HYPERSPECTRAL REFLECTANCE AND THEIR RELATIONSHIPS WITH SPRING WHEAT GROWTH STATUS CHARACTERISTICS IN RAINED AGRICULTURE AREAS OF LOESS PLATEAU

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KEY WORDS: Spr-wheat; Hyperspectral Reflectance; Growth Satus; Red Edge Parameter; LAI; Chlorophyll;

ABSTRACT:

Diagnosis of crop growth and nutrient status is critical for prediction of agriculture yield and quality at Growth stage. Two experiments, one in 2006 and one in 2007 were conducted to find out spr-wheat canopy and leaf spectral characters non-destructively measurement, and for assessing spring wheat growth status non-destructively at the Experimental Farm (30º53′ N，104º25′ E) of Lanzhou University and Dingxi arid meteorology and agriculture experiment station(35° 32′ N,104° 37′ E) of CMA, China. The experiment included four cultivars (Heshangtou(a), Gaoyuan602(b), Longchun8139(c) and Dingxi24(d) and seven levels of denesity (D) application in year 2006 and four spring cultivars, four levels of density(D) and three repetition treatments in year 2007. Hyperspectral canopy and leaf reflectance (350–2500 nm) data recorded at various growth stages were measured by an ASD Field Spec Pro FR2500 in different stages, and the contents of Leaf area indices (LAI) of spr-wheat，measured by a LAI2000 plant canopy analyzer, chlorophyll of the leaf, measured by a SPAD502, ground dry biomass, ground fresh biomass and the plant height(PH) to the spectra were determined. The results are following: firstly, the spectral differences are clear for the canopy and leaves of spr-wheat under different density levels, and the canopy spectral reflectance are gradually getting smaller in the visible region and bigger in the near infrared region along with density level increasing at jointing, booting, heading and filling stage, but this change is not evidence at ripening stage; secondly, there are obviously difference in four kinds spr-wheat in canopy and leaf scales spectral reflectance; thirdly, There are “double peak” phenomena for the spr-wheat at nutrition grown stage. Additionally, there were ‘blue shift’ phenomena for the position of red edge (λ red); Fourthly, the relationship between the spectral vegetation indices and the biochemical parameters indicated that the LAI have the best relationship with DVI and the relativity are the best between the spectral index(λ red) and the chlorophyll among the selected spectral index, PVI and FW,plant height (PH) are good correlation. This indicated that some right spectral variables would be used to estimate the LAI, FW, the PH and chlorophyll for spr-wheat. Furthermore, the correlation of the spectral index and the biochemical properties of vegetation are effected by the different cultivars.

1. INTRODUCTION

Spring wheat yield is closely related to crop growth status before the heading stage, Therefore, indicators related to crop growth status before heading stage have been frequently employed in various models to predict grain yield and yield components (Cui andLee, 2002; Ntanos andKoutroubas, 2002; Casanova et al., 2000).

remote sensing has attracted a great deal of attention in terms of application for crop monitoring. Hyperspectral remote sensing acquiring images in narrow (<10 nm) and continuous spectral bands provides a continuousspectrum for each pixel, unlike multi-spectral systemsthat acquire images in a few broad (>50 nm) spectral bands.Therefore, its data is considered more sensitive to specificcrop variables (Hansen and Schjoerring, 2003).

Accurate quantitative estimates of biochemical properties of vegetation canopies are important applications of remote sensing for terrestrial ecology(Gao, B. –C,etal,1995).The spr-wheat is one of the main grain crops in China and the correlations of the output, type and structure of the colony are closely. And the canopy for the spring wheat absorption and reflectance the sun light is a main factor to effect on the quality and the output of the wheat. It provided important evidence for remote sensing monitoring growth and estimating the output by observation the spectral variable and the relationship among the reflectance and biophysical parameters such as the leaf area index (LAI), the dry biomass, and wet biomass, the chlorophyll content. The report on the estimating the photosynthetical active radiation (PAR), the grown state and chlorophyll

Content using the cotton hyperspectral reflectance data, meanwhile, estimating the coefficient of the PAR, the nitrogen status are often seen(Sh ibayamaM,1989; Dalezio s N R,2001; Pattey E,2001; Thenkabail P S,2000; TangYL,2003), but the study on hyperspectral reflectance and red edge character the same time for the spring wheat are few.

