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Study on Hyperspectral Reflectance of Brown Planthopper (*Nilaparvata lugens*) Infestation in Rice

S. Sivaranjani[1], V. Geethalakshmi[1], S. Pazhanivelan[1], J.S. Kennedy[1], S.P. Ramanathan[1]

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ABSTRACT

Background: Pest management plays crucial role in yield prediction in all crops. In Rice, Brown Planthopper (BPH) plays major role in yield reduction. Pest forewarning in agriculture is the important tool and popularly used in various countries to avoid huge fertilizer and pesticide application. In this regard, Hyperspectral remote sensing gives various information about the spectral characteristics of BPH infected plants.

Methods: Investigations were carried out to assess the damage of BPH infestation at the field level using a portable Hyper spectral radiometer. The farmers field at the BPH prone area of Kuttalam block, Nagapattinam district, Tamil Nadu was chosen to analyze the spectral reflectance of BPH -infected and uninfected plants and derive certain vegetation indices for accurate forewarning. The specific spectral bands from visible to infra-red (445 nm, 550 nm, 670 nm, 760 nm, 800 nm) were utilized to detect of BPH-infested plants over the field area.

Result: Among various vegetation indices, the index MCARI (Modified Chlorophyll Absorption Reflectance Index) was performed well with high accuracy from early to late infestation at the field level and considered as the most effective tool in Precision Agriculture. As a result, The specific indices were analysed over BPH infected area to prevent greater spreading of pest damage and to minimize pesticides in the field.

Key words: BPH damage, Rice, Spectral reflectance, Vegetation index.

INTRODUCTION

Rice (*Oryza sativa*) is a major cereal crop with a rich source of carbohydrates and starch. Different species of rice occupy different parts of the world (Latif *et al*., 2011). Insects pose a colossal threat to cereal crops and significantly reduce crop production and productivity (Jena *et al.,* 2006). Among various insect pests, the BPH (*Nilaparvata lugens*) is currently thought to be Asia's most destructive rice pest. The hotspots of BPH were prone to higher relative humidity of >80% and maximum temperature of >30°C at peak hours and heavy application of nitrogen fertilizer (Wang *et al*., 2008). The BPH affected plants showed diminished chlorophyll and photosynthetic rate and Hopper burn symptoms such as yellowing and wilting of plants (Maisarah and Habibuddin, 2018). High usage of chemicals to control BPH leads to the developing resistance BPH biotypes and expanding environmental hazards over a large area (Zhang *et al*., 2016). Improved crop monitoring techniques, such as hyper and multispectral sensors, are being developed and promoted to increase the sustainability of pest management in modern agriculture lost (Filho *et al.,* 2020). From the perspective of pest management, it is crucial to quantify early symptoms. Biophysical remote sensing is used to identify plant stress brought on by disease or insect activity remotely (Jensen, 1983). The effective use of spectral reflectance to detect of insect infestation depends on determining the specific wavelength highly correlated to a specific infestation. The spectroradiometers use various ranges of light to identify chlorophyll, anthocyanin and carotenoids, and the water content in leaves (Mahlein *et al*., 2013). Using hyper spectral remote sensing, the better forewarning system helps solving farmers pest problems, makes farming more profitable and efficient (Saraf *et al*., 2019). For managing and monitoring natural resources, such as crops, identifying changes in vegetation patterns are crucial. The benefits of vegetation indices in agriculture are the availability of high level analysis over a vast region, and access to different image sources in one place. Some unique vegetation indices are helps to predict crop yield detection, plant vigour and stress (Panda *et al*., 2010). The vegetation index uses linear or nonlinear combinations of reflectance in different spectral bands to produce associated spectral signals (Lei *et al*., 2021). The need of the study is to utilize hyperspectral sensor for early detection of BPH infestation so as to reduce the cost of cultivation in rice growing areas.

[1]Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.

