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Spectral discrimination of healthy and malformed mango panicles using spectroradiometer

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ABSTRACT

The potential of using hyperspectral reflectance data to discriminate healthy and malformed mango panicles, both under field and laboratory conditions was evaluated. The spectral reflectance of both malformed and healthy panicles were collected using ground based portable ASD FS3 spectroradiometer. The spectral data were analyzed with four different indices. Among all the indices Normalized Difference Vegetation Index (NDVI) was found to be the best parameter in differentiating the healthy (0.495) and malformed (0.751) mango panicles significantly under laboratory conditions. NDVI can be used in the differentiation of healthy and malformed mango panicles. The red-edge value (0.0106 and 0.0113) and red edge (692 and 697) position was significantly different for healthy and malformed mango panicles respectively. Hence, it can be concluded that spectral reflectance based indices will be a potential tool in the identification of malformed mango panicles spatially through remote sensing data.

Key words: Mango malformation, spectral discrimination, Normalized Difference Vegetation Index.

INTRODUCTION

Mango malformation is a serious threat to mango industries in several countries. It was first reported in India in 1891 (Kulkarni,7) and it has subsequently been reported from Egypt, South Africa, Sudan, Swaziland, Brazil, Central America, Mexico, USA, Israel, Pakistan and Malaysia. Malformation causes gross deformation of vegetative and floral tissues in mango. Affected flowers are either sterile or abort shortly after fruits have set; as a consequence fruit yields are significantly reduced (Steenkamp *et al*.,17). Economic losses up to 60% have been reported in different commercial mango varieties in India. The etiology of malformation has been a contentious issue, and a wide range of biotic and abiotic factors have been reported to cause the diseases, including viruses, mites and nutritional deficiencies. Convincing evidence that a fungus causes malformation has been in the literature for decades (Britz *et al*., 2).

There are hardly any studies to differentiate the spectral pattern of malformed and healthy mango panicle using hyperspectral remote sensing till date in the world. The present investigation was carried out to differentiate malformed mango plants from that of healthy one through ground based spectral reflectance study.The spectral reflectance characteristics of trees and their canopies are determined by the chemical composition and physical properties of the plants and the spectral properties of the source (Myneni and Ross, 10). The use of reflectance spectra for monitoring vegetation condition now found to be potential, cost effective,eco-friendly, non-destructive technique,due to intensive development of hyperspectral remote sensing equipment. The individual spectral signatures distinguish the species/ plants from each other by the differences in reflectance. Visible, near Infrared (NIR) and Short Wave Infrared (SWIR) regions of spectral reflectance of vegetation is affected by its pigments, cell structure and arrangement and cell water content respectively. Vegetation has a unique spectral signature, which enables it to be distinguished readily from other types of land cover in an optical/near-infrared image. The near infrared (NIR) and visible spectrum of light reflected from a plant varies significantly when crop is under stress. Healthy plants tend to reflect more NIR radiation than stressed plants.The present study is an attempt to use various indices and derivatives of hyperspectral reflectance data for differentiating malformed and healthy panicles of mango.

MATERIALS AND METHODS

The study was conducted in orchards of the Division of Fruits and Horticultural Technolgy, IARI, New Delhi. The spectral reflectance of 40 mango panicles of both healthy and malformed trees of cv. Dashehari were taken under field conditions at 10 m height using portable ladder. The same samples were also collected from the field for taking spectral observation under laboratory conditions. Spectral reflectance data of malformed and healthy mango

