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Spectral signatures of rice crop damaged by brown planthopper under field and glass house conditions

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ABSTRACT

Hyperspectral remote sensing was used to detect the brown planthopper (BPH), *Nilaparvatalugens* (Stal.), stress on rice plants under glasshouse as well as field conditions. The BPH damage influenced rice plant reflectance compared to uninfested plants in the visible (VIS), and near infrared (NIR) regions of electromagnetic spectrum under both the conditions. Plot of correlation coefficients (r), between plant reflectance and BPH damage levels, against wavelengths depicted four sensitive wavelengths *viz*., 1986 nm (r = 0.63), 665 nm (r = 0.58), 1792 nm (r = 0.53) and 500 nm (r = 0.52) in relation to BPH stress detection on rice plants in glasshouse. In field, the sensitive wave lengths were found to be 961nm (r = -0.706), 1201nm (r = -0.705), 764 nm (r =-0.676) and 1664nm (r = -0.609). Mean rice plant reflectance as affected by differential BPH damage varied across nine wave bands *viz*., UV, V, B, G, Y, O, R, NIR and MIR for both glass house and field conditions. Variation in plant reflectance due to BPH damage was smaller at shorter wavelengths (350-730 nm) and larger at longer wavelengths, *viz*., NIR (740-925 nm) followed by mid infrared (MIR) (926-1800 nm), which indicated the possibility of detection of BPH stress on rice and thereby issuing prompt forewarning to stakeholders.

KEYWORDS: Brown planthopper, HyperspectralRemote Sensing, Reflectance, Rice

INTRODUCTION

Rice is the world's most important staple food crop for more than half of the population (Maclean *et al*., 2002), which is true for India also. Approximately, 41.85 m ha area is under rice cultivation in India with a production of 102 million tonnes (Anonymous, 2012). The yield loss due to insect pests in rice has been estimated to 21 to 51 per cent (Prakash*et al*., 2007), which is one of the major reasons for poorer crop productivity in India (Krishnaiah*et al*., 2008). In view of land resource constraint, increase in crop productivity has to be brought through improved crop production and protection technologies. The brown planthopper (BPH), *Nilaparvatalugens* (Stäl.) is one of the noxious rice pests responsible for large scale crop devastation resulting in as high as 60% yield loss (Srivastava*et al*., 2009; Kumar *et al*., 2012). BPH has proven to be a hidden enemy of farmer, difficult to monitor and by the time its damage becomes evident, loss is already inflicted.

Timely detection of its incidence on the crop through regular monitoring is the key to effective management.

Objects can be distinguished through remote sensing technique based on reflectance pattern produced over different wavebands (Lewis, 2003). The spectral reflectance characteristics of plants and their canopies are determined by the chemical composition, physical properties of the plants and the spectral properties of the source (Bauer, 1985; Myneni and Ross, 1991). Biotic stresses such as diseases and insects alter the chlorophyll characteristics, chemical concentrations, cell structure, nutrient and water uptake, and gas exchange of the plant leading to differences in reflectance from crop canopy (Raikes and Burpee, 1998). The use of reflectance spectra for monitoring vegetation condition has gained popularity due to intensive development of hyperspectral remote sensing equipments which provide additional bands within the visible (VIS), near infrared (NIR) and mid infrared (MIR) regions. Most hyperspectral sensors acquire radiance information in less than 10 nm bandwidths from the visible to the MIR region (400-2500 nm) (Asner, 1998). It is possible to collect several hundred spectral bands in a single acquisition thus producing more detailed spectral data through hyperspectral remote sensing (Govender*et al*., 2007). However, it is difficult to determine the cause of plant stress through satellite imagery without standardizing spectral signatures for different types of stresses through ground truth (Asner, 1998).

Yang and Cheng (2001) and Yang *et al*. (2007) found the severity of the BPH and the leaf folder on rice to be differentiable through differences in reflectance from the VIS and NIR regions on the spectral domain. In India, work on spectral signatures of crop pests remains scanty and it was therefore, endeavoured to evaluate hyperspectral remote sensing technique to assess the BPH damage rice.

