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Spectral characteristics of wheat as influenced by nitrogen stress*

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ABSTRACT

A field experiment was conducted during, *rabi* season of the year 2007-08 at Agronomy Farm, Anand Agricultural University, Anand, Gujarat to study the spectral characteristics of wheat (*Triticum aestivum* L.) as influenced by nitrogen stress and variety and to develop the relationship between spectral vegetation indices and growth and yield of wheat. Spectral observations at canopy level were taken between 10 : 30 to 11 : 30 A. M. by using spectroradiometer model Unispec-DC version 2.02 which operates in wavelength of 310-1100 nm covering visible and near infrared portion of the electromagnetic spectrum. The spectral reflectance data of wheat crop clearly demonstrated the differences in spectral reflectance characteristics at different stages of the crop growth. In the initial stage of the crop, the reflectances were found to be partially influenced by soils as the canopy had not fully developed. As the canopy developed, the reflectance increased in green and NIR region and decreased in red region. The spectral reflectances were higher in the treatment having higher N applications. The spectral indices viz., ratio vegetation index (RVI) and normalized difference vegetation index (NDVI) were lowest under no N and highest in 120 kg N. The correlation and regression analysis was carried out and is discussed.

Key words : Nitrogen stress, spectral reflectance, wheat

Wheat *(Triticum aestivum* L.*)* is the most important crop of India grown both in rainfed and in irrigated regions. It serves as a staple food for about a billion people in as many as 43 countries of the world and is the widely cultivated food crop of the world. The major constraints for low productivity of wheat are moisture and nutrient stress caused due to improper management. The abiotic stresses due to fluctuation in temperature and sunshine during crop season also have sustained influence on year-to-year fluctuation in wheat yield. Inadequate supply of water and nutrients, insect/pest attack, disease outbreak and abnormal weather conditions adversely affect the crop growth and restrict the potential yield of crop.

Remote sensing is a technique of obtaining information about an object, area or phenomenon by analyzing data acquired by a device that is not in contact with that object, area or phenomenon (Lillesand and Kiefer, 1987). Remote sensing technique can be used for estimating the N status of growing crops by determining the appropriate wavelength or combinations of wavelengths to characterize crop N deficiency. Walburg *et al.* (1982) demonstrated that N treatments affected reflectance in both the red and near-infrared (NIR) regions of the spectrum, with red reflectance increasing and NIR reflectance decreasing for N-deficient corn canopies. Stone *et al.* (1996) demonstrated that total plant N could be estimated by using spectral radiance measurement at the red (671 nm) and NIR (780 nm) wavelengths.

To use the information contained in the reflectance across wavelengths, several vegetation indices have been proposed. VI is the quantative measure used to measure biomass or vegetative vigour. These indices are primarily based on ratio or difference between the reflectance in various wavelengths. Each index provides a description of the canopy response during period of particular growth stage under the study. RVI (ratio vegetation index; Jordan, 1969) is the simplest among the ratio based VI, which has the ratio of NIR to RED. NDVI (normalized difference vegetation index; Rouse *et al.,* 1974) is the most widely used technique to understand the vegetation health status, it is calculated from the visible red and near infrared light reflected by vegetation.

The objectives of this experiment were to determine the spectral characteristics of wheat as influenced by nitrogen stress, discriminate the wheat varieties and derive the spectral vegetation indices.

MATERIALS AND METHODS

Site and treatments

A field experiment was conducted at Agronomy Farm, Anand Agricultural University, Anand, Gujarat on wheat (*T. aestivum*) having two varieties viz., LOK 1 and GW 496 during *rabi* season of 2007-08. The crop was grown in 4.00 x 1.80 sq. m test plots laid out in split plot design having four replications with two varieties viz., GW 496 and LOK 1 as the main treatments and five nitrogen fertilizer application rates (0, 30, 60, 90 and 120 kg N) as sub-treatments.

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Spectral and biometric data

Spectral observations at canopy level were taken at 10 days interval starting at 25 days after sowing (DAS) by using Unispec-DC version 2.02. Spectroradiometer operated in wavelength of 310-1100 nm covering visible and near infrared portion of the spectrum. Data were taken between 10:30-11:30 A. M. on cloud free days from all plots under different treatments. Observations were taken at different growth stages of wheat like tillering, jointing, booting, heading, flowering, milking, dough and maturity. Spectral data were used to derive the different vegetation indices. The reflectance was calculated as the ratio between the reflected and incident spectra of the canopy. The RVI value was calculated by dividing canopy reflectance of NIR band with R band i. e. NIR/R. The NDVI calculated difference between reflectance of NIR band and R band divided by sum of these two bands viz., (NIR-R)/(NIR+R). Correlations were worked out between spectral indices at different stages with the biomass, LAI and grain yield. Significant correlations obtained were used to develop regression models.

