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Spectral Reflectance Dynamics For Nutrient Stress Assay- A Brief Review

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ABSTRACT

Soil and plant analyses are the main techniques for the estimation of N and P nutrients. These tests are costly, time consuming and do not represent the whole field because of the variability of N and P levels in soil and other factors like moisture, climatic and plant conditions. Because of the large soil variability, traditional testing either becomes unrepresentative or costly because of many samples that need to be collected across fields. With increase in the use of variable rate technology and precision agriculture, multi-spectral/hyperspectral remote sensing has the capability to identify and estimate remotely the nutritional status of plants. The need for early detection and identification of stress and its causes can never be over emphasized. Irrigation and fertilizers are vital and costly inputs in agricultural production and are used to increase the productivity of the crop. This necessitates understanding the specific requirement of the crop and strategies for their better management. Monitoring and assessing crop growth, identifying the stress conditions are extremely important to develop strategies. Remote sensing technique can be used on large scale to monitor the crop under different stress condition. Spectral reflectance forms the basis for remote sensing. Measurements with high spectral resolution open up new opportunities to find characteristic spectral features related to the crop status. The nitrogen (N) and phosphorus (P) are major plant nutrient elements that are required to be supplied for vegetation production. Determining these nutrients are usually done through soil and plant testing. For precision management of nutrients these techniques are either expensive or inaccurate. Under-supply of these nutrients leads to loss of plant production whereas an oversupply leads to runoff from the paddock causing nitrification or downstream eutrophication. Remote sensing technique can play an important role in analyzing plant nutrients in a timely fashion. The hyperspectral reflectance study revealed different combination of wavelengths in different growth stages of a crop. The hyperspectral remotely sensed estimate provides accurate, timely and fast spatial and temporal measurements of plant N and P.

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INTRODUCTION

India attained not only self-sufficiency in food but surplus food production, an important step towards achieving food security. However, Rao (1982) observed that potential yield of food crops in India, even when growing improved varieties, still remain at about 20% because of stresses such as nutrient, water and disease. Irrigation and fertilizers are vital and costly inputs in agricultural production and are used to increase the productivity of the crop. This necessitates understanding the specific requirement of the crop and strategies for their better management. Considerable improvements may be expected from the extension of spectral resolution down to bandwidths of a few nanometers (Gilabert *et al*., 1996). Vegetation indices evaluated from these resolutions in the visible and infrared region, show good correlation with chlorophyll concentration, the factor most affected during crop stress.

Plant stress, which reduces chlorophyll production in leaves, will cause leaves to absorb less in the chlorophyll absorption bands; such leaf will appear yellowish or chlorotic and will have a higher reflectance, particularly in the red region. Other pigments contributing to spectral reflectance characteristics of a plant leaf are carotenes, xanthophylls (yellow pigments) and anthocyanins (red pigments). Chlorophyll masks the colour of these other pigment except during senescence when the leaf chlorophyll content is at the minimum. At the NIR, leaves typically reflect 40-50% and absorb less than 5% of the incident energy (Srivastava *et al*., 1998). The high reflectance, as well as transmittance in the NIR "plateau" between 700 and 1300 nm are explained by multiple reflections in the internal mesophyll structure, caused by differences in the reflective indices of the cell wall and intracellular cavity. Since internal structure of leaves often differ considerably among species, reflectance differences are frequently greater in the NIR than in the visible wavelengths. Because of multiple transmittance and reflectance, there is an increase in NIR reflectance through layers of leaves with the maximum of 70-80% reflectance at about eight leaves layer (Allen and Richardson, 1986).

To reduce the stresses in crop, fertilizer acts as the major factor. Indian soils are devoid mainly of nitrogen and potash, which are incorporated physically in the field at required levels and required growth stage. Simple Ratio (SR), Normalized Difference Vegetation Index (NDVI) and Photochemical Reflectance Index (PRI) all these indices and grain yield were found greater under irrigated wheat than under rainfed conditions (Aparicio *et al*., 2000). LAI was most closely correlated with the spectral reflectance indices, with SR and PRI being the best and the worst indices, respectively, for the assessment of crop growth and yield. In rainfed conditions, the spectral reflectance indices measured at any crop stage were positively correlated ($P<0.05$) with LAI and yield. Under irrigated conditions, correlations were only significant during the second half of the grain filling. He suggested that for durum wheat, the usefulness of the SR and NDVI for calculating green area and grain yield is limited to LAI value <3.