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panicles were collected under field conditions using Field Spec 3 Analytical Spectral Devices (ASD) Spectroradiometer covering wavelength ranging from 350 to 2500 nm. Before collection of spectral reflectance, instrument was optimized with respect to solar radiation. Dark current (which many a times acts as noise) was removed and put in collecting reflectance using a white reference panel called spectralon. Average of 50 spectral scans of ASD was considered as reflectance for each sample. Each spectral measurement produced a single spectrum. The instrument had facility to communicate through wireless access with specially designed laptop computer, which could be used to record and process data through ASD software. At laboratory conditions the samples were radiated with two calibrated 100 W halogen lamps at 30° zenith and at radial distance of 0.70 m under dark room conditions. The measured reflectance was calibrated using white reference panel-spectralon. All the recorded spectral values were converted into Tab delimited text file format using the View Spec Pro (Ver. 4.05) software to facilitate data transfer and data share with other software. The spectral reflectance curve was plotted in Microsoft Office Excel having wavelength in x-axis and reflectance in y-axis. These spectra were analyzed for further characterization. Pre-processing of spectral data includes development of derivative data sets for reflectance data. Absorption features in reflectance spectra were enhanced using derivative spectroscopy.The process of creating derivative spectra proceeded using finite approximation to calculate the change in reflectance over a bandwidth $\Delta\lambda$, defined as $\Delta\lambda = \lambda j - \lambda i$, where $\lambda j > \lambda i$ (Tsai and Philpot, 18). The estimation equations for the first derivative and n^th^ derivative are shown in equations 1 and 2 as described by Demetriades-Shah (5). First and second derivatives of reflectance were calculated for all the spectral data sets using following equations 1 and 2.

$$\left.\frac{ds}{d\lambda}\right|_i \approx \frac{s(\lambda_i) - s(\lambda_j)}{\Delta\lambda} \qquad \text{.........................(1)}$$

$$\left.\frac{d^n s}{d\lambda^n}\right|_j = \frac{d}{d\lambda}\left(\frac{d^{(n-1)}s}{d\lambda^{(n-1)}}\right) \qquad \text{.........................(2)}$$

Different spectral indices were calculated like Normalized Difference Vegetation Index (NDVI) (Rouse *et al*., 14), Normalized Pigment Chlorophyll Ratio Index (NPCI)(Penuelas *et al*., 12) and Structure Insensitive Pigment Index (SIPI) (Penuelas *et al*., 11). First derivative of spectra was calculated and plotted against the wavelength along with the reflectance values for the wavelength range 450 to 710 nm (Fig. 2). The first derivative spectra are very useful

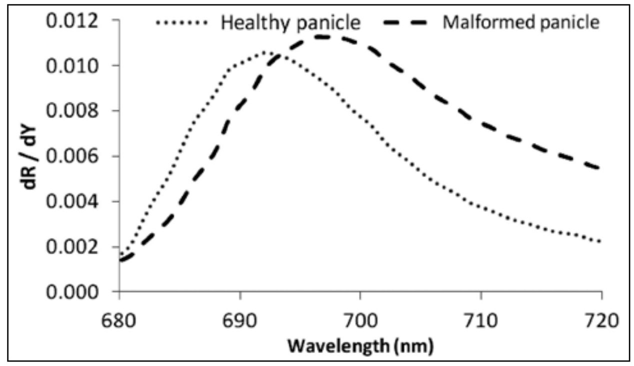

Fig. 2. Spectral pattern of 1st derivative of malformed and healthy mango panicle at laboratory showing the shift in peak.

in finding the red edge position and red edge value. It is observed from the curve that a sudden change in the reflectance value will be magnified in the first derivative. The change in reflectance from red to infra red region is characterized by three regions, *i.e*. (i) increase in slope; (ii) attains a peak value and (iii) decrease in slope. The slope is defined by the first derivative of reflectance with respect to wavelength. The maximum value of 1st derivative in the region 650 to 750 nm is called the inflection point. The red edge position (REP) was calculated using the first and second derivatives. The wavelength coinciding with zero values of the second derivatives was taken as REP value. The red edge value (REV) was calculated using the first and second derivatives. The value that coincides with zero values of the second derivatives was taken as REV for analysis. The data and the indices derived are statistically analyzed using ANOVA technique.

RESULTS AND DISCUSSION

The reflectance in different wavelength region was dependent on unique interaction of electromagnetic spectrum with the biophysical composition of the mango panicle. Hence, the signatures of both healthy and malformed panicles were found different (Fig. 1). Compared to spectral reflectance collected in laboratory conditions, the spectral reflectance collected in field conditions was having noises at around 1400, 1900 and beyond 2300 nm, but the trend of both the signatures were found to be same. While comparing spectral signatures of both healthy and malformed panicles it was observed that the reflectance of malformed one is lower than that of healthy one in the visible and SWIR region and higher in NIR region.