RESULTS AND DISCUSSION

Spectral reflectance characteristics of wheat

The overall mean of spectral reflectance of wheat crop at different stages is plotted in Fig. 1. It may be seen that the spectral reflectance characteristics of wheat are different at different stages. These changes were due to changes in the canopy structure and pigments during the developmental stages. During tillering stage the canopy was not fully developed and soil contribution to the canopy reflectance was large. Although the spectral signature showed some characteristics of green vegetation (lower reflectance in the red region). In NIR region, the value ranged from 0.44 to 0.47μ at tillering stage. As the canopy developed reflectance increased upto maximum contrast at jointing stage. The reflectance in visible region was highest at this stage. Similarly, the reflectance in NIR region was highest at jointing stage with values ranging from 0.81 to 0.84. Xiaoping *et al.* (2008) also reported similar results. As the crop growth progressed further, the senescence of lower leaves affected the canopy reflectance and the reflectance contrast started reducing. At the maturity stage, green peak in visible region almost disappeared and the spectral signature showed a linear trend across the red region (i.e. the transition zone between red and NIR).

Spectral indices as influenced by nitrogen

Ratio vegetation index (RVI)

The RVI as influenced by N treatments during different stages of crop growth are presented in Fig. 2. It was observed that the value of RVI was 10 to 12 at 25 DAS and it reached to its maximum value (28-23) at 35 DAS. Thereafter, it decreased slowly in all the treatments with the advancement of the crop. The value of RVI was maximum in treatment N-1 (120 kg N ha^{-1}) at all the growth stages, and it was minimum in treatment N-5 (0 kg N ha^{-1}) at most of the growth stages. Ansari *et al.* (2006) also reported similar results. At 35 DAS, a peak in reflectance for all treatments was observed. Thus, RVI can be used to detect nitrogen stress in wheat crop during most of the crop stages except at 25 DAS.

Normalized difference vegetation index (NDVI)

The NDVI, an indicator of status of crop vigour, as influenced by nitrogen treatment is presented in Fig. 3. The values of NDVI at 25 DAS varied between 0.82 to 0.85. Thus, NDVI increased to its maximum values between 0.93 to 0.95 at 35 DAS. Thereafter, it decreased slowly and reduced to 0.84 to 0.89 at 75 DAS in all the treatments. Among all the N treatments, the NDVI was maximum in the treatment N-1, and the minimum NDVI value was found in the treatment N-5. Its values in N-1 treatment were always higher than in rest of the treatments. Thus, NDVI can be used to differentiate the nitrogen stress in the crop particularly after 35 DAS. Ansari *et al.* (2006) also reported similar results.

Nitrogen stress caused decrease in reflectance in NIR region (Fig. 4). It was observed that NIR reflectance was highest (0.46 to 0.31) for N-1 (120 kg N ha^{-1}) and lowest (0.39 to 0.28) for N-5 treatment during all stages of the crop growth. The differences in reflectance were more or less same thereafter the period except at 25 and 75 DAS. These results were supported by the work of Stanhill *et al.* (1972) and Ansari *et al.* (2006).

Correlation of biomass, LAI and grain yield with RVI and NDVI

Correlation analysis showed that RVI at all stages of crop had positive correlations with biomass, LAI and grain yield. At jointing stage, RVI was significantly correlated with the biomass, LAI and grain yield, the highest significant correlation ($r=0.896^{**}$) was obtained with the grain yield at jointing stage. At milking stage, it had highly significant correlation with biomass and LAI. RVI at all the stages of crop had positive correlations with biomass, LAI and grain yield. The values and trend of correlation coefficients with biomass, LAI and grain yield were, however, different. It may be seen that the values of correlation coefficients with biomass increased with the advancement of the crop. Thus, RVI was found to be a good indicator of biomass of the crop (Table 1).

