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Spectral reflectance characteristics of healthy and yellow mosaic virus infected soybean (*Glycine max* L.) leaves in a semiarid environment

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ABSTRACT

Field experiments were conducted during *Kharif* 2009 and 2010 at IARI farm, New Delhi to study the spectral reflectance characteristics of YMV susceptible (JS-335) and tolerant (Pusa-9814) varieties. In both the years, 90-100% leaves of the variety, JS-335 and 5-10% leaves of the variety, Pusa-9814 were infected with the disease in the field. In order to characterize spectral reflectance of healthy and YMV infected soybean crop, soybean leaves were collected from YMV-infected crop (JS-335) and healthy crop (Pusa-9814) and taken to laboratory for reflectance measurement under controlled condition. Leaf chlorophyll content was measured using DMSO method. Normalized Difference Vegetation Index (NDVI), Ratio Vegetation Index (RVI), Greeness Index (GI), Photochemical Reflectance Index (PRI) and Leaf Moisture Vegetation Index 1 (LMVI1) were computed and it was observed that NDVI was found to be useful in detecting yellow mosaic virus infected soybean.

Key words: Yellow mosaic virus, soybean, Glycine max L., hyperspectral remote sensing.

Remote sensing can be used as a detection and monitoring tool, if the damaged crop area by disease infection/ insect infestation is big enough. In India, application of remote sensing in agriculture had been started through detection of coconut wilt disease at Kerala coast when Dakshnamurty (1971) mapped that area during 1968-69 using ektachrome infrared photography from a helicopter. Later the main focus of this subject was shifted to crop identification, area delineation, yield estimation, soil mapping and classification, desertification studies etc. Remote sensing had hardly been used in crop protection area due to some inherent problems as insect infestation or disease infection occurs mainly within crop canopy. Biotic stress symptoms are generally confusing with abiotic stress symptoms. Damaged symptoms may appear on the canopy, but sporadic in nature and too small to be detected by the sensors. Return period of polar orbital satellites are 14-21 days, but a pest/disease infested area requires frequent monitoring (2-3 days interval) for any action plan (Das, 2010). With the advent of hyper-spectral remote sensing and capacity to spectral scanning at 1nm interval, there is scope for detection of plant biotic and abiotic stresses precisely. Spectral characteristics of peanut crop infected by late leafspot disease under rainfed condition at Hyderabad, Andhra Pradesh was studied by Prabhakar et al (2006) with in a spectral range of 300-1100nm. Data were recorded at 7-10 days interval with hand held spectroradiometer 1.6 m above the crop canopy 2 hours after solar noon. Disease infection was rated on 0-4 scale. At initial stage (8 September, 2005) healthy and diseased (scale 1) plants could not be differentiated and could be differentiated on 29th September and 11th October 2005 (disease scale 2 and above). In satellite based remote sensing, Franke and Menz,(2007) could detect the fungal diseases of wheat at farm level in Germany using QuickBird imageries.

White fly transmitted yellow mosaic virus (YMV) disease is a major constraint in improving the productivity of grain legumes in India. Yield loss per annum due to YMV disease was estimated to be \$ 300 million taking blackgram, mungbean and soybean together . Hyper-spectral Remote Sensing can be used for distinguishing healthy and YMV infected soybean crop and estimation of soybean yield loss due to YMV over a large area.

MATERIALS AND METHODS

Field experiment was conducted during *kharif* season of 2009 at IARI, New Delhi to study the effect of weather variability on crop growth, insect-pest and disease interaction with weather and seed yield. Three soybean cultivars viz., JS-335, Pusa-9712 and Pusa-9814 were sown on 7th July and 22nd July. During *kharif* 2010 the same three varieties were sown on 17th and 29th July. The

Table 1: Vegetation Indices for characterization of Yellow Vein Mosaic infection in soybean plant

S. No.	Indices	Formula	References
1	NDVI	(R850-R670)/(R850+R670)	Rouse etal., 1973
2	RVI	R850/R670	Pearson et al., 1972
3	GI	R554/R677	Zarco-Tejada et al., 2005
4	PRI	(R529-R569)/(R529+R569)	Penuelas, et al., 1997
5	LMVI1	(R1094-R983)/(R1094+R983)	Galvão et al., 2005

Table 2: Specific plant parameters of healthy and infected soybean leaf for 2009 and 2010

Parameters	2009		2010	
	Healthy	Infected	Healthy	Infected
Specific Leaf Area (cm^2 gm^{-1})	154.3	111.2	128.2	113.2
Leaf Moisture Thickness (g cm^{-2})	0.014	0.015	0.012	0.015
Chlorophyll content (mg g^{-1} of fresh leaves)	1.209	0.435	1.489	0.604

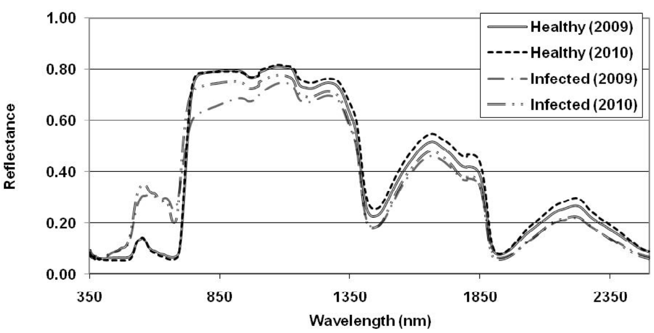

Fig. 1 : Spectral signature of healthy and YMV infected soybean leaves in 2009 and 2010.

