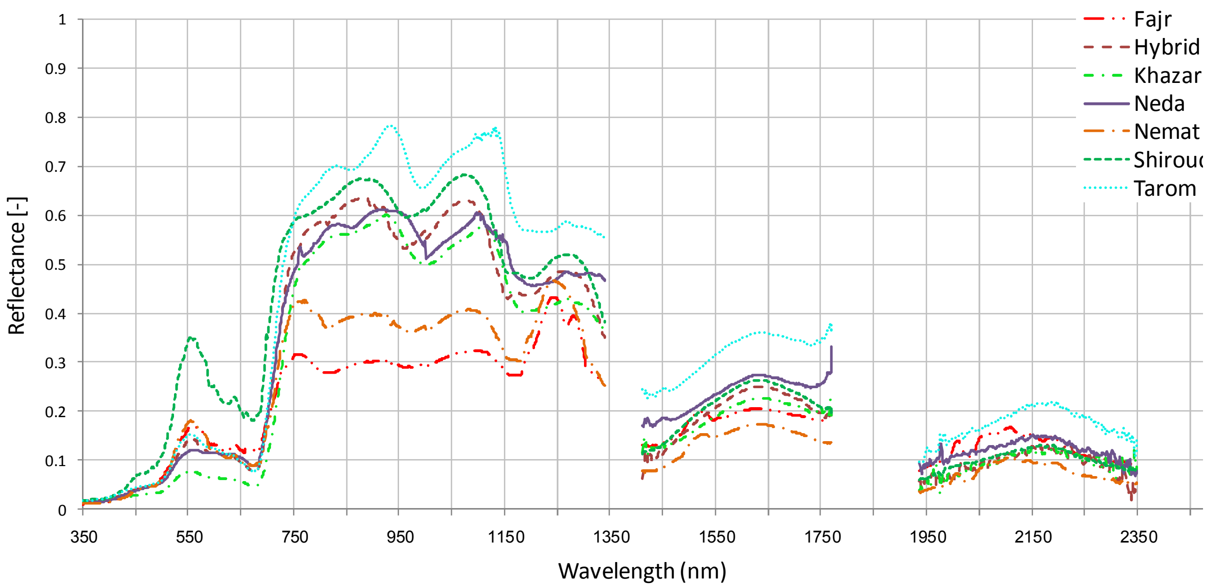

Figure 6. Averaged spectral fingerprints of seven dominant rice variety canopies (namely: Khazar, Hybrid, Fajr, Shiroudi, Nemat, Neda, Tarom).

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in this study confirms significant differences between various rice varieties at wavelengths related to chlorophyll content, nitrogen, canopy water content and photosynthesis intensity. To evaluate differences between pairs, paired Tukey's test was used. Results of this test for chlorophyll content, nitrogen, canopy water content, photosynthesis intensity and background elimination are presented in Table 2.

Datt index calculated as $(R_{850}–R_{710})/(R_{850}–R_{680})$ which is sensitive to chlorophyll content showed significant spectral differences between different rice varieties (α= 0.01, P< 0.0001). Only Tarom was found to be not significantly different from Hybrid and Neda (Figure 7). $NDSI_{[410,\ 550]}$ index sensitive to low chlorophyll contents also did not show a significant difference between Neda and Tarom. All other differences were statistically significant. Similar to $NDSI_{[410,\ 550]}$, *NDVI* also indicated a significant difference between Fajr and other varieties. *VI* and *GRI* are more sensitive to nitrogen than other indices and give similar results (Figure 7). Fajr was found to be significantly different from all other varieties except for Nemat, using both indices. Also, Hybrid, Khazar and Neda showed significant differences from other varieties. No significant difference was found between Shiroudi and Fajr using *VI* as well as between Shiroudi and Nemat using *GRI*. The sensitive to canopy water content R_{900}/R_{970} index indicated significant differences between Hybrid and Khazar, Fajr, Nemat, Neda and Tarom. Khazar was also found to be significantly different from Neda, Hybrid and Shiroudi regarding canopy water content (α= 0.01, P< 0.0001). Also, significant differences were found between Neda and Khazar, Shiroudi, Nemat and Hybrid as well as between Shiroudi and Tarom, Khazar and Neda. Other paired combinations were not significantly different.