Corresponding Author: S. Sivaranjani, Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India. Email: sivaranjaniagrmet@gmail.com

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MATERIALS AND METHODS

The Infestation of *N. lugens* was heavily damaged in Rice along farmers field at Palayagudalur village, Kuttalam Block, Nagapattinam district Tamil Nadu (11.032932°N and 79.549255°E) and it is measured with the instrument-Spectroradiometer to know spectral reflectance of the crop. The growing season was *Rabi* (2022) and the age of seedlings was 120 days old transplanted seedlings which is the long duration variety (ADT 51). Alluvial clay was the dominant soil type over the block. The fertiliser used was 150:60:60 NPK/ha. Irrigation was done on alternate days. The average fortnight maximum and minimum temperature occurred in the study area was 30°C and 20°C with a relative humidity of more than 93%. During observations, we found only BPH damage at the field. Because BPH damage was more likely to occur in that particular block during rabi season by every year than any other pest damage. We observed the appearance of BPH Symptoms and the number of BPH as <25 BPH/hill for Class 1 symptoms, 25-50 BPH/hill for Class 3 symptoms, 50-100 BPH/hill for Class 5 symptoms and >100 BPH for Class 7 symptoms and Class 8 symptoms were not discussed in this paper since there is no need of forewarning. Moreover in our study area, the complete wilting and dead plants not available before that pesticides application was done to control over it. We followed the standard evaluation for the BPH damage given by INGER (IRRI, Cuttack) (Table 1).

This BPH damage was captured by Spectroradiometer GER 1500, (S/N 1500-002128, Year-2009) a portable device covering UV, Visible and Infra-red region from 350 nm to 1050 nm. The observation of spectral reflectance was taken between 1200 and 1400 hours during the daytime. The device should be kept 1 m above the height of the plant, and the sighting laser should have a 4° field of view and be oriented closer to the plant leaves. Initially, a white reference board was used for reference prior to data collection to calibrate for the lighting conditions. After the captured reflectance, Certain vegetation indices were evaluated to know sensitive spectral bands to give better forewarning (Table 2).

Statistical analysis

A general linear model was generated with univariate ANOVA with Classes as the main effects at various wavebands. A post hoc analysis with Duncan's homogenous test was

Table 1: Classification of BPH infestation level.

BPH infestation class	BPH symptoms and injure level
Class 0	No damage
Class 1	Slight yellowing of few leaves
Class 3	Partial Yellow with No hopper Burn
Class 5	Hopper burn and >25% wilting
Class 7	Hopper burn with >50% wilting
Class 8	Complete wilting and dead plants.

Source: INGER (1996).

Table 2: The vegetation indices used for BPH Infestation analysis.

Spectral index	Formula	Purpose	Reference
Modified chlorophyll absorption reflectance index. (MCARI)	$[(R_{700} - R_{670})-0.2(R_{700} - R_{550})]*(R_{700}/R_{670})$	Leaf chlorophyll and vegetation stress	(Daughtry *et al.*, 2000)
Normalized difference vegetation index (NDVI)	$(R_{800} - R_{670}) / (R_{800} + R_{670})$	Leaf chlorophyll	(Rouse *et al.*, 1974)
Normalized pigment chlorophyll index (NPCI)	$(R_{685} - R_{445})/ (R_{685} + R_{445})$	Leaf chlorophyll and LAI	(Penuelas *et al.*, 1993)
Red- edge chlorophyll index ($CI_{Red\ edge}$)	$(R_{760}/ R_{700} - 1)$	Leaf chlorophyll and vegetation stress	(Gitelson *et al.*, 2003 and 2005).
Green normalized difference vegetation index (GNDVI)	$(R_{750} - R_{550}) / (R_{750} + R_{550})$	Leaf chlorophyll	(Gitelson *et al.*, 1996)

employed to identify similar mean reflectance values. Superscripted alphabets that are different are statistically significantly different (Table 3).