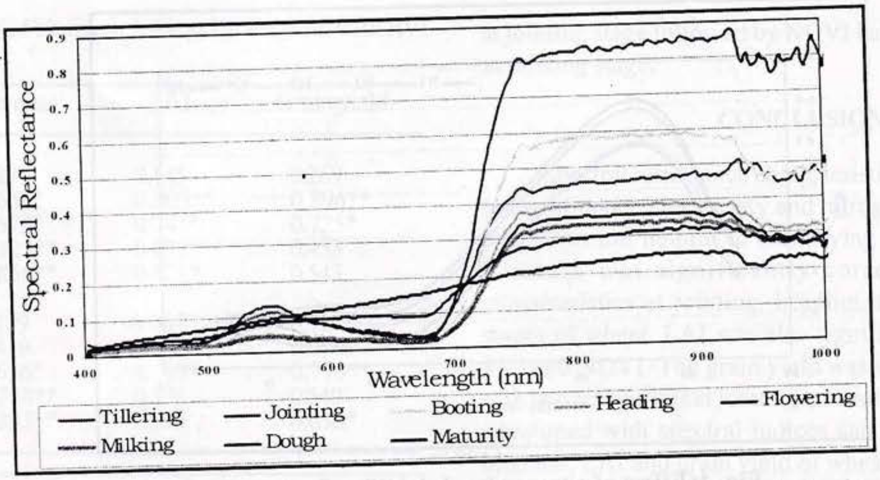


Fig. 1: Spectral reflectance characteristics of wheat at different growth stages

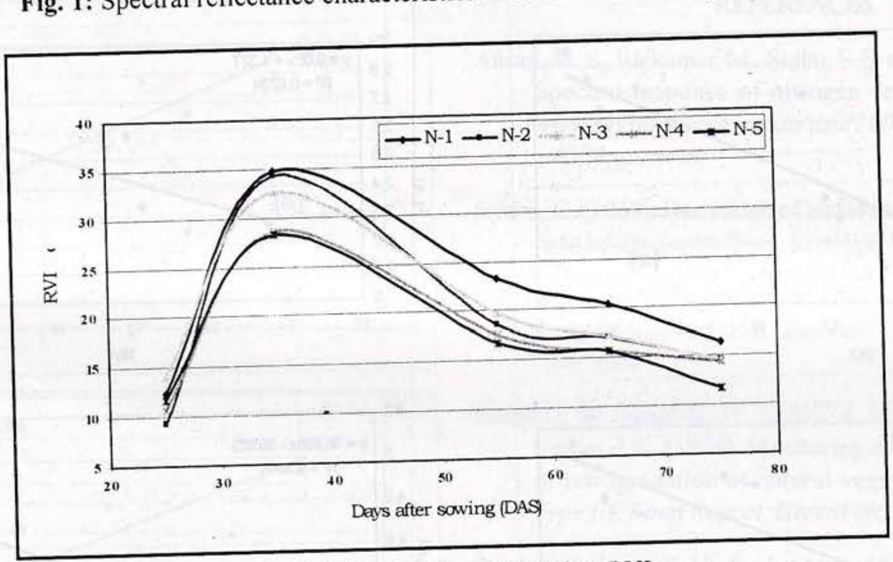


Fig. 2: Effect of nitrogen level on RVI

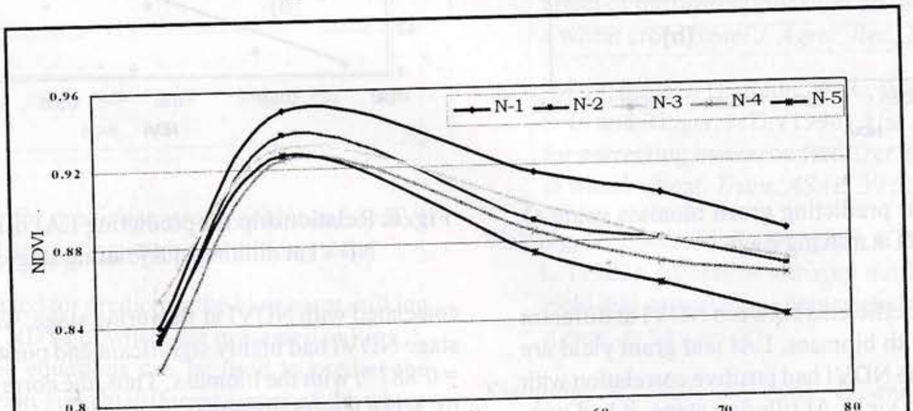