The object of this study is to capture the impacts of the species, LAI and density on the spectral reflectance and offer the prime basis for the growth monitoring and remote sensing estimating output.

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2. EXPERIMENTAL METHODS AND MATERIALS

2.1 Experimental design

Experiment one: From April to August in 2006, the experiment was carried out at the loess plateau ecological experimental station（E104º25′，N30º53′） of the key laboratory of the nation arid agriculture at the Northern Mountain Yuzhong, lanzhou university. The soil type is yellow soft soil and the four cultivars are Dingxi35, Gaoyuan602, Longchun8139 and Dingxi24. The density grads is 100 grains/m2，200 grains / m2，400 grains / m2，600 grains / m2，800 grains / m2，1600 grains / m2，3200 grains / m2.The sample site is 2m×2m and in order to ensure the precision the part of the wheat provide to observe the biophysical parameters was apart from the spectral observation.

Experiment two: In Dingxi arid meteorology and agriculture experiment station (35°32′N, 104°37′E) of CMA, China. And the four cultivars are Dingxi35 Gaoyuan602, Longchun8139 and Dingxi38, the area is 3m×3m, the line is 12 meter, and the field management is the same to experiment one.

2.2 Measurement

The canopy and leaf spectral reflectance was measured using a portable ASD Field Spec Pro FR2500 spectroradiometer (Analytical Spectral Devices Inc., Boulder, CO, USA) with spectral range from 350 to 2500 nm (1 nm intervals). The spectral resolution was 3, and 10 nm for the ranges 350–1000 and 1000–2500 nm, respectively. The optical sensor of the spectroradiometer was mounted in the frame of a supplemental light source with a 50-mm distance from target leaf surface. The sight angle is 5° and 25°.A Spectralon white reference panel was used to optimize the instrument to 100% reflectance at all wavebands prior to canopy and leaf reflectance measurements. When measuring leaf reflectance, the sight angle is 5° and that is 25° for the canopy reflectance measurement. Spectral measurements were collected around solar noon on clear days using the following protocol: canopy reference measurement was collected twenty-five times at five spots and the height of the sensor and the canopy was one meter. At the last, the average value was the reflectance of the spot, followed by one reference measurement collected from a white field reference panel. The white field reference panel was made of a lighter, more portable material than the Spectralon panel and enabled more frequent calibration measurements to be made within the field without damaging the coating of the Spectralon panel itself. Meanwhile, the leaf of the stem reflectance was collected ten times each spot and the interval was 0.1 meter then obtain the average value.

Leaf area index (LAI) was recorded using the LAI-2000 plant canopy analyzer. Plant components were dried at 70℃ and weighed to determine the dry biomass. The chlorophyll measures by a SPAD502 and the plant height is determined synchronously.

2.3 Selection and definition of spectral indices

Spectral indices were computed by chlorophyll absorption around 640~660nm and 430~450nm (Table1). Furthermore, as we all know, the red edge parameter is another important index to the vegetation grown status. The quantitative describe the red edge feature are main following three: (1) the position of red edge(λred), that is the wavelength of the maximum of the first derivative reflectance in red region((680-760nm); (2) the range of the red edge(Dλred), that is the maximum of the first derivative reflectance in red region((680-760nm); (3) The area of the red edge (Sred) , that is the area of the first derivative reflectance surrounded. In this paper, the first derivative reflectance is calculated by difference, Dλ=（Ri + 1）-（Ri -1）/（λi+ 1） -（λi – 1）， and the Ri is the reflectance when the wavelegth is i. some research indicated that there are two factors determined the position and the slope of the red edge, one is the chlorophyll, it cause the change of the spectral varies around 700nm and the other is scatter feature of the plant, it was determined by the structure of the canopy and leaf and so on(Boochs F,1990; Horler D N H,1983).