MATERIALS AND METHODS

Generation of differential brown planthopper (BPH) damage

Glasshouse pot experiment

Experiments for creating differential BPH damage levels were undertaken during k*harif* 2010 and 2011 at Indian Agricultural Research Institute, New Delhi (28°36′ 36″N 77°13′ 48″E). Twenty two days old seedlings of Pusa Basmati 1 rice were transplanted in black opaque plastic pots of 0.3 m diameter and 0.2 m height in a glasshouse at three seedlings per pot. The plants were maintained following the recommended agronomic practices. The **e**xperiments had six treatments (Table 1), which comprised of differential BPH damage ranging from uninfested plants (level 0) to complete hopper burn (level 9) in accordance with INGER(1996). Each treatment was replicated four times wherein 45-day old seedlings were infested with differential number of brachypterous females and winged males to obtain different damage levels. The planthopper population maintained on potted rice plants in the glasshouse was used in the study.

Field experiments

Field experiments for generating variable BPH damage levels were carried out at Indian Agricultural Research

Institute, New Delhi during *kharif*2010 and 2011. The 22 -day old seedlings of Pusa Basmati 1 rice were transplanted at 2 seedlings per hill in 24 plots measuring (3x2.5 m). Crop was raised following recommended agronomic practices. Other pests such as stem borer and leaf folder were managed through application of cartap hydrochloride 50 SP@ 0.1%. Aforesaid experimentswere maintained in the form of variable level of plant protection with four replications (Table 1). Variable levels of BPH damage were generated through application of buprofezin 25 EC @ 0.05% at different crop growth stages. Reflectance measurements were made during 70 to 80 days after transplanting (DAT) both the years.

Spectral measurements and analysis

Reflectance spectra ranging from 350-2500 nm for different BPH damage levels on rice plants were measured with a field portable spectroradiometer (FieldSpec3, Analytical Spectral Devices (ASD), USA). Before observation, the instrument was calibrated with respect to solar radiation using a reference panel, spectralon. Reflectance spectrum was obtained through comparison of radiance of the target plants with that of the spectralon. Instrument was set to produce an average of 50 spectra of a target at a time. All the pots were brought under the sun before observation wherein exclusion of background shadow was ensured. With 25^o field of view, sensor was kept at 80 cm height above the plant canopy to ensure complete plant canopy coverage. Reflectance from rice plants were recorded from fixed positions under cloudless sunlight condition between 1100 h and 1300 h IST. Rice plant reflectances recorded at 75 DAT during the two years were pooled for analysis. Rice plant reflectance in pot and field experiments were analyzed and interpreted separately.

Plant reflectance values were averaged at every 10 nm interval and jumps at 1000 and 1800 nm were smoothened using Hyper Agri software developed at IARI, New Delhi (Pers. communication). Noises at 1355-1424, 1805-1964 and 2445-2500 nm were removed. Mean spectral reflectance for different wave bands viz., ultraviolet (UV) (350-399 nm), violet (V) (400-424 nm), blue (B) (425-489 nm), green (G) (490-559 nm), yellow (Y) (560-584 nm), orange (O) (585-639 nm), red (R) (640-730 nm), NIR (740-925 nm) and MIR (926-1800 nm) were also calculated. Changes in spectral reflectance with differential BPH damage were evaluated through linear correlation. Correlation coefficients (r) were plotted against wavelengths and wavelengths corresponding to peaks of the correlation - wavelength curve were identified as sensitive wavelengths (Yang *et al*., 2007; Prabhakar*et al*., 2011).

RESULTS AND DISCUSSION

Spectral reflectance in relation to BPH infestation

Both glasshouse and field experiments, spectral reflectance curve (Fig 1A; Fig 1B) depicted that uninfested plants had lower reflectance than infested plants in the VIS region in general with peak reflectance being at 550 to 560 nm. However, they showed higher reflectance both in the NIR region. Aforesaid peak reflectance of uninfested plants at 550-560 nm was nonetheless higher than that of infested plants. Reflectance in the VIS (400-700 nm) was found to be directly related to BPH damage wherein reflectance increased with an increase in damage from 400 nm to the red edge shoulder at 675 nm under glass house pot experiments corresponding being at 668 nm under field experiments. On the contrary, in the NIR region (740- 925 nm), reflectance decreased with an increase in BPH damage. Rice plant reflectance thus exhibited negative relationship with BPH damage. Mean rice plant reflectance as affected by differential BPH damage varied across nine wave bands *viz*., UV, V, B, G, Y, O, R, NIR and MIR (Fig. 2A; Fig.2B). Variation in plant reflectance due to BPH damage was smaller at shorter wavelengths (350-730 nm) and larger at longer wavelengths, *viz*., NIR (740-925 nm) followed by MIR (926-1800 nm). The greatest difference in plant reflectance occurred between BPH damage level 9 and damage level 0 in the NIR region under both glass house pot and field experiments.