Fig. 3: Effect of nitrogen level on NDVI

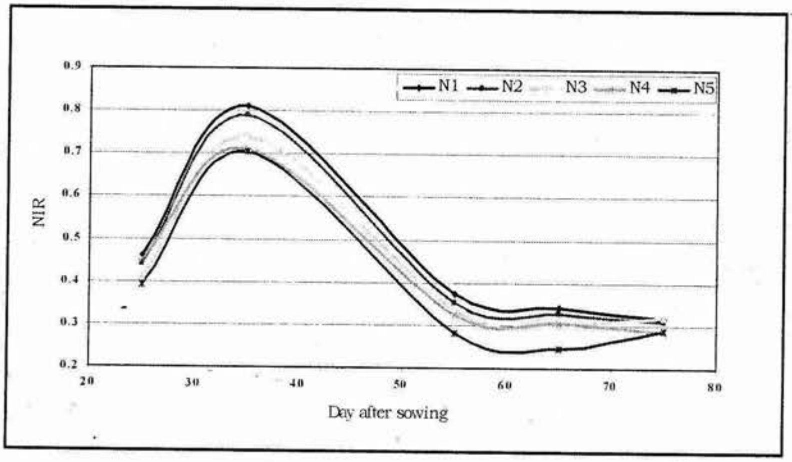


Fig. 4: Effect of nitrogen level on NIR reflectance.

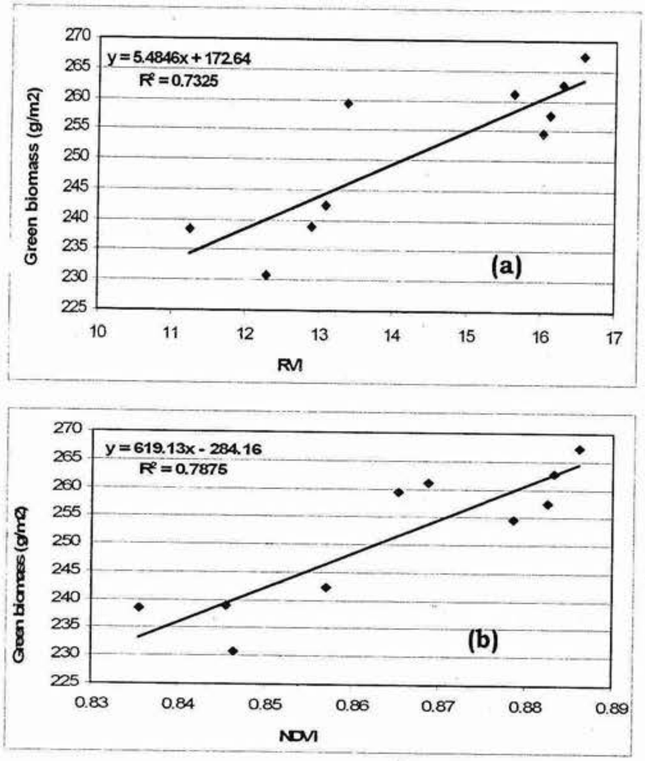


Fig. 5: Relationship for predicting green biomass using a) RVI and b) NDVI at milking stage.

