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MAPPING OF COTTON MEALYBUG (HEMIPTERA: PSEUDOCOCCIDAE) DAMAGE IN SIRSA DISTRICT, HARYANA USING GEOSPATIAL TECHNIQUE

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ABSTRACT

Detection of crop stress is one of the major applications of remote sensing in agriculture. Many researchers have confirmed the ability of remote sensing techniques for detection of pest/disease on cotton. Hence, this research was designed to investigate, (1) to study the spectral properties of noninfested and mealybug infested cotton crop (ii) damage assessment using remote sensing derived index. Mealybug-infested cotton crop showed significantly lower reflectance in the near infrared region and higher in the visible region of the spectrum compared with the non-infested cotton crop. Mealybug Pest Stress Index-8 (MPSI-8), a remote sensing index derived in this study shows a significant negative relationship with mealybug severity (r^2=0.6319) and shows the potential to assess the pest and disease damage because of its characteristic that include pigment, leaf structure, and water sensitive band. MPSI-8 depicts the change in pigment concentration and water stress and shows a negative relationship with mealybug severity. The high negative value of the index shows the high severity of mealybug. Land Surface Temperature (LST) also shows a positive and significant relationship with mealybug severity (r^2=0.5921).Multiple linear regression analysis showed a strong relationships (r^2=0.752) between mealybug severity and remotely derive index. Model developed in this study for the mealybug damage assessment in cotton crop yielded significant relationship (r^2=0.752) and was applied on satellite data of 21st September 2009 which reveals high severity of mealybug and it was low on 24th September 2010 which confirms the significance of the model and can be used in the identification of mealybug infested cotton zones. These results indicate that remote sensing data have the potential to distinguish damage by mealybug and quantify its abundance in cotton.

KEYWORDS: MPSI-8, LST, Mealybug, Severity Index and Remote Sensing

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INTRODUCTION

Agriculture is the backbone of the India and has a significant influence on Indian economy. This emphasizes the need for the mechanism for regular monitoring of pest/disease effect on the crop condition. There is a various aspect of monitoring crop condition starting from soil moisture availability, plant health condition and stress caused by an abiotic and biotic factor such as temperature, rainfall and humidity and biotic factors such as pest and disease. Any retardation from the normal growth pattern affects crop growth and finally reduces the yield and hence it is very important to monitor crop condition for the entire cycle of growth.

Cotton (Gossypium sp.), the white gold, is the world's leading fiber crop and second most important oilseed crop. Cotton is grown in more than 80 countries; during 2010-11, a total of 24.74 million tons of lint were produced. Six major cotton growing countries are China, India, U.S.A., Pakistan, Brazil, and Uzbekistan, account for 78% of the total area and contribute to 83% of the global cotton production. Among them Brazil (1475 kg/ha) holds highest productivity level, followed by China (1226 kg/ha), U.S.A. (910 kg/ha), Uzbekistan (684 kg/ha), Pakistan (636 kg/ha) and India (475 kg/ha).India accounts for about 32% of the total cotton area and contributes to 21% of the global cotton production, currently ranking second after China [1].

The cotton growing area in India can be broadly divided into three zones on the basis of the agro-climatic condition. North Zone, this zone comprises Punjab, Haryana, and Rajasthan and account for about 12% of the total cotton area in India viz, Punjab (4.75), Haryana (4.48%) and Rajasthan (2.96 %). Central Zone, this zone comprises Madhya Pradesh, Maharashtra, and Gujarat and accounts for about 65% of the total cotton area in India viz. Madhya Pradesh (5.82%), Maharashtra (35.57%) and Gujarat (23.57). South Zone, this zone comprises Andhra Pradesh, Karnataka and Tamil Nadu and accounts for about 22% of the total cotton area in India viz. Andhra Pradesh (15.95), Karnataka (4.75%) and Tamil Nadu (1.16%) [1].