Pigments concentration and performance, leaf water content, and plant health conditions (drought and other environmental stresses) greatly influence photosynthesis process. Photosynthesis indicator indices used in this study showed significant differences between some of the rice varieties. Tarom showed significant differences with all other varieties using

Table 2. Analysis of variance of the spectral reflectance of rice varieties using the studied indices.

			Tarom	Shiroudi	Nemat	Neda	Khazar	Hybrid	Fajr		
Chlorophyll	*NDVI*	Fajr	**	**	**	**	**	**		Hybrid	*Datt*
		Hybrid	**	**	NS[a]	NS	NS	**	**	Khazar	
		Khazar	NS	**	NS	NS	**	**	**	Neda	
		Neda	**	NS	NS	**	**	**	**	Nemat	
		Nemat	**	NS	**	**	**	**	**	Shiroudi	
		Shiroudi	**	**	**	NS	**	NS	**	Tarom	
Nitrogen	*VI*	Fajr	**	NS	NS	**	**	**	**	Hybrid	*GRI*
		Hybrid	**	**	**	**	**	**	**	Khazar	
		Khazar	**	**	**	**	**	**	**	Neda	
		Neda	**	**	**	**	**	**	NS	Nemat	
		Nemat	**	**	NS	**	**	**	**	Shiroudi	
		Shiroudi	**	**	**	NS	**	**	**	Tarom	
	NDSI [940, 1122]	Fajr	NS	**	NS	NS	NS	NS	**	Hybrid	NDSI [1050, 1122]
		Hybrid	NS	NS	NS	**	**	**	**	Khazar	
		Khazar	NS	**	NS	**	**	**	**	Neda	
		Neda	NS	**	NS	**	**	NS	NS	Nemat	
		Nemat	NS	NS	NS	**	**	NS	NS	Shiroudi	
		Shiroudi	**	**	**	NS	NS	**	NS	Tarom	
Leaf water	R_{900}/R_{970}	Fajr	NS	NS	NS	NS	NS	**			
		Hybrid	**	NS	**	**	**				
		Khazar	NS	**	NS	**					
		Neda	NS	**	**						
		Nemat	NS	NS							
		Shiroudi	**								
Photosynthesis intensity	*PRI3*	Fajr	**	NS	**	**	NS	**	**	Hybrid	*PRI1*
		Hybrid	**	NS	NS	**	NS	**	**	Khazar	
		Khazar	**	NS	**	**	**	**	**	Neda	
		Neda	**	NS	**	**	**	NS	**	Nemat	
		Nemat		**	**	**	**	**	**	Shiroudi	
		Shiroudi	**	**	**	**	NS	**	**	Tarom	
	PRI2	Fajr	**	**	**	NS	**	**			
		Hybrid	**	NS	NS	NS	NS				
		Khazar	**	**	NS	**					
		Neda	**	NS	**						
		Nemat	**	**							
		Shiroudi	**								
Minimize soil effect	*SAVI*	Fajr	**	**	**	**	**	**			
		Hybrid	**	**	**	**	**				
		Khazar	NS	**	**	NS					
		Neda	**	**	**						
		Nemat	**	NS							
		Shiroudi	**								
Chlorophyll/Carotenoid	*SIPI*	Fajr	**	**	**	**	**	**			
		Hybrid	NS	**	NS	NS	NS				
		Khazar	NS	**	NS	NS					
		Neda	NS	NS	NS						
		Nemat	**	NS							
		Shiroudi	**								