RESULTS AND DISCUSSION

Spatial signature of *N. lugens*

In the present study, we observed a significant variance between the spectral reflectance of BPH infected rice plants and the symptoms of different classes ($p<0.001$). Yang and Cheng (2001) evaluated the spectral properties of rice plants at various levels of *N. lugens* infestation and he stated that across infestations, there were noticeable changes in reflectance at 755 and 890 nm wavelengths. In the current study also, the highest significant difference of reflectance was observed in the NIR (740 nm-925 nm) and Red region (640 nm-739 nm) than visible and UV region (Table 3) (Fig 1). This is due to high absorption of radiation by visible region and maximum reflection and transmission in the NIR region Lei *et al*. (2021). The wavelength range (640-740 nm) in the red region is regarded as a reflection sign of insect damage Liu and Sun (2016). Here, the spectral signature of BPH damaged plants showed a decreased trend with slight increase in the visible region (350 nm-639 nm) and a decrease with a steep rise in the red region (640 nm-739 nm). However, it follows steady and stable up to the NIR region (740 nm-925 nm) (Fig 1). Our Study results were highly correlated with the BPH study of Prasannakumar *et al*. (2013) and he reported that BPH damage was greater at longer wavelengths (740 nm-925 nm) and lower at shorter wavelengths (350 nm-730 nm). The same trend followed in our study; the healthy plants showed higher reflectance radiation in NIR region than the BPH-infected plants. The Previous study of Lu *et al*. (2022) also revealed similar spectral signature for leaf mite infestation in the crop jujube. A similar trend was pursued in the earlier study of Riedell and Blackmer (1999) observed in wheat seedlings with aphids (*Diuraphis noxia*) and greenbugs (*Schizaphis graminum*). Prabhakar *et al.* (2013) also revealed the minimal reflectance was observed in BPH infected plants in Rice and Mealy bug infected plants in cotton. He stated that the reduced reflectance in the advanced stage of infestation (class 3 and above) is due to the reduction in leaf pigments and damages in internal leaf structure as a result of loss of xylem and phloem tissue.

Spatial indices of *N.lugens*

As the result of this study, we estimated five vegetation indices with respect to different classes of BPH infestation for forewarning. The selection of these indices were made,

Table 3: Spectral reflectance of BPH Infestation at various classes.

Wavelength	Class 0	Class 1	Class 3	Class 5	Class 7	ANOVA
UV (350-399)	13.92 ± 1.05^{a}	12.01 ± 1.05^{b}	9.96 ± 1.05^{c}	4.23 ± 1.05^{d}	1.74 ± 1.05^{e}	<0.0001
V (400-424)	7.37 ± 1.52^{a}	7.07 ± 1.52^{b}	5.73 ± 1.52^{c}	2.45 ± 1.52^{d}	1.02 ± 1.52^{e}	<0.0001
B (425-489)	8.50 ± 0.90^{a}	7.95 ± 0.90^{b}	6.50 ± 0.90^{c}	3.08 ± 0.90^{d}	1.28 ± 0.90^{e}	<0.0001
G (490-559)	15.42 ± 0.87^{a}	12.86 ± 0.87^{b}	10.28 ± 0.87^{c}	4.91 ± 0.87^{d}	1.89 ± 0.87^{e}	<0.0001
Y (560-584)	25.28 ± 1.47^{a}	19.88 ± 1.47^{b}	15.54 ± 1.47^{c}	6.55 ± 1.47^{d}	2.42 ± 1.47^{e}	<0.0001
O (585-639)	18.13 ± 0.96^{a}	14.64 ± 0.96^{b}	11.67 ± 0.96^{c}	7.55 ± 0.96^{d}	2.77 ± 0.96^{e}	<0.0001
R (640-739)	22.57 ± 0.71^{a}	18.14 ± 0.71^{b}	14.84 ± 0.71^{b}	10.66 ± 0.71^{c}	4.04 ± 0.71^{d}	<0.0001
NIR (740-925)	96.30 ± 0.52^{a}	81.02 ± 0.52^{b}	69.90 ± 0.52^{c}	19.39 ± 0.52^{d}	10.45 ± 0.52^{e}	<0.0001