Remote sensing has the potential to be used as an effective and inexpensive technique to identify diseased plants in a crop; mainly infected plants have different spectral response compared to healthy plants [2]. When plants get stressed with disease, absorption of incident light changes in the visible and Near Infra-Red (NIR) range [3], this is probably due to the decreased chlorophyll content, changes in other pigments & internal structure. The change of absorption consequently influences the reflectance of stressed plants. Therefore, in comparing the spectrum difference of stressed and healthy plants, we are able to identify the stress severity of green vegetation. Since the chlorophyll content tends to decrease under disease stress, absorption of incident solar radiation by green plants decreases in the visible region. Consequently, spectral reflectance is higher in the red region and decrease in the NIR range depending on the infection severity.

Remote sensing has the potential to be used as an effective and inexpensive technique to identify diseased plants on a field scale, mainly because infected plants have different spectral response compared to healthy plants [2].Studies on remote sensing applications to crop diseases are very few [4], though the potential for application of remote sensing techniques to epidemiological problems has long been argued [5]. Current epidemiological application of remote sensing is essentially a mapping exercise to demonstrate the relevant ecological variables and processes that can be observed remotely [6]. Quantitative analysis of remote sensing data for diseased crop identification has not been extensively studied, in spite of being a potential application of remote sensing to crop disease control.

The diseased plants behave differently in spectral reflectance and thermal emission from healthy ones, which provide the possibility of remote sensing technology to identify the diseased plants through quantitative analysis of their spectral differences. The strong spectral reflectance of green plants in the NIR range is mainly due to its internal foliar structure. Plants under disease stress also show various degrees of internal structural changes, which lead to a decrease of spectral reflectance in the NIR range [4].

Cotton mealybug Phenacoccus Solenopsis spread from infected to healthy plants via the wind, irrigated water, rain, ants, and birds or by sticking/clinging to equipment, animals or people. Mealybugs can feed on all parts of a plant, but prefer actively growing leaf tissue, petioles, and leaf veins. They damage the plants by sucking sap from leaves, twigs, stems, roots and fruiting bodies. They inject toxic saliva into the plant parts causing chlorosis, stunting, deformation and death of plants [7]

Mealybugs overrun the leaves, bolls, and branches, feed upon phloem sap and discharge extensive honeydew, on which dark dirty mold growth develops, accordingly influencing the photosynthetic capacity of the plant. Manifestations of plants infested during the vegetative stage incorporate distorted and bushy shoots crinkled curved leaves and hindered plants that dry totally in extreme cases. Late season indications incorporate plants with less, less and disfigured bolls, reduced vigor and early crop senescence. Mealybugs can also stain cotton lint and reduce quality [8,9]

The objective of the present study was (1) to study the spectral properties of noninfested and mealybug infested cotton crop (ii) damage assessment using remote sensing derived index

MATERIALS AND METHODS

Study area

Sirsa is situated in the northwestern part of Haryana State, India and confined within 29^{0}13’ to 29^{0}59’ North and 74^0 30’ to 75^0 7’ East (Fig. 1), lies in the arid, hot agro-ecological zone of India. The district has two types of soils viz Sierozem and Desert soils. The sierozem soils are found in major parts of the district and desert soils are comparatively found in the smaller part of the district especially in the southern part of the district. These soils vary from sandy loam to loamy sands in texture and are marginally fertile. Ghaggar river, a seasonal river in the district is a major drainage of the area. Cotton is the major Kharif crop, sowing start from May to June and the picking in the month of October-November.

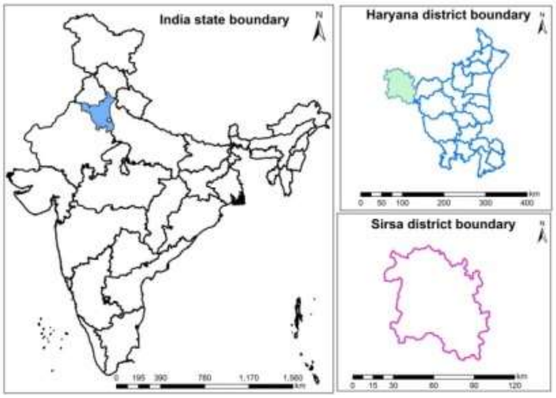

Fig: 1 Study area map

Field data collection

The field visits of mealybug infested area were chosen in cotton during Kharif season 2009 and 2010 the area was chosen randomly taking into account crop infestation. The geographic locations of healthy and infested cotton crop were recorded with the help of GPS. Mealybug infested cotton, close and field view collected during ground observation is shown in Fig.2. 100 plants were chosen and severity of mealybug was calculated. Table 1 and 2 shows a grading system of mealybug infestation and general format for calculating severity index of mealybug.