Higher reflectance of rice plants in the VIS region with an increase in BPH damage was indicative of reduction in chlorophyll content of leaves due to the pest feeding, which was perceptible through visual observations. The BPH damaged plants exhibited hopper burn symptoms in the form of yellowing, curling and wilting of leaves. Uninfested plants were greener, which might absorb radiations in the blue (450 nm) and the red (680 nm) bands better than infested plants. Higher plant reflectance in the VIS region owing to changes in the biochemical characteristics of photosynthetic pigments due to pest feeding has been reported earlier (Salisbury and Ross, 1969; Gausman, 1982; Mass and Dunlap, 1989). Likewise, other studies that have reported plant reflectance pattern in the VIS region similar to the present study include that on BPH damage in rice (Yang and Cheng, 2001), and green bug (Mirik*et al*., 2006a) and Russian wheat aphid (Mirik*et al*, 2007) damage in wheat. However, greater peak reflectance of uninfested plants than infested plants at 550-560 nm might be attributed to higher reflection of green light (500 to 600 nm) by more concentrated green leaf pigments in uninfested plants, which has also been observed earlier (Riedell and Blackmer 1999; Mirik*et al.*, 2006b; Mirik*et al.*, 2007).

Lower reflectance of infested plants in the NIR region (675- 1125 nm) compared to uninfested plants could be ascribed to leaf curling, shrinking and wilting due to BPH damage that might have led to scattering of incident radiation rather than their reflectance from leaf surface. Reduced plant reflectance owing to leaf colour fading, cell structure damage and alteration in air-cell spongy mesophyll, responsible for photon scattering in the NIR region, has earlier been observed in BPH (Yang *et al.*, 2007), mustard aphid (Kumar *et al*., 2010) and cotton leafhoppers (Prabhakar*et al*., 2011). Asner (1998) also reported the maximum reflectance from uninfested plants (level 0) due to the strongest multiple scattering and transmittance in the NIR region

Identification of sensitive bands through correlation

In glasshouse experiment, correlation coefficients (r) between mean plant reflectance and BPH damage levels when plotted against wavelengths, resulted in identification of four sensitive bands at 1986 nm (r = 0.63), 665 nm (r = 0.58), 1792 nm (r = 0.53) and 500 nm (r = 0.52) (Fig. 3A). However, under field conditions, the corresponding four distinct sensitive bands being at 961nm (r = -0.706), 1201 nm (r = -0.705), 764 nm (r = -0.676) and 1664nm (r = -0.609) (Fig. 3B).

The correlation–wavelength curve showed peaks and troughs throughout the spectral domain of 350–2500 nm, which indicates that not only the spectral characteristics but also the optical properties and reflectance were waveband-dependent; this has also been observed in previous studies (Asner, 1998; Yang and Chen, 2004). Zhou *et al.* (2010). These workers were able to detect BPH stress in rice under greenhouse conditions through ground-based hyperspectral radiometry, and they identified several bands from the visible to MIR wavelengths that proved sensitive to BPH damage. Contrary to pot experiments, the linear intensity correlation for field data showed a negative relationship between BPH damage and rice spectral reflectance that resulted in identification of different sensitive bands. This might be due to, multiple factors influencing reflectance of plant canopy. Prabhakar*et al*. (2011) attributed inconsistent any in relationship between spectral indices and field-measured spectral reflectance to one or several biotic and abiotic factors such as differences in edaphic factors, solar angle, prevailing atmospheric conditions, cultivar and crop growth stages.

Table 1: Differential brown planthopper damage levels for measuring rice plant reflectance in glasshouse pot and field experiment (*INGER, 1996)

Scale/Treatment*	BPH damage Symptom
Level 0	No damage
Level 1	Slight yellowing of a few plants
Level 3	Leaves partially yellow but with no hopperburn
Level 5	Leaves with pronounced yellowing and some stunting or wilting, 10-25% of plants with hopperburn
Level 7	More than half the plants wilting or with hopperburn, remaining plants severely stunted
Level 9	All plants dead

To ensure reliable assessment of BPH damage through remote sensing, sensitive wavelengths for BPH need to be distinguished from those of other pests of rice such as leaf folder and leaf blast that might occur simultaneously in the field and show overlapping effects on plants. Note that the occurrence of these pests on crop in North India is temporally separated – that is, while leaf folder and leaf blast are important during the pre-flowering crop phase, BPH occurs during the post-flowering phase. Nonetheless, information on spectral signatures of important pests of rice is required for meaningful application of remote sensing techniques in pest management.