Different spectral indices were used to discriminate mango malformed and healthy panicles.

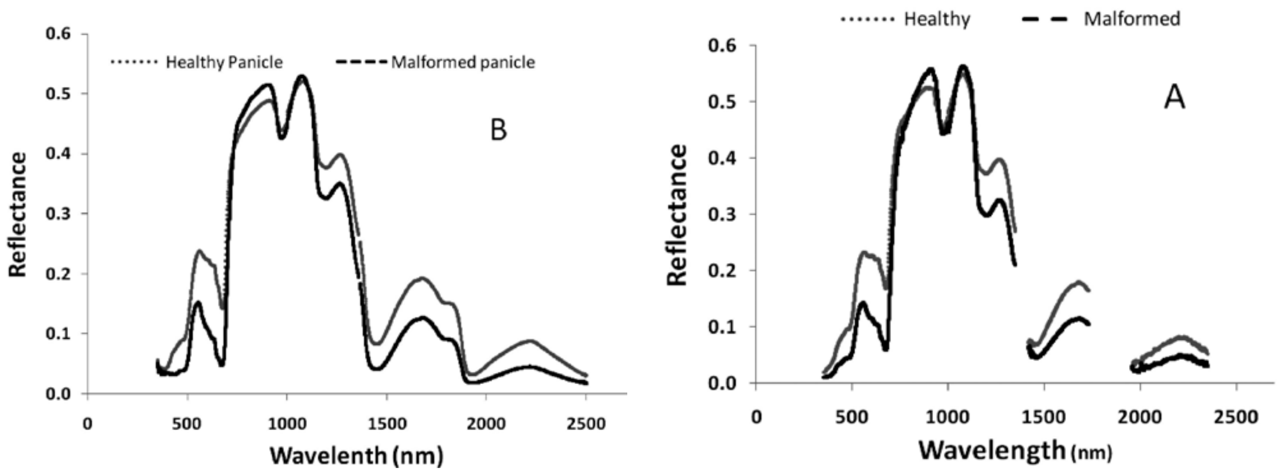

Fig. 1. Spectral response curve of malformed and healthy panicle of mango at laboratory (B) and field conditions (A).

Normalized difference vegetation index (NDVI) is commonly used as vegetation index to differentiate the healthy and stressed or diseased plant. The results revealed that the NDVI values are significantly different for healthy and malformed panicles. Higher NDVI value was obtained in malformed panicles compared to healthy panicles in both field and laboratory conditions. The Structure Insensitive Pigment Index (SIPI) and The Normalized Pigment Chlorophyll Ratio Index (NPCI) revealed opposite trend as that of NDVI. It was high in case of healthy panicle in comparison to malformed one and the trend is same for both laboratory and field conditions (Table 1). Shifting of REP to lower wavelength is called as blue shift and towards higher value called red shift. REP and REV were given for healthy and malformed panicles. The REP and REV were higher in case of malformed panicle compared to healthy panicle (Table 1).

The spectral reflectance data clearly indicated that in the visible region the malformed panicles were having lower reflectance than the healthy one. Majority of the reflectance in the visible region was governed by chlorophyll content. Higher the chlorophyll content, higher is the absorption in the visible region. The chlorophyll content is an important parameter for testing plant status. It is sensitive to the status of plant nutrition (Moran *et al.*, 9) as well as various types of stresses (Carter *et al.*, 3) and it also reveals plant aging (Merzlyak *et al.*, 8). However, the chlorophyll content in disease plant will be less. However, the malformed panicles which continue to hang on the trees remained green and hence were having higher chlorophyll content than healthier ones, while healthy panicles grew further, resulting in flowering. Over the period, chlorophyll content of healthy panicles reduces. Hence, it has lower reflectance. In the Near Infra Red (NIR) region, the reflectance is more governed by cell structural arrangement. Better the cell structure higher is the reflectance in NIR region. Compared to healthy panicles, the malformed panicles had better structural arrangement of cell thereby higher reflectance in this region. Similarly, in Short Wave Infra Red (SWIR) region, the reflectance is affected by cell water content, *i.e.*, higher the water content, less is

Table 1. Vegetative Indices, REP and REV of healthy and malformed panicles of mango at laboratory (A) and field conditions (B).