** Significant difference (α= 0.01), [a] Not significant.

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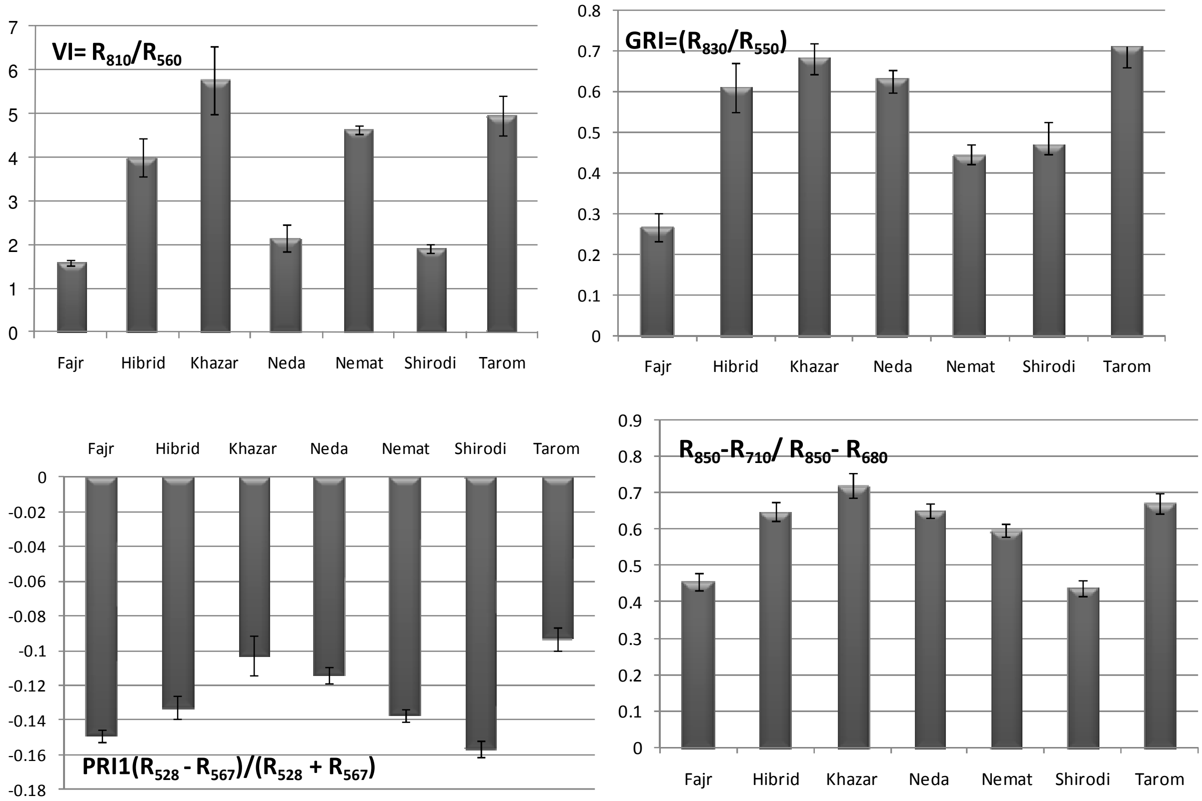

Figure 7. Mean and standard deviation of some vegetation indices calculated on seven rice variety.

PRI2 index (α= 0.01, P< 0.0001). This variety also showed significant differences compared to all other varieties using *PRI1* and *PRI3* indices, except Khazar and Nemat, respectively (α= 0.01, P< 0.0001). Neda was also found to be significantly different from Fajr using RPIs. Hybrid and Nemat were not significantly different using any of the three indices. All other comparisons are presented in Table 2.

Figure 3 depicts the canopy of the studied rice varieties shows differences in ear and stalk density in unit area. These differences result in different soil background reflectance for various rice varieties. A set of variable factors such as soil moisture content, soil type, organic content and chemical properties plays roles in such an effect which is different at different wavelengths. Using wavelength least influenced by soil background reflectance will help to accurately evaluate plant spectral reflectance. Analysis using *SAVI* index indicates significant differences between samples (α= 0.01, P< 0.0001). Fajr was found to be significantly different from all other varieties whereas Tarom was different from all but Khazar, Shiroudi from all but Nemat, and Neda from all but Hybrid and Khazar.

DISCUSSION

In field measurements, slight changes in wind velocity, temperature, and humidity occurring in a fraction of minute during spectroradiometry may possibly lead to errors in the performance of the spectroradiometer (Schaepman, 1998; Pfitzner *et al*., 2006). Therefore, an increase in the number of scans (around 100 scans) is more reliable.

Although differences in the spectrums of different rice varieties can be visually identified, the patterns and shapes of the spectrum boast greater significance. Due to the fact that the light intensity changes during sampling may influence spectral reflectance values, a simple comparison of the original reflectance values at each wavelength may not be very useful. Having strong relationships between the desired variables and vegetation indices based on the previous researches are, therefore, meant to enhance spectral differences as well as eliminating or mitigating unfavorable effects on spectral reflectance (Gausman and Allen, 1973). The selection of indices used in the present study was based on available literature (Inoue *et al.*, 2008; Wang *et al.*, 2008) that prove the strong relationships between the indices and the desired variables and the logic of eliminating unfavorable effects on spectral reflectance.