Spectral Reflectance and Crop Biometrics

Measurements with high spectral resolution open up new opportunities to find characteristic spectral features related to the crop status. Considerable improvements may be expected from the extension of spectral resolution down to bandwidths of a few nanometers (Gilabert *et al*., 1996). Vegetation indices evaluated from these resolutions in the visible and infrared region, show good correlation with chlorophyll concentration, the factor most affected during crop stress.

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Crop N status and shoot growth rate of rice were found directly related to the formation of crop components. However, N uptake rate per second was not a reliable variable to relate to production. Until flowering, the N use efficiency for leaf biomass and specific leaf weight were constant. The sum of LAI of rice crop at the panicle differentiation stage, heading stage and 20 days after heading is positively correlated with the Nitrogen rates (Lin *et al*, 1990).

Chlorophyll contents, yield and seed quality of rice are affected by nitrogen fertilizer. Nitrogen application results in an increment in chlorophyll content (Gopal *et al*, 1999; Jago *et al*., 1995; Jain *et al*., 1999). However, Sader *et al* (1990) concluded that leaf chlorophyll content measured after 30 days growth was unaffected by N rate.

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Determination of wavelengths for calculating N and P vegetation indices
The remote sensing collects reflectance data from the leaf surface of plant or crop canopy in the different wavelength range especially in visible and NIR. These spectral studies provide an estimate of the sensitive wavelengths responsible for the determination of N and P in crops or plants. From these wavelengths, sensitive vegetation indices could be derive for a better estimation of deficiency of plant N (Raper *et al*., 2013) and P in advance of actual deficiency visibly shown by crops or plants. N and P stresses have been monitored and estimated through specific electro-magnetic wavelengths (Curran *et al.*, 2001; Fonteneli *et al.*, 2004; Osborne *et al.*, 2004; Petisco *et al.*, 2005). It is found that these stresses have been detected in plants using the visible and NIR spectrums ie, in blue, green, red and infra red regions (Sembiring *et al.*, 1998; Osborne *et al.*, 2002; Zhao *et al.*, 2003; Osborne *et al.*, 2004; Ayala-Silva and Beyl, 2005; Bogrekci and Lee, 2005). It is important that the estimation of nutrients is better using the plants than soil, because plants are seen easily than soil (Schepers *et al.*, 1996; Sembiring *et al.*, 1998; Asner *et al.*, 1999).

N and P Reflectance
The visible and NIR regions of electromagnetic spectra are useful to characterize the N stress of plants (Thomas and Oerther, 1972; Blackmer *et al.*, 1994; Tarpley *et al.*, 2000; Graeff and Claupein, 2003; Fridgen and Varco, 2004) in different crops. To better estimate nutrients from reflectance studies, vegetation indices (VIs) have been derived (Ma *et al.*, 1996; Sembiring *et al.*, 2000; Hansen and Schjoerring, 2003; Zhao *et al.*, 2005; Ansari *et al* 2006; Zhu *et al.*, 2007; Li *et al.*, 2008; Zhu *et al.*, 2008). However, the estimation of N in wheat flag leaf is also possible by using whole spectra in the region of visible and NIR (Bonfil *et al.*, 2005). The spectral reflectance is changed depending on the growth stage or phenologies of plants. For example, N has been predicted at the silking stage in corn (Schepers *et al.*, 1996) and at the flowering stage in cotton (Fridgen and Varco, 2004). Studies show that the spectral signature of N deficient plants changed with the plant growth stages (Osborne *et al.*, 2002; Ayala-Silva and Beyl, 2005; Ansari *et al.*, 2008). The application of N in the also changed the position of wavelength from longer to shorter or vice versa in the visible and NIR ranges (Fridgen and Varco, 2004; Li *et al.*, 2006; Mutanga and Skidmore, 2007), which shows that the different concentrations of the plant N exhibit differently for detecting N (Mistele *et al*., 2010). NIR reflectance spectroscopy analysis of phosphorus is carried out in sugarcane leaves (Chen *et al.,* 2002) and other crop including wheat (Sembiring *et al.*, 1998; Ayala-Silva and Beyl, 2005 and Jorgensen *et al.,* 2006).