Table 1. Description of the symptoms of damage due to different levels of Solenopsis mealybug feeding effect in cotton [8]

Level of Infestation	Symptoms of damage
Grade-0	Healthy Plant
Grade-1	About 1–10 mealybugs scattered over the plan
Grade-2	At least one branch heavily infested with mealybugs
Grade-3	Two or more branches heavily infested with mealybug crinkled or twisted top few leaves with bunchy appearance, slight sooty mold development
Grade-4	Complete plant infested, stunted growth with sooty mold all over the plant, dry, reduced crop vigor and early crop senescence

Table 2. General format of grades and plant infested

Grades	0	1	2	3	4
Plants	X1	X2	X3	X4	X5

Multiple, Percentage infestation and severity Index were calculated based on the following a formula.

Multiple =Grade1*X2+ Grade2*X3+ Grade3*X4+ Grade4*X5…… (1)

% Infestation =Infected Plant / Total Plant…………………….…. (2)

Severity Index (SI) =Multiple/Total Plant infected……………..(3)

Fig: 2 (a) Healthy cotton crop (b) Field view of cotton crop damage by mealybug (c) Severely Infested cotton plant (d) close-up view of mealybug infestation on cotton

Remote sensing data processing and preparation of database

Landsat TM5 data with seven spectral band viz. Blue (0.45-0.52 µm), Green (0.52-0.60 µm), Red (0.63-0.69 µm), Near Infrared (0.76-0.90 µm), Shortwave infrared (1.55-1.75 µm), Thermal (10.4-12.5 µm) and Shortwave infrared (2.08-2.35 µm). To monitor the crop condition, multi-date satellite data were downloaded for the year 2009 and 2010.For the pixel level reflectance conversion, FLAASH module, (Fast Line-of-Sight Atmospheric Analysis of Spectral Hypercubes) atmospheric correction module in ENVI 4.4 software was used. It adapts MODTRAN (MODerate spectral resolution atmospheric TRANSmittance) algorithm to satellite data and output in surface reflectance was obtained for individual satellite data. ISODATA clustering technique was used for land use land cover map preparation and within the cotton area mask; remotely derived index and reflectance value of different band of mealybug infested and the healthy cotton crop was extracted from different sites observed. The relation between remote sensing based index and Severity Index (SI) were evaluated and finally used for the model development and validation.

$$\text{MPSI}-8=\frac{(\rho_{nir}+\rho_{green})-(\rho_{swir}+\rho_{blue})}{(\rho_{nir}+\rho_{green})+(\rho_{swir}+\rho_{blue})}$$

Where

MPSI-8= Mealybug Pest Stress Index-8

ρ is the reflectance at corresponding band depicted as a subscript

Land surface temperature (LST) for this study was computed from the literature [10].

Data analysis

Regression analysis was performed on the mean value of remotely derived index from the healthy and infested cotton crop. The correlation coefficient (r) and coefficient of determination (r^2) between the SI and remotely derived index were estimated from the data of different infested location (n = 93), during the year 2009 and 2010.