Results of the present study reveal that by using *Datt* and *PRI1* indices, in 19 out of 21 studied cases, significant differences (α= 0.01) in rice variety reflectance could be established. This is promising for the possibility of mapping cultivated areas of these rice varieties using hyperspectral remotely sensed data. Xue and Yang (2009) and Datt (1999) also reported similar results indicating the sensitivity of *Datt* index to chlorophyll content in various species. In their studies on all wavelengths related to photosynthesis intensities, Inoue *et al.* (2008) also obtained significant relationships between *NDSIs* and factors affecting photosynthesis. Different sensitivities of the selected indices to variables such as chlorophyll indicate the importance of selecting appropriate wavelengths for the vegetation cover under consideration. A number of indices for each variable, such as chlorophyll, have been developed and each index might be more sensitive for certain rice varieties. This is mainly due to different chlorophyll contents; if maximum spectral absorbance at any given wavelength is saturated by low chlorophyll content, that wavelength would be appropriate for low chlorophyll species. In other words, it would have enough sensitivity to chlorophyll content but would not be appropriate for high chlorophyll content species. Thus, a specific index at a specific wavelength might not have similar sensitivities in different species. This is why researchers have used different wavelengths in the range of red and infrared wavelengths to calculate NDVI based on corresponding pigment contents. It is therefore recommended that the best wavelengths be adopted by measuring variables and establishing relationships between experimental data and wavelengths.

Although the application of vegetation indices helps to enhance spectral differences including pigment contents, leaf water content, or plant cellular structure, it has the drawback of limiting us to certain wavelengths. It is therefore suggested that multiple variable statistical analyses, such as partial least square regression, be used to select the most appropriate wavelengths for the comparison of the spectral differences between studied varieties (Bajwa, 2006). Considering the evaluation of canopy spectral reflectance in crop species, using auxiliary information such as soil spectral reflectance, leaf area index, and canopy water content can help to obtain more comprehensive and more accurate results for the study of spectral differences in rice varieties.

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بررسی خصوصیات انعکاس طیفی تاج پوشش هفت رقم برنج ایرانی

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چکیده

تامین اطلاعات مربوط به سطح اراضی زیر کشت برنج و میزان محصول آن، لازمه مدیریت پایدار و سیاستگذاری اقتصادی این کالای استراتژیک می‌باشد. با افزایش قدرت تفکیک طیفی و مکانی داده‌های ماهواره ای، امکان تهیه این چنین اطلاعات به صورت به هنگام و دقیق تا حد زیادی فراهم شده است. بررسی انعکاس طیفی گیاه توسط طیف سنجی زمینی امکان تشخیص ارقام مختلف برنج و تهیه نقشه پراکنش آنها را به ویژه در استفاده از سنجش از دور ابر طیفی افزایش میدهد. به این منظور برای اولین بار مشخصه‌های طیفی هفت رقم بومی برنج شمال ایران در مزرعه تحقیقاتی موسسه تحقیقات برنج ایران در مازندران اندازه گیری شد. اندازه‌گیری‌ها توسط یک دستگاه طیف سنج زمینی در دامنه طول موج ۳۵۰ تا ۲۵۰۰ نانومتر در نور و شرایط طبیعی صورت گرفت. به منظور حذف داده‌های دارای خطا و همچنین خطای موجود در منحنی های انعکاس طیفی نمونه‌های اندازه‌گیری شده، منحنی‌ها به طور مجزا مورد بررسی کیفیت قرار گرفتند. برای بارزسازی تفاوت‌های احتمالی بازتاب طیفی رقم‌های مورد مطالعه، مجموعه‌ای منتخب از شاخص‌های طیفی مهم و حساس به غلظت کلروفیل، شدت فتوسنتز، نیتروژن و میزان آب موجود در تاج گیاه محاسبه شدند. در ادامه تجزیه و تحلیل آماری واریانس و آزمون جفتی توکی به منظور بررسی مقایسه جفتی رقم‌های برنج انجام گردید. نتایج نشان می دهد که در صورت استفاده از شاخص های Datt و PRI1 در ۱۹ حالت از ۲۱ حالت مورد بررسی تفاوت معنی دار (α=۰/۰۱) بین بازتاب رقم های برنج وجود دارد. این مطلب نوید بخش امکان تهیه نقشه مناطق زیر کشت هر یک از رقم های برنج بر اساس داده های سنجش از دوری Hyperspectral میباشد.