Wavelength for N and P Stress
Researchers found that N deficiency is detected in the green, red edge and NIR region of spectra at different growth stages (Blackmer *et al.,* 1994, Zhao *et al.,* 2003 and Osborne *et al.,* 2002). Blackmer *et al.,* 1994 studied the reflectance of ear leaves in the visible range and found the green (550 nm) region was best to detect N deficiency in corn. While Zhao *et al*., 2003 found stress N plants could be distinguished at the green (552 nm) and red edge (710 nm) in corn. Osborne *et al.,* (2002) studied the canopy hyper spectral reflectance between 350-1000 nm in corn and identified. The separable wavelength ranges for P stress are also dependent on the growth stages. The phosphorus concentration of pine needle (*Pinus elliottii*) leaves was found to correlate with the five wavelengths at 584, 612, 1040, 1448 and 1894 nm selected by step wise regression for all three sets of methodology data used i.e., first derivative spectra, band-normalized to centre and band-normalized to area, respectively (Curran *et al.*, 2001). At two leaf stage, P stressed plants are found significantly separable at UV to blue (245.5-504 nm) and green to NIR (549-1100 nm). At initiation of tillering growth stage, separable wavelength of P stress are found at UV (245.5-250.5 nm and 362.5-371 nm), blue (435-489 nm), green to red (513-637.5 nm), red edge (692-731 nm), NIR (763-917 nm,1082-1094 nm), Like wise at all growth stages there are specific wavelength range. The results also show that plant deficiencies in N & P can be detected in the early growth stages (Z12 and Z20) prior to visible deficiency symptoms being detected by the human eye (Ansari *et al.,* 2008, Christensen *et al.,* 2004, Osborne *et al.*2002, Graeff *et al.,* 2001). The reflectance wavelengths are used to predict P concentration in the NIR (730 and 930 nm) and blue (440 and 445 nm) region of the spectrum in a corn canopy in the early growth stages at V6 and V8 (Osborne *et al*.2002). Thus, above finding also suggests that hyper spectral wavelength range in UV, green, red, red edge, NIR could be possible to establish P stress for a specific growth stage and specially at early stages. The identification of nutrient deficiencies in early growth stages will allow remedial treatment without yield penalties especially for P. Milton *et al* (1991) found that there was horizontal shift of red edge position with the growth stage and it was toward longer wavelength. These results are also confirmed by Ayala-Silva and Beyl (2005), Fridgen and Varco, 2004; Li *et al.*, 2006; Mutanga and Skidmore, 2007.

EPILOGUE

Spectral resolution open up new opportunities to find characteristic spectral features related to the crop status. Considerable improvements may be expected from the extension of spectral resolution down to bandwidths of a few nanometers. Vegetation indices evaluated from these resolutions in the visible and infrared region, show good correlation with chlorophyll concentration, the factor most affected during crop stress. Remote sensing technique is used on large scale to monitor the crop under different stress condition. Spectral reflectance forms the basis for remote sensing.