Indices	Reference	Formulation
NDVI	Rouse etal.(1974)	$NDVI = \frac{R_{nir} - R_{red}}{R_{nir} + R_{red}} = \frac{R850 - R650}{R850 + R650}$
EVI	Huete et al., (2002),	$EVI = 2.5 \times \frac{R_{nir} - R_{red}}{R_{nir} + 6 \times R_{red} - 7.5 \times R_{blue} + 1} = \frac{2.5 \times R_{850} - R_{650}}{R_{850} + 6 \times R_{650} - 7.5 \times R_{450} + 1}$
NDWI	Gao (1996)	$NDWI == \frac{R_{860} - R_{1240}}{R_{860} + R_{1240}}$
RVI	Pearson&Miller (1972)	$RVI = \frac{R_{nir}}{R_{red}} = \frac{R_{850}}{R_{650}}$
PVI	Richardson&Wiegand (1977)	$PVI = \frac{R_{nir} - aR_{red} - b}{\sqrt{(1+a^2)}} = \frac{R_{850} - a \times R_{650} - b}{\sqrt{(1+a^2)}}$ (a=10.489,b=6.604)
SAVI	Huete(1988)	$SAVI = \frac{R_{nir} - R_{red}}{R_{nir} + R_{red} + L}(1+L)$, L=0.5
DVI	Jordan(1969)	$DVI=R_{nir}-R_{red}=R_{850}-R_{650}$
λ_{red}		the position of red edge
$D\lambda_{red}$		the maximum of the first derivative reflectance in red region((680-760nm)
R670/R550		
R670/R440		

Table.1 the camputed of the spectral indices

3. EXPEEERIMENTAL RESULTS AND DISCUSSION

3.1 The canopy and leaf hyperspectral feature for spr-wheat in different stage

In different growth stage, the hyperspectral reflectance of the canopy level and the leaf level are different, the hyperspectral reflectance of the canopy level and the leaf level are different, and that of the canopy is highest at jointing stage and lowest at ripening stage in the visible (VIS) region and in the shortwave infrared (SWIR) and the spectral variation trend is similar, meanwhile, that is highest at flowering~filling stage in the near infrared region. The green peak disappeared at ripening stage. On the contrary, the leaf hyperspectral reflectance is highest at jointing stage than other stage in the near infrared region, and the reflectance in green region is falling at ripening stage.

In summary, the spectral difference is significant to monitoring the growth status in different stage.

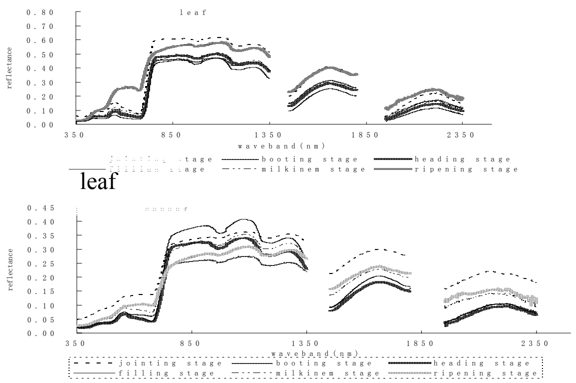

Figure.1 The canopy and leaf hyperspectral for spr-wheat in growth stage

3.2 The charactering of the canopy and leaf for spr-wheat in different density

Fig.1A~Fig.1D show the reflectance of canopy and leaf at the booming and ripening stages in seven density scales (d1~d7 indicate from sparse to bushy). It shows that the curves were similar but the reflectance values are different. The spectral differences are clear for the canopy and leaves of spr-wheat under different density levels, and the canopy spectral reflectance are gradually getting smaller in the visible (VIS) region and bigger in the near infrared (NIR) region along with density level increasing at booting stage, but this change is not evidence at ripening stage. The difference of the spectral reflectance of the leaf from the top on the main stem is little in VIS region and great in NIR region at booting stage and this difference in VIS and NIR is coherence along with the different density. At ripening stage, the spectral reflectance of the leaf is bigger in middle density level. And the leaf reflectance of D7 was the least because of the competitive growth, the LAI of the D7 was the least and the leaf reflectan was lower. Moreover, the other breeds have the same variety trends.