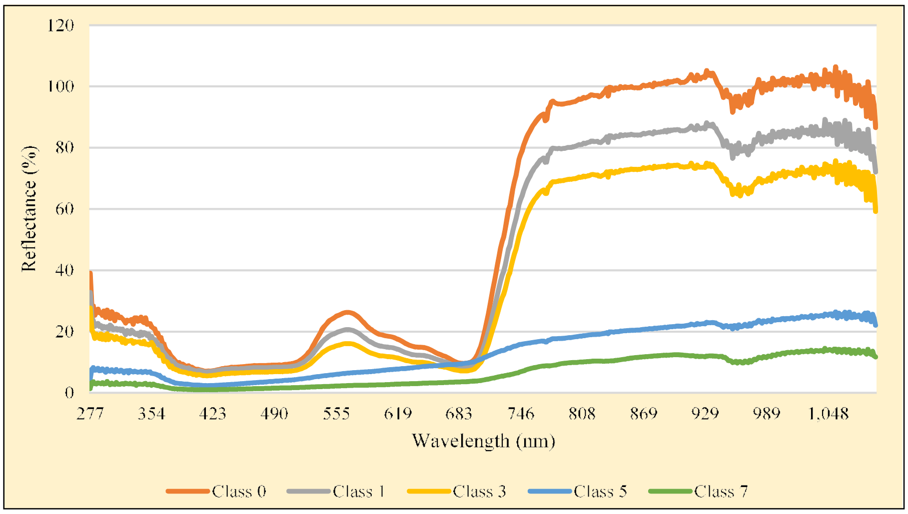

Fig 1: Reflectance percentage of BPH infestation by different classes.

because they significantly affect the amount of leaf chlorophyll in the plant canopy. BPH sucks plant sap, which results in decreased chlorophyll content in the plants. In the indices, NDVI (R^2=0.62, P<0.001, F<0.05), CIred edge (R^2=0.76, P<0.001, F<0.05), GNDVI (R^2=0.15, P<0.001, F<0.10) follows slight variation upto class 3 symptoms then rapidly decrease with rise upto class 7 symptoms (Fig 2). Huang *et al.* (2015) manifested that the estimation of BPH infestation through the indices NDVI, CIred edge, GNDVI was unsatisfactory due to poor detection at early infestation. Hence these indices are very difficult to predict and interpret over large area. The index NPCI (R^2=0.75, P<0.1, F<0.05), it showed an inverse relationship with respect to class 0 to 7 symptoms which is very controversial and complex to interpret. A Similar outcome was suggested by Prabhakar *et al*. (2013) in BPH infestation in Rice and he stated that the values of NPCI were meandering with low to high infestation where it doesn't follow any trend. However, in our present study, the indices MCARI (R^2=0.93, P<0.001, F<0.05) revealed high significance in all statistical analyses and it proved to be worth prediction in all classes of BPH infestation. Hence it decreased linearly from lower to higher infestation (Fig 2). Luo *et al*. (2013) suggested in the same way that MCARI was the best indices to predict Aphid (*Sitobion avenae)* infestation in Wheat under field conditions based on the high correlation and significant difference of p<0.0001. He also stated that among various indices such as NPCI, PRI, NDWI, NBNDVI and PSRI, the indices MCARI was performed better. It is proved by the results of Lu *et al*. (2022) an leaf mite (*Tetranychus truncatus Ehara*) infestation in the tree jujube. He also suggested that the indices MCARI can be used to predict from mild infestation to severe infestation. The results of our study were confirmed by the previous studies of Huang *et al*. (2015) in rice BPH