REFERENCES

1. Allen WA and Richardson AJ (1986) Interaction of light with a plant canopy. *J Optical Soc America* 58: 1023-1028
2. Ansari, M S, Mahey, R K, Sidhu, S S & Bahl, G S (2006) Spectral response of nitrogen fertilization in cotton (*Gossypium* species). In *13th Australian Agronomy Conference* Perth, Australia
3. Ansari, M S, Young, K R & Nicolas, M E (2008) Leaf Spectral Response to Nitrogen and Phosphorus Deficiencies in Wheat. In *Proceeding of 5th International Crop Science Congress* Jeju, Korea. p 230-231.
4. Asner, G P, Townsend, a R & Bustamante, M M C (1999) Spectrometry of Pasture Condition and Biogeochemistry in the Central Amazon. *Geophysical Research Letters,* 26**,** 2769-2772.
5. Aparicio N, Villegas D, Casadesus J, Araus JL and Royo C (2000) Spectral vegetation indices as nondestructive tool for determining durum wheat yield. *Agronomy J* 92 (1): 83-91.
6. Ayala-Silva, T & Beyl, C A (2005) Changes in Spectral Reflectance of Wheat Leaves in Response to Specific Macronutrient Deficiency. *Advances in Space Research,* 35**,** 305-317.
7. Blackmer, T M, Schepers, J S & Varvel, G E (1994) Light Reflectance Compared with Other Nitrogen Stress Measurements in Corn Leaves. *Agronomy Journal,* 86**,** 934-938.
8. Bogrekci, I & Lee, W S (2005) Spectral Phosphorus Mapping Using Diffuse Reflectance of Soils and Grass. *Biosystems Engineering,* 91**,** 305-312.
9. Bonfil, D J, Karnieli, A, Raz, M, Mufradi, I, Asido, S, Egozi, H, Hoffman, A & Schmilovitch, Z E (2005) Rapid Assessing of Water and Nitrogen Status in Wheat Flag Leaves. *Journal of Food Agriculture & Environment,* 3**,** 148-153.
10. Chen, M, Glaz, B, Gilbert, R A, Daroub, S H, Barton, F E & Wan, Y (2002) Near-Infrared Reflectance Spectroscopy Analysis of Phosphorus in Sugarcane Leaves. *Agronomy Journal,* 94**,** 1324-1331.
11. Christensen, L K, Bennedsen, B S, Jorgensen, R N & Nielsen, H (2004) Modelling Nitrogen and Phosphorus Content at Early Growth Stages in Spring Barley Using Hyperspectral Line Scanning. *Biosystems Engineering,* 88**,** 19-24.
12. Curran, P J, Dungan, J L & Peterson, D L (2001) Estimating the Foliar Biochemical Concentration of Leaves with Reflectance Spectrometry. Testing the Kokaly and Clark Methodologies. *Remote Sensing of Environment,* 76**,** 349-359.
13. Fonteneli, R S, Scheffer-Basso, S M, Durr, J W, Appelt, J V, Bortolini, F & Haubert, F A (2004) Prediction of Chemical Composition of Cynodon Spp. By near Infrared Reflectance Spectroscopy. *Revista Brasileira De Zootecnia-Brazilian Journal of Animal Science,* 33**,** 838-842.
14. Fridgen, J L & Varco, J J (2004) Dependency of Cotton Leaf Nitrogen, Chlorophyll, and Reflectance on Nitrogen and Potassium Availability. *Agronomy Journal,* 96**,** 63-69.
15. Graeff, S & Claupein, W (2003) Quantifying Nitrogen Status of Corn (Zea Mays L.) in the Field by Reflectance Measurements. *European Journal of Agronomy,* 19**,** 611-618.
16. Graeff, S, Steffens, D & Schubert, S (2001) Use of Reflectance Measurements for the Early Detection of N, P, Mg, and Fe Deficiencies in Zea Mays L. *Journal of Plant Nutrition and Soil Science-Zeitschrift Fur Pflanzenernahrung Und Bodenkunde,* 164**,** 445-450.
17. Gilabert MA, Gandia, S and Melia J (1996) Analysis of spectral biophysical relationships for a corn canopy. *Remote Sens Environ* 55: 11-20.
18. Gopal M, Devi KR and Lingam B (1999) Effect of seeding density, level and time of N applicationin direct sown rice under puddle contions. *J Res ANGRAU 27* (1-2): 53-55.
19. Hansen, P M & Schjoerring, J K (2003) Reflectance Measurement of Canopy Biomass and Nitrogen Status in Wheat Crops Using Normalized Difference Vegetation Indices and Partial Least Squares Regression. *Remote Sensing of Environment,* 86**,** 542-553.
20. Jago RA and Curran PJ (1995) The effect of land contamination on the relationship between the red edge and chlorophyll concentration of a grass and canopy. In *RSS95: Remote Sensing in Action*, Nottingham: Remote Sensing Society, pp 442-449.
21. Jain V, Pal M, Lakkineni KC and Abrol YP (1999) Photosynthetic characteristics in two wheat genotypes as affected by nitrogen nutrition. *Biologia Plantarum* 42 (2): 217-222.
22. Jorgensen, R N, Hansen, P M & Bro, R (2006) Exploratory Study of Winter Wheat Reflectance During Vegetative Growth Using Three-Mode Component Analysis. *International Journal of Remote Sensing,* 27**,** 919-937.
23. Li, Y, Zhu, Y & Cao, W (2006) Characterizing Canopy Hyperspectral and Multispectral Reflectance under Different N-Application Conditions in Wheat. *Journal of Triticeae Crops,* 26**,** 103-108.
24. Lin XZ, Huang QM and Tu ZP (1990) Studies on high yield cultivation of rice in Guangdong by controlling chlorophyll content and leaf area index. *Jiangsu J Agri Sci* 6: 20-26.