RESULTS AND DISCUSSION

Reflectance profile of healthy and diseased cotton crop

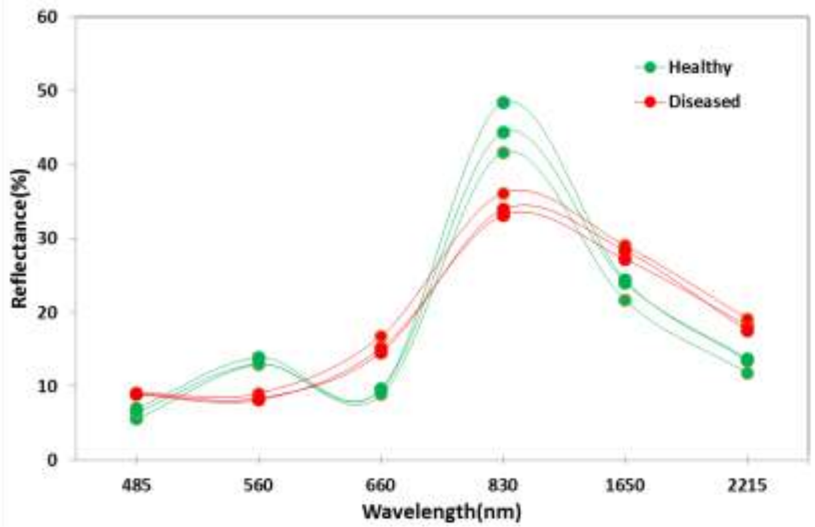

Fig: 3 Spectral reflectance profile of healthy and diseased cotton crop

Reflectance from the mealybug-infested and noninfested cotton crop is shown in Fig 3. It is evident that the spectral response of the mealybug-infested cotton crop was significantly affected by mealybug (Fig. 3). The reflectance of the cotton crop in the NIR region was significantly lower in contrast to a significant increase in the visible spectrum due to mealybug feeding (Fig. 3). In SWIR region also, the spectral response of the mealybug-infested cotton crop showed a significant difference compared to the non-infested cotton crop which attributed to changes in leaf water content. Mealybug-infested cotton crop captured less or reflected more light than the non-infested cotton crop in NIR and Visible region.

Relationship between Severity Index (SI) and remote sensing derived index

MPSI-8 computed based upon, Blue and Red band, a chlorophyll touchy band, Green band, NIR, leaf structure and SWIR, water sensitive band. A negative correlation (r =- 0.79) indicated that as the severity of the mealybug increase causes a decrease in the index value. Significant linear relationship (r^2 =0.63) between of SI and MPSI-8 shows that index has a higher value at low severity but decreases as mealybug severity increases (Fig.4b). The observed negative value of the index might be the reason of loss of green leaf area and high reflectance in blue and SWIR band, which is sensitive to pigment and leaf water content lead to the negative value of MPSI-8. The high negative value demonstrates that the green leaf damaged as a result of mealybug infestation and observed a reduction in NIR reflectance and higher reflectance in the Blue & SWIR band in this study was similar to [11,12]. LST showed the correlation coefficient (r^2= 0.59) with mealybug severity (Fig.4a).

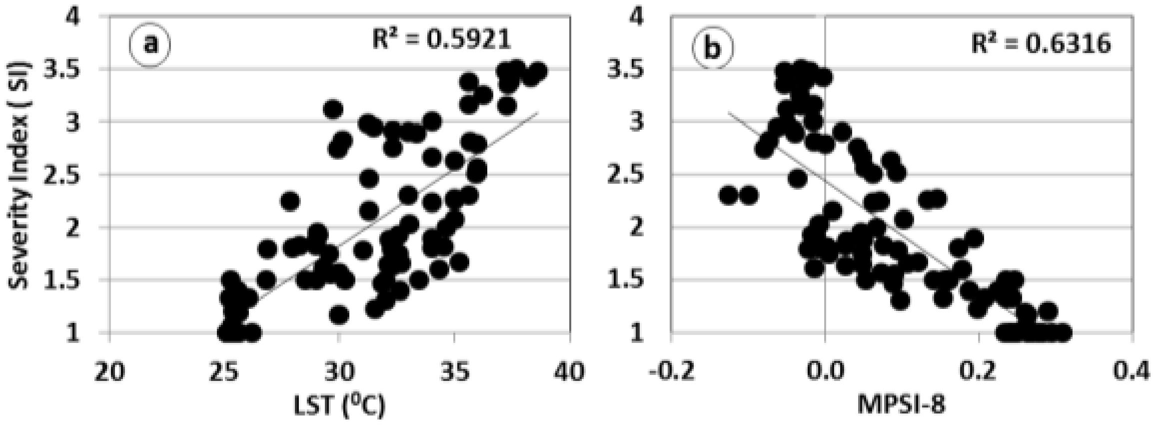

Fig 4: Relationship between Severity Index (SI) and (a) LST (b) MPSI-8 associated with different sites

Remote sensing based model development for mealybug damage assessment

Remote sensing based model was developed by using, Land surface temperature (LST), and Mealybug Pest Stress Index-8 (MPSI-8) as independent variable and Severity Index (SI), dependent variable.

