8. Geiger, A., Moosmann, F., Car, O. and Schuster, B., Automatic camera and range sensor calibration using a single shot. In Proceedings – IEEE International Conference on Robotics and Automation, 2012.
9. Lebourgeois, V., Bégué, A., Labbé, S., Mallavan, B., Prevot, L. and Roux, B., Can commercial digital cameras be used as multispectral? A crop monitoring test. *Sensors*, 2008, **8**(11), 7300–7322.
10. Han, G. Y., Jung, H. S. and Kwon, O., How to utilize vegetation survey using drone image and image analysis software. *J. Ecol. Environ.*, 2017, **41**(18).
11. Sorensen, T., A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons. Kongelige Danske Videnskabernes Selskab. *Biologiske Skrifier*, 1948, **5**, 1–34.
12. Gara, T. W., Murwira, A., Chivhenge, E., Dube, T. and Bangira, T., Estimating wood volume from canopy area in deciduous woodlands of Zimbabwe. *South Forests: J. For. Sci.*, 2014, **76**(4), 237–244.
13. Baatz, M. and Schape, A., Multiresolution segmentation: an optimization approach for high quality multi-scale image segmentation. In *Angewandte Geographische Informations – Verarbeitung*, *XII* (eds Strobl, J., Blaschke, T. and Griesbner, G.), Wichmann Verlag, Karlsruhe, Germany, 2000, pp. 12–23.
14. Getzin, S., Wiegand, K. and Schöning, I., Assessing biodiversity in forests using very high-resolution images and unmanned aerial vehicles. *Methods Ecol. Evol.*, 2012, **3**, 397–404.
15. Oldeland, J., Stoltenberg, G. A., Naftal, L. and Strohbach, J. B., The potential of UAV derived image features for discriminating savannah tree species. In *The Roles of Remote Sensing in Nature Conservation* (eds Díaz-Delgado, R., Lucas, R. and Hurford, C.), Springer, Germany, 2017, pp. 183–201.
16. Yu, X., Hyyppä, J., Vastaranta, M., Holopainen, M. and Viitala, R., Predicting individual tree attributes from airborne laser point clouds based on the random forests technique. *ISPRS J. Photogramm*., 2011, **66**, 28–37.
17. Whitehead, K. and Hugenholtz, C. H., Remote sensing of the environment with small unmanned aircraft systems (UASs), part 1: a review of progress and challenges. *J. Unmanned Veh. Syst*., 2014, **2**(3), 69–85.

ACKNOWLEDGEMENTS. We thank the Director, Botanical Survey of India, Shillong Circle for allowing us to conduct UAV survey and forest inventory data collection. We thank anonymous reviewers for suggestions to improve the article.

Received 26 April 2019; revised accepted 16 July 2019

doi: 10.18520/cs/v117/i7/1194-1199

Imidacloprid efficacy against brown planthopper, *Nilaparvata lugens* under elevated carbon dioxide and temperature

Govindharaj Guru-Pirasanna-Pandi[1,2,*], Subhash Chander[1], Madan Pal Singh[1], P. S. Soumia[1] and M. Sujithra[1]

[1]Indian Agricultural Research Institute, New Delhi 110 012, India
[2]National Rice Research Institute, Cuttack 753 006, India

Influence of elevated CO_2 and temperature (elevated condition (EC)) vis-à-vis ambient CO_2 and temperature (ambient condition (AC)) on plant (rice) growth, insect *Nilaparvata lugens* (brown planthopper (BPH)) population and insecticide (Imidacloprid) efficacy was evaluated under open top chamber conditions. EC had a positive effect on rice crop through increase in tillers numbers (18.4%), reproductive tillers (20.5%) but inflicted negative effect on 1000-grain weight (11.7%) and grain yield (11.9%). Likewise, higher canopy cover of the plant was noticed under EC (16.1 cm) when compared to AC (12.9 cm). With respect to BPH population during 2013 and 2014, EC exhibited positive effect by enhancing its mean population to 66.1 and 49.4 hoppers hill^{-1} respectively, compared to corresponding 36.8 and 29.5 hoppers hill^{-1} under AC. With respect to Imidacloprid efficacy against BPH, LC_{50} was significantly lower under EC (0.044%) in comparison to AC (0.065). Similarly, in 2013 under AC, 500, 600, 700 l ha^{-1} spray volume caused >50% BPH mortality than 400 l ha^{-1} at 5 day after spray. However, during the same exposure period under EC, only 700 and 600 l ha^{-1} produced more than 50% mortality compared to 500 and 400 l ha^{-1}. Positive influence of EC on BPH population resulted in significantly higher yield loss (41.1%) compared to ambient (26.5%) in untreated check. Though LC_{50} under EC was less, higher canopy size and more BPH population resulted in increase in spray volume to cause similar mortality as of AC. The present results indicated that spray volumes of 400 and 500 l ha^{-1} was found insufficient to manage BPH population under EC; hence the current management strategies for BPH needs to be redefined under changing climatic conditions.

Keywords: Basmati rice, brown planthopper, climate change, elevated CO_2, insecticide.

ATMOSPHERIC CO_2 level has increased from 280 ppm during pre-industrial period to 400 ppm at present and Intergovernmental Panel on Climate Change (IPCC) projected it to reach 550 ppm by 2050 (ref. 1). Further by 2100, atmospheric CO_2 would reach 730–1020 ppm in the

*For correspondence. (e-mail: guruagri@gmail.com)