BPH damage on rice crop could be distinguished based on differences in reflectance of uninfested and infested plants mainly in the NIR region and to certain extent in the visible region of the electromagnetic spectrum. Variations in rice plant reflectances found among the wave bands further confirmed facilitation of hyper spectral remote sensing indetection of pest damage to crop easier than population counts of the pest.

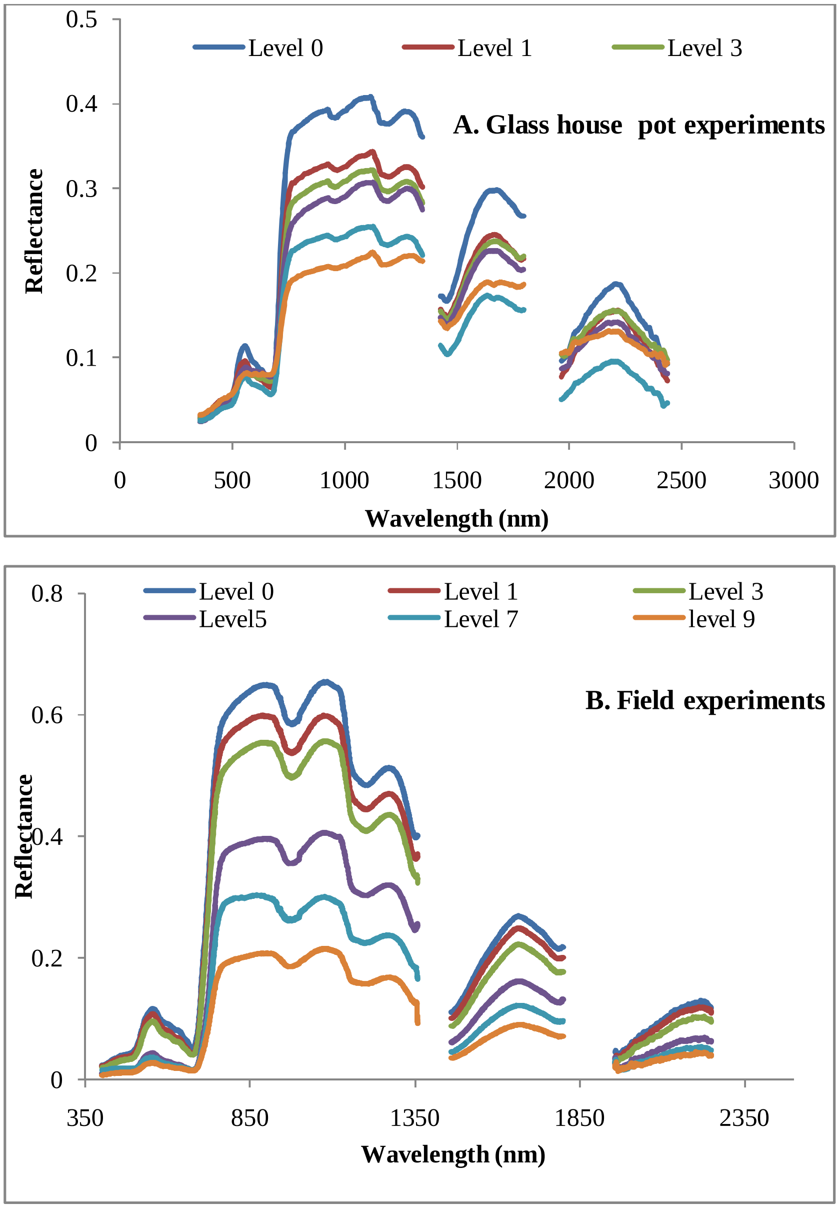

Fig. 1: Reflectance spectra of rice plants at different wave bands in relation to variable brown planthopper damage in glass house pot (A) and field experiments (B)