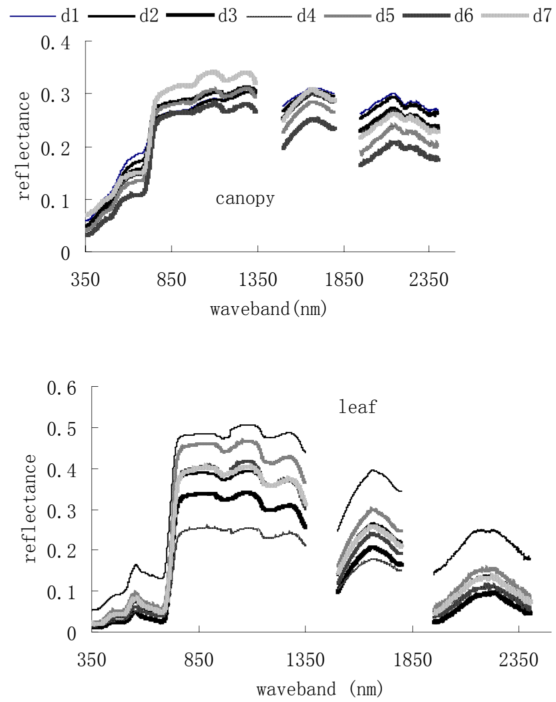

Figure.2 The charactering of the canopy hyperspectral for spr-wheat in different density at booting stage

3.3 The hyperspectral in different for the spr-wheat

The hyperspectral reflectance of the canopy and the leaf for the four spr-wheat breeds in the same density were compared and it indicated that there are no obviously difference in these four kinds spr-wheat in canopy spectral reflectance, while the spectral reflectance difference of leaf level is clearly in the near infrared (NIR) region at booting stage, and the biggest is the Longchun8139, Dingxi24 the second, Heshangtou the third and Gaoyuan602 spr-wheat the forth. The difference of reflectance maybe connected with the bearing feature for each cultivar. The longchun8139 is a kind of earliness species and the plant growth is blooming. And the grown stage of Dingxi24 is longer and the leaf is bigger and the color of the leaf is thicker, the leaf of Gaoyuan602 and Heshangtou is little. It indicates the possibility to identify the wheat type using the hyperspectral reflectance data by the experiment.

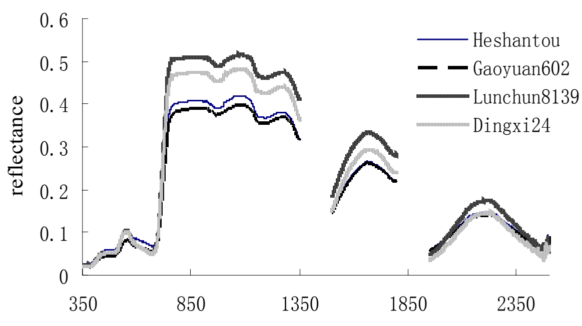

Figure.3 The leaf hyperspectral of the different species spr-wheat

3.4 The red edge feature of the canopy and leaf for spr-wheat

Like most of the green vegetation, there are “double peak” or “multi-peak” phenomena for the spr-wheat at growth stage, just the “double peak” feature is not notably because of the impacts of the soil spectral at the beginning of the growth stage, and it disappeared until the wheat mature and the leaf turn to yellow.

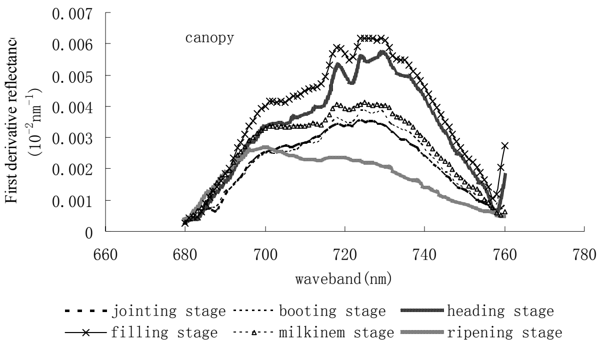

Figure.4 the first derivative spectra of canopy red edge for spr-wheat in different stage