Index	NDVI		NPCI		SIPI		REP		REV	
	A	B	A	B	A	B	A	B	A	B
Healthy panicle	0.495*	0.503*	0.376*	0.369*	1.248*	1.235*	0.0106	0.0086	692	693
Malformed panicle	0.751*	0.780*	0.256*	0.317*	1.067*	1.067*	0.0113	0.0092	697	695
LSD *(P ≥ 0.05)*										
Treatment	0.046		0.046		0.043		0.0319		2.0151	
Method	0.046		0.046		0.043		0.0319		2.0151	

*Significantly different at 5%

the reflectance. The malformed tissues have higher tendency of holding moisture compared to healthy panicles. The molecular mobility of water was higher in malformed panicles when compared with healthy panicles when measured with Proton NMR. Hence, the reflectance of malformed panicles in SWIR region was lower than that of healthy one. The results also coincides with the results of the (Chappelle *et al*., 4; Myneni and Ross, 10) who reported that most of the time, broadband absorption peaks were present in the visible/near infrared reflectance spectrum at 400 to 500 nm (blue absorption), 660 to 680 and 740 nm (chlorophyll absorption), 970 and 1450 nm (water absorption). The spectral absorption in plants and the spectral reflectance from them is also influenced by the physical structure of the surface and the cells structure in the samples. The results are similar to the findings of Blackburn (1) for SIPI and of Riedell and Blackmer (13) for NPCI. The NDVI values were related to reflectance values of red and NIR regions. As shown in (Table 1), the malformed panicles were having high NDVI values compared to healthy ones. As discussed above, chlorophyll content is higher and cell structure is better in case of malformed panicle and healthy panicle turns to yellow and brown colour due to transformation of chlorophyll pigments, hence the higher value of these indices. SIPI and NPCI, which showed opposite trend, *i.e.*, lower the chlorophyll content higher is NPCI and poor the cell structure arrangement, higher is the SIPI value. In case of malformed one, both SIPI and NPCI value were low and can be justified with same above explanation.

The first derivative of reflectance spectra in 650 to 710 nm range, *i.e*. 'red edge' gives information about stress levels in plants. The blue shift indicated the stress condition and red shift indicates healthy condition. The Fig. 2 shows that the malformed panicles had red shift, whereas, healthy panicles had blue shift. In normal conditions, the plants under stress are having a shift toward blue and the plants which are in normal conditions have the red shift (Fitzgerald, 6). However, in this study the trend was reverse since the healthy panicles were found having less chlorophyll content (640 nm) and low green colour, whereas, the malformed panicles had higher chlorophyll content. Singh *et al.* (15) reported that malformed panicles have higher protein as compared to healthy panicles. The results of first derivative were similar with the findings of Smith *et al*. (16). They reported that changes in the ratio of relative heights of maxima in the first derivatives of 'red edge' have been revealed when chlorophyll content varies. The 'red edge' value was significantly higher in malformed panicle when compared to healthy panicle.

The present study to differentiate healthy and malformed mango panicles using spectral reflectance data revealed the potential use of hyperspectral remote sensing to discriminate them. All the indices derived from hyperspectral reflectance were very promising. The best suited approach for discrimination was 'red edge' technique. Higher 'red edge' value and 'red edge'position (red shift) indicated malformed panicle which is opposite of the general trend, *i.e*., blue shift of REP and lower REV indicates diseased or stress plant. It was also observed that the hyper-indices like NDVI, SIPI and NPCI can be used to differentiate the malformed panicles from healthy one. The study proves the potential use of hyperspectral satellite data of moderate resolution to discriminate mango malformed areas at regional scale.

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