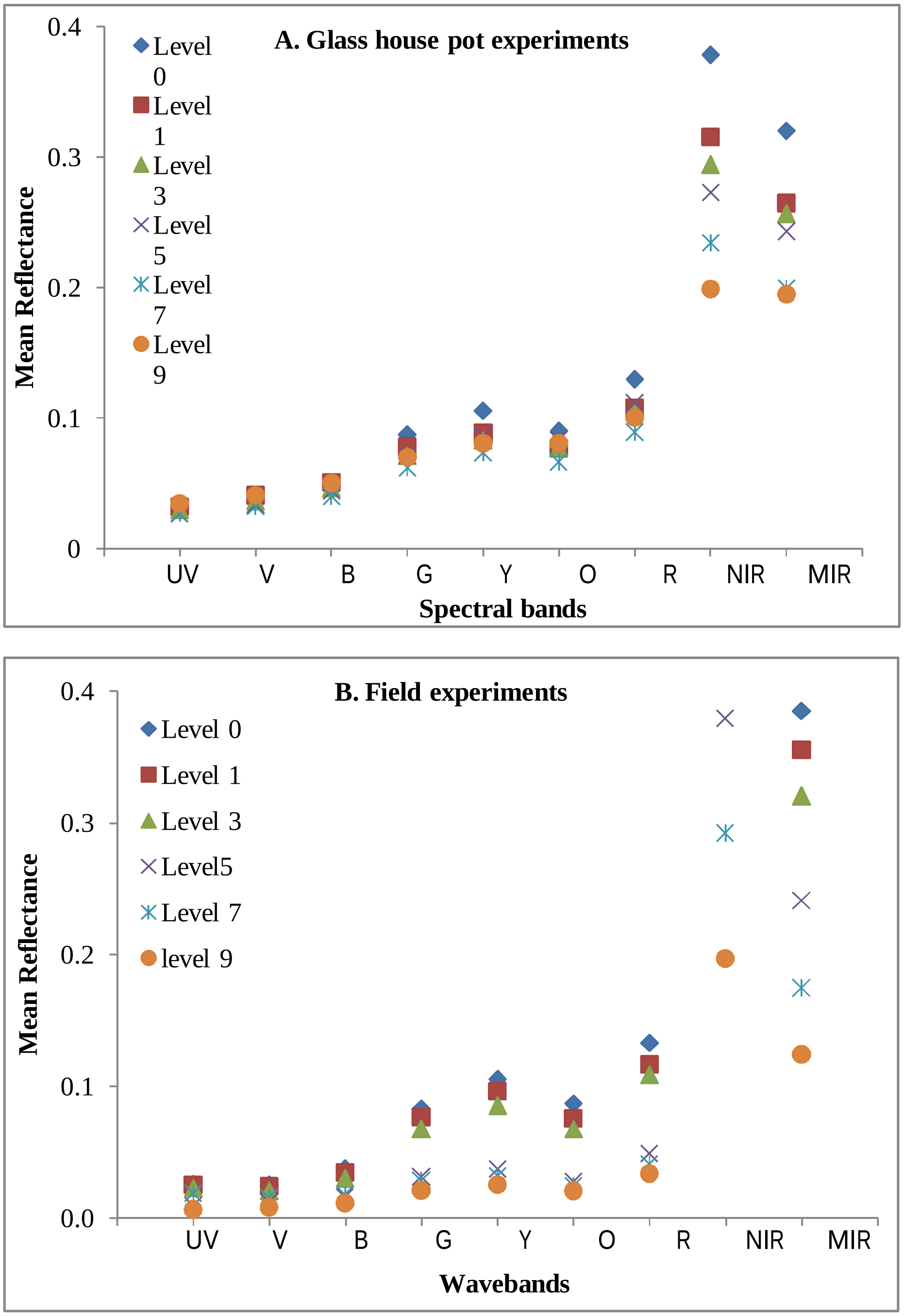

Fig. 2 Variation in mean reflectance (based on different spectral ranges within a band) in relation to variable brown planthopper damage in glass house pot (A) and field experiments (B)