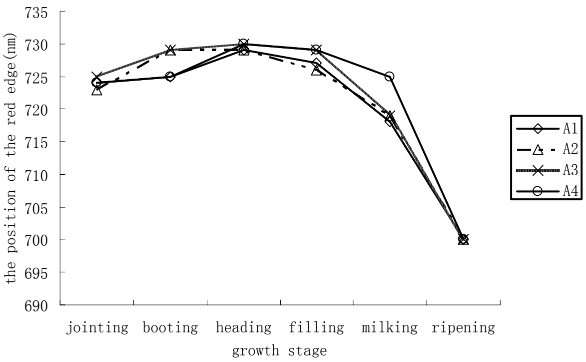

Figure.5 The position of the red edge change of canopy for spr-wheat in different four densities in different stage

From the Fig.4 and Fig.5, the red edge position of the canopy reflectance is at 700~730nm region during the growth stage, Additionally, by the grown stage from the joinging stage to heading stage, there were “red shift” phenomena weakly and from heading stage to ripening stage, there were “blue shift” phenomena remarkably, and for the λ red , D λ red and Sred of the canopy and leaf spectra are decrease from jointing stage to ripening. This shows that the λ red, D λ red and Sred are the signal of the wheat growing. it also shows that the red edge position maybe the indicator for the vegetation in stress status.

3.5 The relationship of the hyperspecral data and the biophysical Parameters

For the sake of analyzing the correlations among the ground dry weight (ADM), the plant height (PH) and the hyperspectral variable, we selected the rate of the special band and the red edge parameter to built the following spectral variable listed in table.1.

From Fig.6,Fig.7 and the table.2, The leaf area indices (*LAI*),the above ground fresh biomass, above ground dry biomass , plant height, chlorophyll are significantly correlative to the spectral Vegetation Indices: normalized difference vegetation index(NDVI), soil adjusted vegetation index (SAVI)， ratio vegetation index (RVI) ,difference vegetation index (DVI) and perpendicular vegetation index (PVI), etal, and the relationship of *PVI* with plant height and above ground fresh-biomass-weitht(FW) is the best(R=0. 563,P<0.01;r=0.685,P<0.01), and the *LAI* have the best relationship with *DVI* (r=0.694,P<0.01) and the relativity are the best between the spectral index(R670/440) and the chlorophyll among the selected spectral index(r=-0.846,P<0.01), λ_{red} and plant chlorophyll content are good correlation. This indicated that some right spectral variables would be used to estimate the *LAI, ADM, the PH* and chlorophyll for spr-wheat. Furthermore, the correlation of the spectral index and the biochemical properties of vegetation are effected by the different cultivars.