25. Ma, B L, Morrison, M J & Dwyer, L M (1996) Canopy Light Reflectance and Field Greenness to Assess Nitrogen Fertilization and Yield of Maize. *Agronomy Journal,* 88**,** 915-920.
26. Milton, N M, Eiswerth, B A & Ager, C M (1991) Effect of Phosphorus Deficiency on Spectral Reflectance and Morphology of Soybean Plants. *Remote Sensing of Environment,* 36**,** 121-127.
27. Mistele,B., & Schmidhalter, U. 2010.Tractor-based quadrilateral spectral reflectance measurements to detect biomass and total aerial nitrogen in winter wheat. Agron. J. 102:499–506
28. Mutanga, O & Skidmore, A K (2007) Red Edge Shift and Biochemical Content in Grass Canopies. *Isprs Journal of Photogrammetry and Remote Sensing,* 62**,** 34-42.
29. Osborne, S L, Schepers, J S, Francis, D D & Schlemmer, M R (2002) Detection of Phosphorus and Nitrogen Deficiencies in Corn Using Spectral Radiance Measurements. *Agronomy Journal,* 94**,** 1215-1221.
30. Osborne, S L, Schepers, J S & Schlemmer, M R (2004) Detecting Nitrogen and Phosphorus Stress in Corn Using Multi-Spectral Imagery. *Communications in Soil Science and Plant Analysis,* 35**,** 505-516.
31. Petisco, C, Garcia-Criado, B, De Aldana, B R V, Zabalgogeazcoa, I, Mediavilla, S & Garcia-Ciudad, A (2005) Use of near-Infrared Reflectance Spectroscopy in Predicting Nitrogen, Phosphorus and Calcium Contents in Heterogeneous Woody Plant Species. *Analytical and Bioanalytical Chemistry,* 382**,** 458-465.
32. Raper, TB., Varco, JJ., and Hubbard, KJ. 2013 Canopy-Based Normalized Difference Vegetation Index Sensors for Monitoring Cotton Nitrogen Status, *Agron. J,* 105,1345–1354
33. Rao MV (1982) Wheat production problems in India. Proc. National seminar on productivity in wheat and wheat products, held in Vigyan Bhawan, New Delhi, April 29-30, pp 5-9.
34. Srivastava SK, Nageswara Rao PP and Jayaraman V (1998) Towards space borne terrestrial imaging spectrometry. *Scientific Report ISRO-NNRMS-SR*: 41-98
35. Schepers, J S, Blackmer, T M, Wilhelm, W W & Resende, M (1996) Transmittance and Reflectance Measurements of Corn Leaves from Plants with Different Nitrogen and Water Supply. *Journal of Plant Physiology,* 148**,** 523-529.
36. Sembiring, H, Raun, W R, Johnson, G V, Stone, M L, Solie, J B & Phillips, S B (1998) Detection of Nitrogen and Phosphorus Nutrient Status in Winter Wheat Using Spectral Radiance. *Journal of Plant Nutrition,* 21**,** 1207-1233.
37. Tarpley, L, Reddy, K R & Sassenrath-Cole, G F (2000) Reflectance Indices with Precision and Accuracy in Predicting Cotton Leaf Nitrogen Concentration. *Crop Science,* 40**,** 1814-1819.
38. Thomas, J R & Oerther, G F (1972) Estimating Nitrogen Content of Sweet Pepper Leaves by Reflectance Measurements. *Agronomy Journal.,* 64**,** 11-13.
39. Zhao, D H, Li, J L & Qi, J G (2005) Identification of Red and Nir Spectral Regions and Vegetative Indices for Discrimination of Cotton Nitrogen Stress and Growth Stage. *Computers and Electronics in Agriculture,* 48**,** 155-169.
40. Zhao, D L, Reddy, K R, Kakani, V G, Read, J J & Carter, G A (2003) Corn (Zea Mays L.) Growth, Leaf Pigment Concentration, Photosynthesis and Leaf Hyperspectral Reflectance Properties as Affected by Nitrogen Supply. *Plant and Soil,* 257**,** 205-217.
41. Zhu, Y, Yao, X, Tian, Y C, Liu, X J & Cao, W X (2008) Analysis of Common Canopy Vegetation Indices for Indicating Leaf Nitrogen Accumulations in Wheat and Rice. *International Journal of Applied Earth Observation and Geoinformation,* 10**,** 1-10.
42. Zhu, Y, Zhou, D, Yao, X, Tian, Y & Cao, W (2007) Quantitative Relationships of Leaf Nitrogen Status to Canopy Spectral Reflectance in Rice. *Australian Journal of Agricultural Research,* 58**,** 1077-1085.

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