The developed model shows a significant relationship with severity index (r^2=0.752). F-ratio is 137.754, which is very unlikely to have happened by chance (p<0.001). The standard error of estimate (SEOE) was 0.375.

Development of a model based on spectral vegetation indices

$$\mathbf{Y} = -0.338+0.084*\text{LST} - 3.324*\text{MPSI-8}$$

r= **0.867** $\mathbf{r^2 = 0.752}$ **n = 93 ---------(4)**

Sig. at $p < 0.001$, SEOE = 0.375, F=137.754

Where, Y = Severity Index

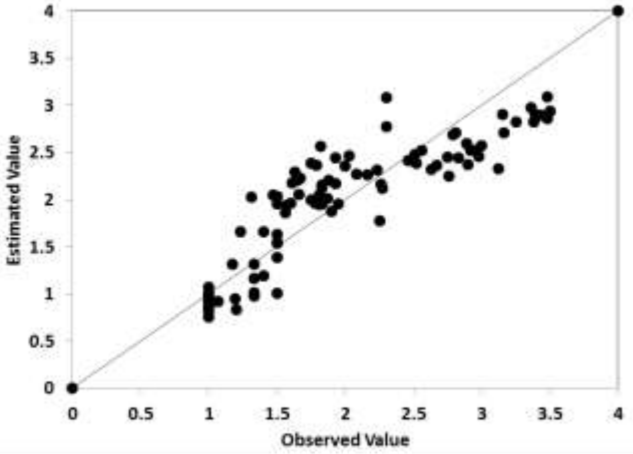

Fig.5: 1:1 relationships between estimated and observed severity index value by the model

Fig.5 demonstrates the scatter plot of estimated and observed value along the 1:1 line. This 1:1 line demonstrates the anticipating limit of the model with SEOE of 0.375. In this model, the majority of the anticipated qualities are concentrated close to the 1:1 line which shows great precision as it matches with the observed values.

LST, which represents surface temperature shows positive coefficient value, reveals the significance of LST in anticipating the severity of mealybug. Relationship of mealybug severity with LST demonstrated that high surface temperature zone i.e. low moisture area develops the conductive environment for mealybug infestation and their growth.MPSI-8 shows a negative relationship with severity index shows that mealybug infestation causes loss of pigment, green area and water stress in the cotton crop.

Utilizing the Equation 4, applied on 21st September 2009 and 24th September 2010, using the Erdas Imagine software's Modeller Module, Spatial impact of mealybug on cotton appears in Fig. 6a and 6b