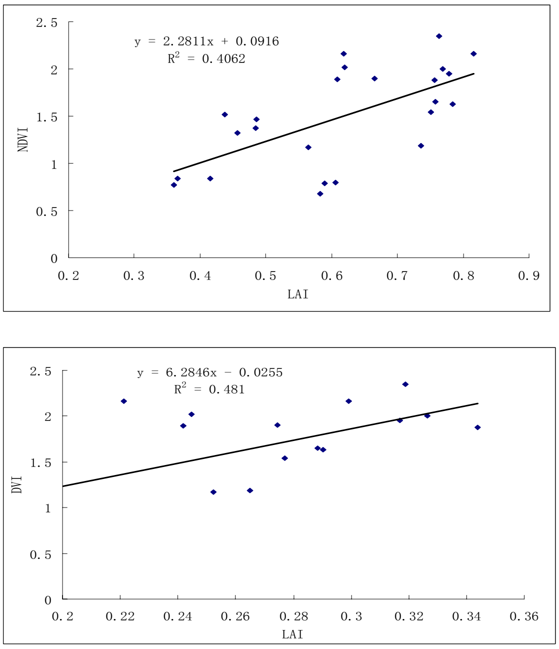

Figure.6 the relationship between the spectral indices and the LAI

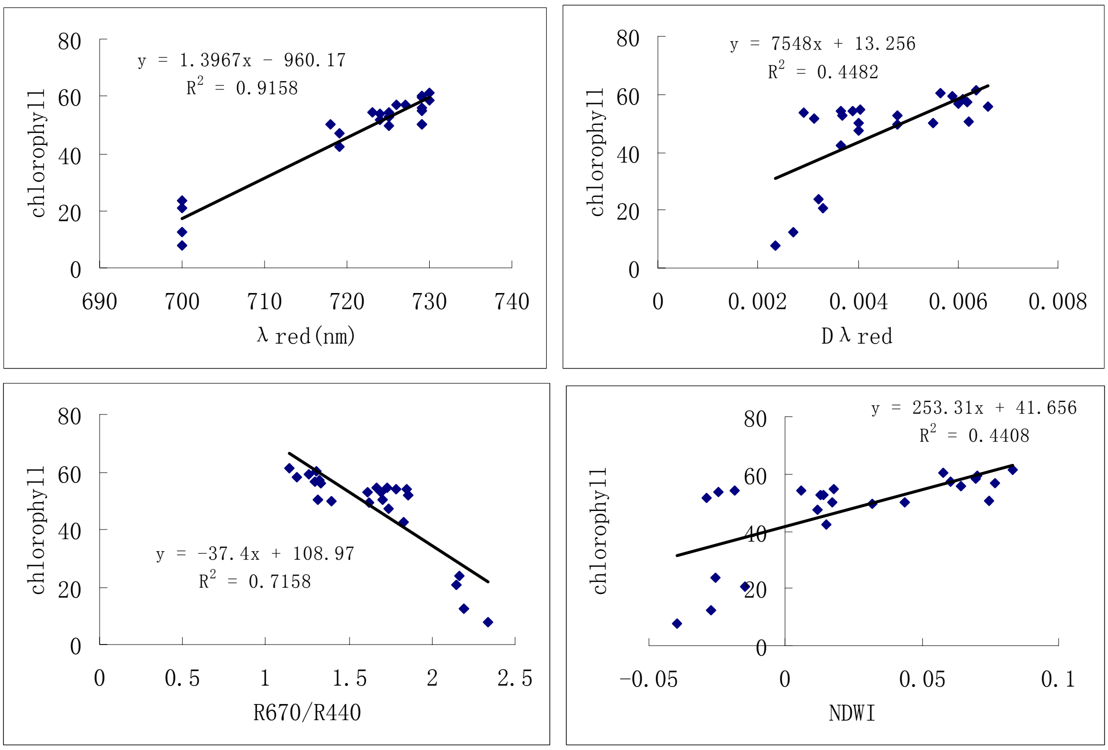

Figure.7 the relationships between the chlorophyll and spectral indices

3.6 indices / BP	NDVI	EVI	NDWI	RVI	PVI	SAVI	DVI	λ_{red}	R670/ R440
LAI	0.637**	0.678**	0.594**	0.625**	0.614**	0.692**	0.694**	0.06	-0.39
chlorophyll	0.599**	0.605**	0. 684**	0.583**	0.489*	0.622**	0.621**	0.957**	-0.832**
DW	0.213	0.178	0.068	0.136	0.305	0.169	0.112	0.202	-0.533**
FW	0.66**	0.646**	0.586**	0.612**	0.685**	0.637**	0.581**	-0.546	-0.003
PH	0.532**	0.541**	0.444**	0.5**	0.563**	0.539**	0.508**	-0.70	-0.22

Table.2 the relationship between the spectral indices and the biophysical Parameters (BP)

4. CONLUSION

The canopy and leaf reflectance are affected by the plant density scale in different spectral region in every grown stage. Moreover, the difference in booting stage and ripening stage is notable; using the spectral reflectance characteristic could monitor the grown status. The experiment also indicated the possible to distinguish spr-wheat type using NIR region. The red edge parameter feature showed that "double peak" at grown stage and "blue shift" phenomena from the booting stage to the ripening stage. Furthermore, the Dλ_{red} maybe used to estimate the yield and the λred may indicate the grown stage. Review on the relationships between the special variable and the biophysical parameter found that the correlation among the relationship of DVI and LAI is best at whole growth stage, PVI and PH and FW are the best. The λ_{red} and PH have non-correlations. Furthermore, λ_{red} and the chlorophyll has the best relationship. This research only obtains the spectral in growth stage of the spring wheat, so the change of the whole grown stage of the vegetation in arid area needs to study deeply in future.

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