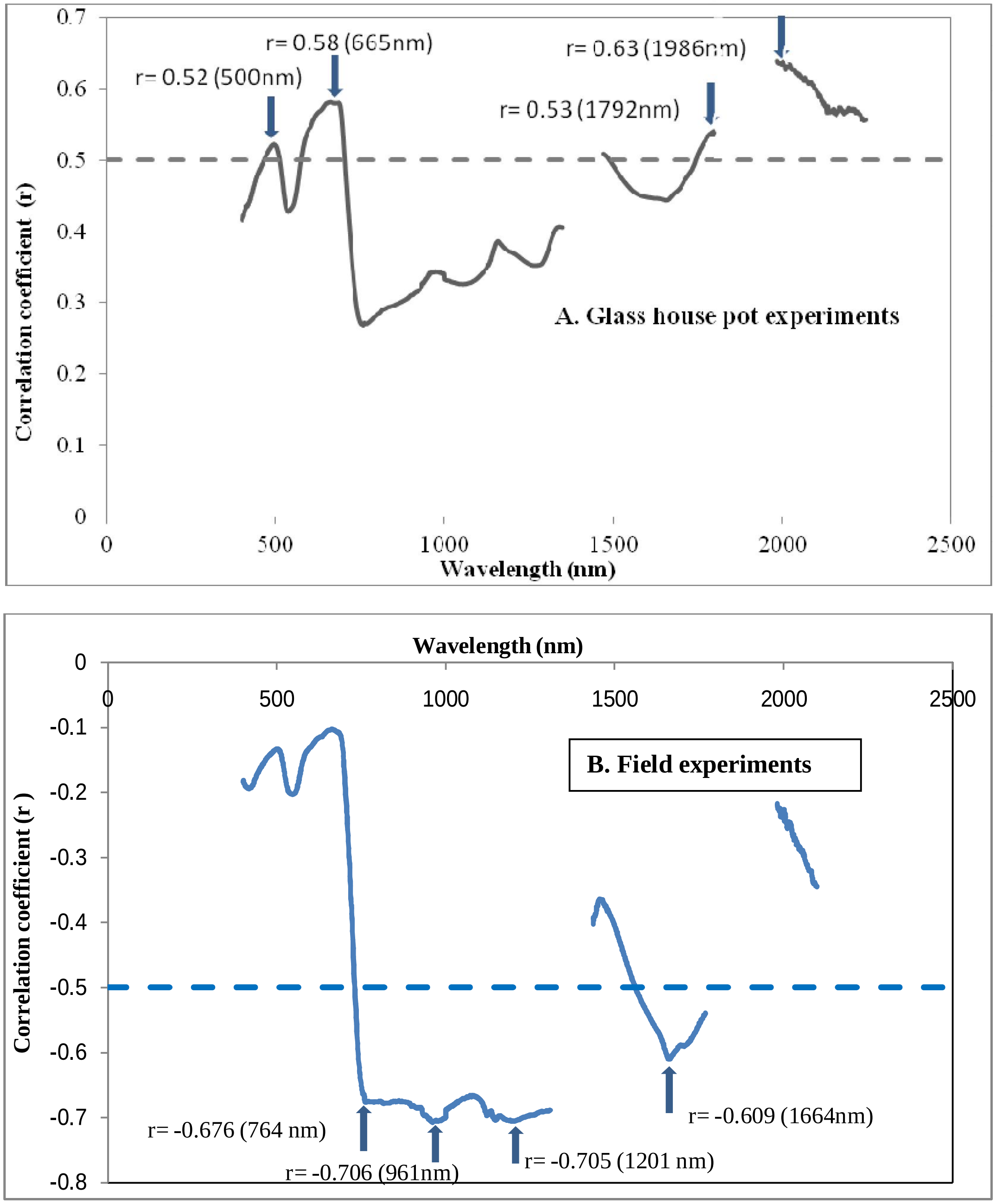

Fig. 3 Correlation coefficient (r) between reflectance spectra of rice plants at different wave bands and variable brown planthopper infestation in glas s house pot (A) and field experiments (B)

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REFERENCES

Anonymous, 2012.Annual report 2010-2011.*Department of Agriculture and Cooperation, Minister of Agriculture*. Govt. of India, pp-31.

Asner, G. P., 1998. Biophysical and biological sources of variability in canopy reflectance.*Remote sens.Environ.*,**64**: 234-253.

Bauer, M.E., 1985. Spectral inputs in crop identification and condition assessment. *Proc. Inst. Electric.and Electron Eng.*,**1071**: 1071-1085.

Gausman, H.W., 1982. Visible light reflectance, transmittance, and absorptance of differently pigmented cotton leaves.*Remote Sens. Environ.*,**13**: 233-238.

Govender, M., Chetty, K. and Bulcock, H., 2007.A review of hyperspectral remote sensing and its application in vegetation and water resource studies.*Water Sci.*, **33**: 145-152.

International Network for Genetic Evaluation of Rice (INGER), 1996.*Genetic Resources Center.Standard Evaluation of System for Rice.*International Rice Resource Institute, Manila, Philippines, pp-26.