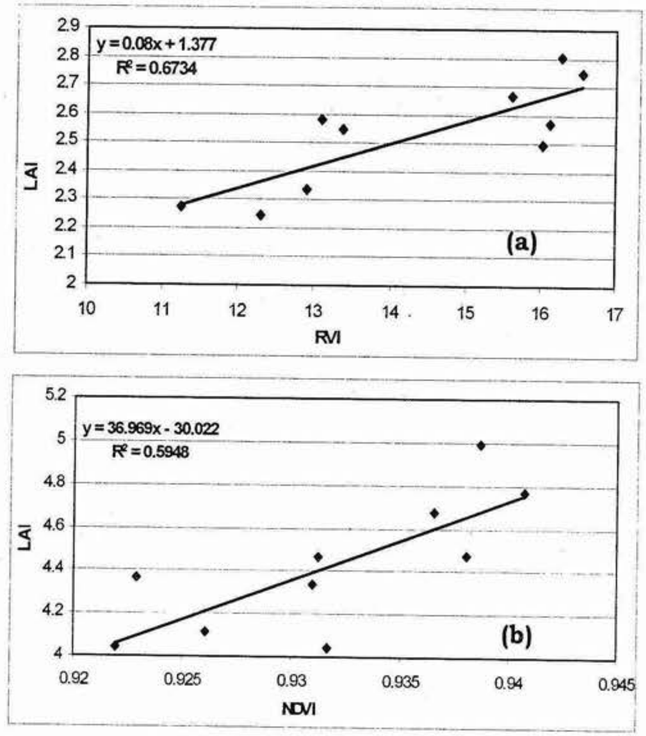


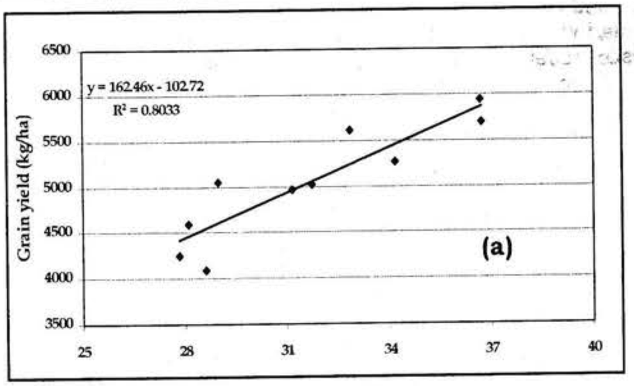
Fig. 6: Relationship for predicting LAI using a) RVI and b) NDVI at milking and jointing stage.

The correlation coefficients between NDVI at different stages of wheat crop with biomass, LAI and grain yield are presented in Table 1. The NDVI had positive correlation with biomass, LAI and grain yield. At tillering stage, it had non-significant correlation with biomass, LAI and grain yield. At jointing stage, however, it had significant correlation with LAI and grain yield. NDVI at heading stage had significant correlation with all parameters. Biomass was significantly correlated with NDVI at flowering stage, whereas at milking stage NDVI had highly significant and positive correlation ($r = 0.887^{**}$) with the biomass. Thus, the correlation coefficient of NDVI with biomass constantly increased with the advancement of the crop upto milking stage. This trend is similar to that observed with RVI.

Regression model was developed to predict biomass, LAI and grain yield using RVI and NDVI of wheat crop. The

Table 1: Correlation of biomass, LAI and grain yield with RVI and NDVI

Stages	Biomass	LAI	Grain yield
RVI			
Tillering	0.271	0.145	0.269
Jointing	0.660*	0.803**	0.896**
Heading	0.678*	0.741*	0.725*
Flowering	0.825**	0.671*	0.453
Milking	0.856**	0.821*	0.543
NDVI			
Tillering	0.119	-0.067	0.121
Jointing	0.419	0.771**	0.690*
Heading	0.636*	0.707*	0.770**
Flowering	0.778**	0.556	0.540
Milking	0.887**	0.852	0.636*



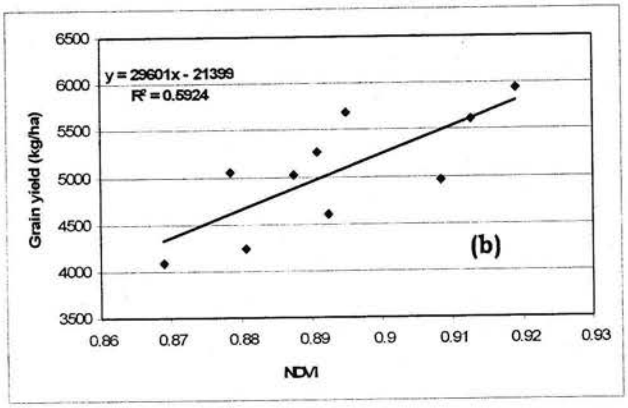


Fig. 7: Relationship for predicting grain yield using a) RVI and b) NDVI at jointing stage and milking stage.

best two models selected for predicting the biomass at milking stage using RVI and NDVI of wheat are presented in Figs. 5, 6 and 7. Thus, these equations can be used to predict the biomass, LAI and grain yield at different stages of the wheat crop. NDVI explained maximum (R^2=0.788) variation in the green biomass followed by RVI (R^2=0.733) at milking stage. In LAI, RVI explained maximum (R^2=0.673) variation at milking stage, whereas NDVI explained 59% variation at jointing stage. In grain yield, RVI explained maximum (80.3%) variation at jointing stage followed by NDVI having variation (59.2%) at milking stage.

CONCLUSION

Spectral reflectance characteristics of wheat were found to be influenced by variety and nitrogen stress. The spectral signatures are helpful in identifying the stage of the crop. Biomass was significantly correlated with spectral characteristics at jointing, heading, flowering and milking stages of wheat. LAI was also significantly correlated with RVI and NDVI. The grain yield was significantly correlated with spectral indices at jointing and milking stages. Regression developed with spectral indices can be used to predict the biomass, LAI and grain yield of wheat.

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