variety JS-335 experienced severe attack of Yellow Mosaic virus disease especially for the first sown crop during both the years. In order to characterize spectral reflectance of healthy and YMV infected soybean crop, soybean leaves were collected from YMV-infected crop (JS-335) and healthy crop (Pusa-9814) and taken to laboratory for reflectance measurement under controlled condition. Spectral data were recorded at 1nm intervals using ASD FieldSpec Spectroradiometer (Analytical Spectral Devices Inc., Boulder, CO, USA) over a 350-2500nm wavelength range. Five measurements were recorded for each YMV-infected and healthy leaves and the resulting data were averaged. Leaf cholorophyll content was measured using DMSO method. Leaf moisture content was found out gravimetrically and leaf area by leaf area meter (Model). Normalized Difference Vegetation Index (NDVI), Ratio Vegetation Index (RVI), Greeness Index (GI), Photochemical Reflectance Index (PRI) and Leaf Water Vegetation Index 1 (LMVI1) were calculated using the formula as described in Table 1. NDVI and RVI are broadband vegetation indices / canopy structure indices, GI and PRI are narrow band chlorophyll indices where as LMVI1 is narrow band water indices.

RESULTS AND DISCUSSION

The results obtained in this study were presented with illustration and discussed accordingly below.

Plant parameters affected by disease

Infection of YMV brings some changes in plant physiological parameters which bring down the yield drastically. From Table 2, it can be seen that specific leaf area and leaf chlorophyll content was affected more than leaf moisture thickness. Specific leaf area was reduced by 28% in 2009 and 12 % in 2010. Chlorophyll content reduction was around 65% in the first year and 60% in the second year. Almost drought like situation prevailed during *kharif* season of 2009, but that season of 2010 was a normal monsoon year. Therefore, the effect of 2010 may be due to purely biotic stress (YMV) and that of 2009 was combination of biotic and abiotic stress.

Spectral signature of leaves

The spectral signature of healthy and YMV infected soybean leaves are presented in Fig. 1. It reveals differences in the percent reflectance between healthy and YMV infected soybean leaves throughout the wavelength range of 350-2500 nm. The reflectance of healthy leaves are higher in NIR (0.8) and SWIR ((0.55) region compared to YMV infected leaves (0.75 and 0.45 respectively). In the visible region the reflectance of YMV infected leaves (0.31) is higher than the healthy leaves (0.12). Plant stress that causes reduction in chlorophyll leads to an increase in light reflected in the visible range (400-700nm). Conversely, percent reflection in the NIR region (740-1100nm) is reduced as internal leaf structure degenerates. This scattering occurs deep within the leaf tissue, and hence percentage light reflected in the NIR region may provide information on the physiological condition of plant under stress (Nilsson, 1995; Hatfield and Pinter, 1993). Discontinuity between air spaces and

Table 3: Vegetation indices of healthy and YMV infected soybean crop in 2009 and 2010.

Vegetation Indices	Healthy (2009)	Healthy (2010)	Infected (2009)	Infected (2010)
NDVI	0.8451	0.8707	0.4457	0.5734
RVI	11.91	14.46	2.6083	3.68
GI	2.07	2.50	1.20	1.75
PRI	-0.0042	-0.0027	-0.0967	-0.0740
LMVI1	0.0252	0.0282	0.0475	0.0330

plant cell walls leading to high internal light scattering coupled with reduced absorption causes increased NIR reflectance in healthy leaves (Jackson, 1986). The lower reflectance of YMV infected leaves for both the years in the SWIR region can be attributed to the higher total water present in leaves (Lillesand and Kiefer, 2005). The reflectance values for stressed crop also differed over the years. The lowest values during 2009 in NIR region might be the combined effect of both biotic and abiotic stresses. This tool can be useful to differentiate biotic and abiotic stresses in future.

Vegetation indices

The spectral indices of healthy and infected leaves are presented in Table 3. The NDVI value was 0.8451 and 0.8707 for healthy leaves in the year 2009 and 2010 respectively, while the same for infected plants was 0.4457 and 0.5734 respectively. It is quite clear that the NDVI value for infected plant is much less than the healthy plant. The difference in values of NDVI in diseased plants during 2009 and 2010 probably due to the difference in nature of stresses occurred in those two years. The other indices such as RVI, GI showed similar type of trend but the reduction of values due to infection was less compared to NDVI. PRI and LMVI1 followed the opposite trend.

Hence it can be concluded that the spectral reflectance curve and spectral indices offers scope for potential use of this technology to distinguish healthy and YMV infected soybean crop in a rapid and cost effective manner from large and continuous soybean growing areas. NDVI derived from hyper-spectral sensor data was found to be the best in this regard. It also offers scope to distinguish between biotic and abiotic stresses after some further study.

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