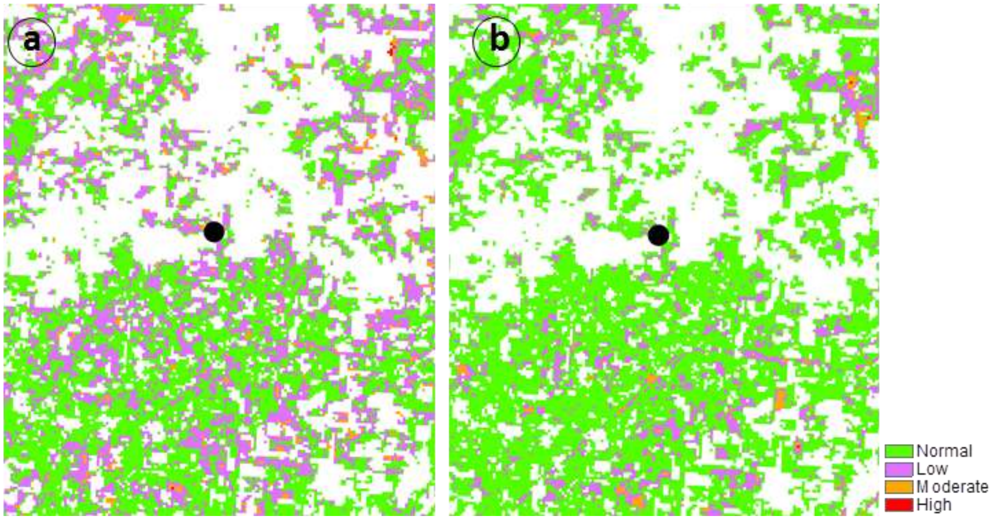

Fig:6 (a) Spatial variation of severity of mealybug surrounding of Fatehpuria village, Sirsa district (21 Sept. 2009) (b) Spatial variation of severity of mealybug surrounding of Fatehpuria village, Sirsa district (24 Sept. 2010)

The intensity of severity is classified into three categories, low, medium and high severity. Areas with low, Moderate and high severity are shown by Purple, Orange, and Red color in map respectively while area having no infestation is shown by green color.

The severity of the mealybug was low & moderate having a large affected area (Fig.6a). Low severity of mealybug (Fig.6b) compared to 2009 was found by the model developed in this study. Validation of the model applicability was confirmed and predicted severity of the mealybug was in agreement to ground observation. The severity of mealybug was high in the year 2009 and reduced in 2010(Fig.6b). Also, the extensive cotton area was affected in 2009 (Fig.6a) which is confirmed by the ground survey but in the year 2010, the severity of the mealybug was reduced (Fig.6b).

High reflectance in visible region from the infested crop contrasted with a healthy crop (Fig.3) shows that the mealybug severity causes a reduction in photosynthetic pigment concentration inside the leaf structure. The spectral changes due to mealybug infestation in cotton crop found in this study are similar to study of brown plant hopper in rice [13], cotton aphid in cotton [14], leafhopper in cotton [15], late blight in potato [16], yellow rust in wheat [17] and cotton mealybug in cotton [18,19].

The noteworthy contrast in green band reflectance was seen in the healthy and mealybug invaded cotton crop. Subsequent to the green reflectance is ascribed because of green leaf area of the crop because of which reflectance in the green region reduces. These distinctions in spectral reflectance of the healthy and the mealybug infested cotton crop could be expected because the green band is described by generally higher reflectance because of a chlorophyll substance in the healthy crop [20].

The outcomes show huge contrasts between mealybug-infested and healthy cotton crop in the visible region, NIR, and SWIR region. The change in reflectance properties of mealybug-infested and healthy cotton (Fig.3) could be the growth of dirty mildew fungus on the honeydew discharged by the mealybug on infested plants which damage the leaves inside the structure. High reflectance in the SWIR band could be ascribed to the loss of water from the mealybug-infested cotton crop. These changes found in the study are similar to study carried out by [21].

Thus, reflectance responses of the mealybug-infested cotton crop show that remote sensing has the potential to detect the damage caused by mealybug. Mealybug infestation on cotton significantly increased the visible reflectance and decreased the NIR reflectance when compared with non-infested cotton. The relationships between severity index and spectral indices showed that remotely sensed data transformed into spectral indices provides a method for detecting mealybug and differentiate damaged and healthy cotton crop. In addition, the model developed in this study, applied to the satellite data produced mealybug severity zone maps. These maps provide detailed temporal and spatial information on mealybug severity zone, which can be a very useful tool for mealybug management.

CONCLUSION

Continuously scientific development in the field of remote sensing provides high spectral, spatial and temporal resolution data from airborne or satellite platforms, it is necessary to evaluate and develop a methodology that could be useful in pest/disease management. The integration of remote sensing and GIS techniques for the integrated pest management programs is essential. This research is an effort in that direction and shows the potential of remote sensing indices for mealybug damage assessment in cotton. MPSI-8, a remote sensing index developed in this study shows a negative and significant relation with mealybug severity. LST, surface temperature shows a positive relation with mealybug severity and high surface temperature make the conductive environment for mealybug infestation and could be mapped for identification of probable zone for mealybug. Furthermore, validation of the model with independent data sets showed the capability of detecting the mealybug damage, and hence their potential use in the management of the pest and disease.

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