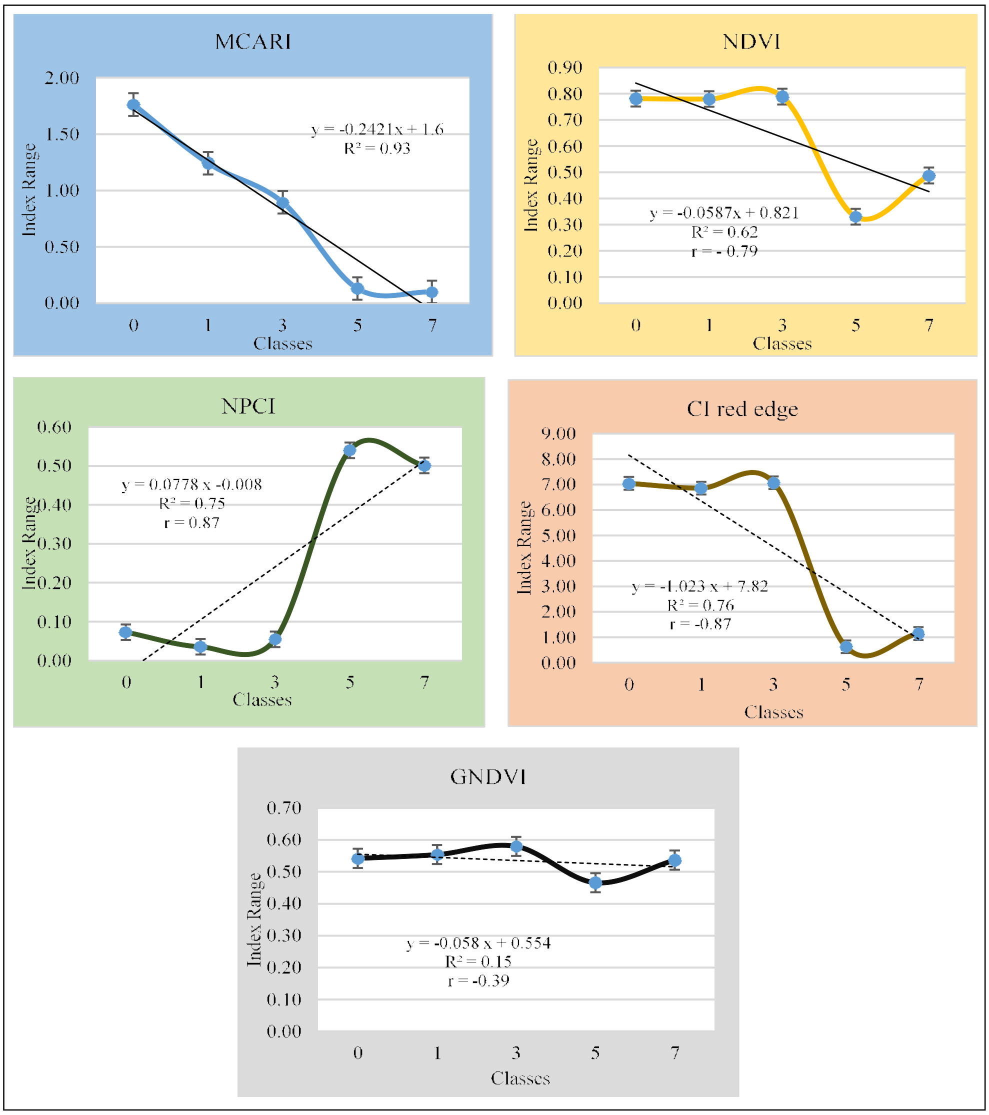

Fig 2: Vegetation indices in relation to different classes of BPH infestation.

infestation using the indices MCARI and he reported that MCARI spectral index was good to predict the BPH damage at slight infestation level across different rates of nitrogenous fertilizer in the field conditions.

CONCLUSION

In future climate change scenarios, due to adverse weather conditions pest outbreaks and survival will become more. In an effort to control, farmers use enormous pesticides which could lead to loss of biodiversity and environmental risk. In this situation better forewarning only helps to avoid the detrimental impact of pests and, economic loss to the farmers and stakeholders. In the upcoming days, the decision-making policymakers should utilize hyperspectral remote sensing, vegetation indices, satellite data and crewless aerial vehicle for the accurate forewarning of the early infestation of any pest and to minimize the production expenditure to the farmers over a large scale. As a result, the above mentioned practice was utilised to identify BPH infestation in rice by large-scale mapping, and it is very beneficial for small-scale farmers for pest management.

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Conflict of interest: None.

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