Krishnaiah, N. V., Lakshmi, V. J., Pasalu, I. C., Katti, G. R. and Padmavathi, C., 2008. Insecticides in Rice-IPM, Past, Present and Future.Directorate of Rice Research, ICAR, Hyderabad, pp-148.

Kumar, J., Vashisth, A., Sehgal, V. K. and Gupta, V. K., 2010.Identification of aphid Infestation in mustard by Hyperspectral Remote Sensing.*J. Agric. Phy.*,**10**: 53-60.

Kumar, H., Maurya, R. P. and Tiwari, S. N., 2012. Study on antibiosis mechanism of resistance in rice against brown plant hopper, *Nilaparvatalugens* (Stal.). *Ann. Plant Prot. Sci.*, **20**(1): 98-101.

Lewis, M. M., 2003. Discriminating vegetation with hyperspectral Imagery-What is possible? Presented at EPA conference Spectral remote Sensing of vegetation, Las Vegas, Nevada, held from March 12-14, 2003.

Maclean, J. L., Dawe, D., Hardy, B. and Hettel, G. P., 2002.Rice Almanac, 3rd ed. CABI Publishing, Wallingford, UK.

Mass, S. J. and Dunlap, J. R., 1989.Reflectance, transmittance, and absorptance of light by normal, etiolated, and albino corn leaves. *Agron. J.*, **81:** 105-110.

Mirik, M., Michels, G. J. Jr., Sabina K. M., Elliott, N. C. and Bowling, R. 2006a.Hyperspectral spectrometry as a means to differentiate uninfested and infested winter wheat by greenbug (Hemiptera: Aphididae). *J. Econ. Entom.*, **99**(5): 1682-1690.

Mirik, M., Michels, G. J., Mirik, S. K., Elliot, N. C. and Bowling, R.

2006b. Hyperspectralspectrometry as a means to differentiate un-infested and infested winter wheat by Greenbug (Hemiptera: Aphididae). *J. Econ. Entom.* **99**:1682–1690.

Mirik, M., Michels, G. J. Jr., Sabina K. M. and Elliott, N. C., 2007. Reflectance characteristics of Russian wheat aphid (Hemiptera: Aphididae) stress and abundance in winter wheat. *Comp. Electron. Agric.*, **57**: 123–134.

Myneni, R. B. and Ross, J., 1991.Photon-Vegetation interactions. Springer-Verlag, Berlin.

Prabhakar, M., Prasad,Y. G., Thirupathi, M., Sreedevi, G., Dharajothi, B. and Venkateswarlu, B., 2011. Use of ground based hyperspectral remote sensing for detection of stress in cotton caused by leafhopper (Hemiptera: Cicadellidae). *Comp. Electron. Agric.*,**79**:189–198.

Prakash, A., Rao, S., Singh, O. N., Tyagi, J. P., Singh, S. and Rath, P. C., 2007. Rice: The Queen of Cereals. AZRA Publication, CRRI, Cuttack, Orissa, India, pp215.

Raikes, C. and Burpee, L. L.1998. Use of multispectral radiometry for assessment of *Rhizoctonia*blight in creeping bent grass. *Phytopatho.*,**88:** 446-449.

Riedell, W. E., and Blackmer, T. M. 1999**.**Leaf reflectance spectra of cereal aphid-damaged wheat.*Crop Sci.*, **39**:1835-1840.

Salisbury, F. B. and Ross, C., 1969. *Plant Physiology.*Wadsworth, Belmont, CA, U.S.A.

Yang, C. M. and Cheng, C. H., 2001.Spectral characteristics of rice plants infested by brown planthoppers.*Proc. Nationl. Sci. Coun.*, **25**(3): 180-186.

Yang, C. M. and Chen, R. K., 2004.Modeling rice growth using hyperspectral reflectance data.*Crop Sci.*, **44:** 1283–1290.

Yang, C. M., Cheng, C. H. and Chen, R. K., 2007. Changes in spectral characteristics of rice canopy infested with brown plant hopper and leaf folder. *Crop Sci.*, **47**: 329–335.

Zhou, Z., Zang, Y., Zhao, Z., Luo, X. and Zhou, X., 2010. Canopy hyper spectral reflectance features of rice caused by rice brown planthopper (*Nilaparvatalugens*) infestation. *American Soc. Agricul. Biol. Engg.*, Pittsburgh, Pennsylvania, June 20 - June 23, 2010.