THE INTERNATIONAL SOCIETY OF PRECISION AGRICULTURE PRESENTS THE
13th INTERNATIONAL CONFERENCE ON
PRECISION AGRICULTURE
July 31-August 4, 2016 • St. Louis, Missouri USA

Assessing Soybean Injury from Dicamba Using RGB and CIR Images Acquired on Small UAVs

Yanbo Huang[1], Howard Brand[2], Dean Pennington[3], Krishna N. Reddy[1], Steven J. Thomson[4]

[1]USDA ARS Crop Production Systems Research Unit, Stoneville, Mississippi

[2]Virginia Polytechnic Institute and State University, Department of Mechanical Engineering, Blacksburg, Virginia

[3]Yazoo Mississippi Delta Joint Water Management District, Stoneville, Mississippi

[4]USDA NIFA Division of Agricultural Systems, Washington DC

A paper from the Proceedings of the
13th International Conference on Precision Agriculture
July 31 – August 3, 2016
St. Louis, Missouri, USA

Abstract. *Dicamba is an herbicide used for postemegence control of several broadleaf weeds in corn, grain sorghum, small grains, and non-cropland. Currently, dicamba-tolerant (DT) soybean and cotton are under development, which provide new options to combat weeds resistant to glyphosate, the most widely used herbicide. With the use of DT-trait cotton and soybean, off-target dicamba drift onto susceptible crops will become a concern. To relate soybean injury to different rates of dicamba applications, field experiments were conducted in 2012, 2013, and 2014 at the research farm of the USDA-ARS Crop Production Systems Research Unit in Stoneville, Mississippi, USA. For the experiments, thirty-two soybean plots were established on a 4.5 ha field of the research farm and, at the four-trifoliolate-leaf stage, treated with dicamba at six rates following a randomized complete block design with four replications. In 2014, five weeks after dicamba treatment, RGB color images were acquired with a GoPro camera on a small octocopter flying over the soybean field. Also, at one and half weeks and 10 weeks after dicamba treatment, RGB color images and near-infrared (NIR) images were acquired by a Canon digital camera and a customized Canon digital camera with NIR pass filter on a fixed-wing remotely controlled plane over the field. RGB color images and NIR images were stacked to generate color infrared (CIR) images of the entire soybean field. Vegetation indices, such as normalized difference photosynthetic vigor ratio extracted from the RGB images and normalized difference vegetation index from CIR images over the dicamba-treated soybean field,* *were highly correlated with soybean yield. A monotonic trend of the vegetation indices was also observed with increasing rates of dicamba. This study demonstrated that the RGB and CIR images acquired on small UAVs have a great potential in assessing crop injury from dicamba spray in the field.*

Keywords. *Soybean, Dicamba, Unmanned Aerial Vehicle, RGB, Color-Infrared.*

Introduction

Dicamba is an herbicide used for postemegence control of several broadleaf weeds in corn, grain sorghum, small grains, and non-cropland. Currently, dicamba-tolerant (DT) soybean and cotton are under development. DT crops provide new options to combat weeds resistant to glyphosate, the most widely used herbicide. Although the launch of DT-trait cotton and soybean is still pending approval of new dicamba formulations by the USEPA (U.S. Environmental Protection Agency, Washington DC), off-target dicamba drift from routine use in dicamba-resistant crops onto susceptible crops has been a concern. It can be predicted that, with the adoption of the DT crop system in the near future, the concern would be much greater with significantly increased numbers of dicamba drift complaints.

Remote sensing provides a cost-effective approach to detect changes in canopy spectral properties in crop injury from off-target herbicide spray. We have assessed crop injury from off-target drift of aerially applied glyphosate using aerial color-infrared (CIR) imagery for soybean, cotton, and corn (Huang et al., 2010, 2015). However, sub-meter spatial resolution of aerial CIR imagery limits the analysis and assessment of the crop herbicide injury (Huang and Reddy, 2015). Unmanned aerial vehicles (UAV) provide a platform that can carry imaging sensors to provide centimeter-level spatial resolution imagery with 3D stereo vision capability to better characterize the canopy over the crop field (Huang et al., 2009; Huang and Reddy, 2015). The purpose of the study was to characterize CIR properties of UAV imagery to relate image parameters to soybean injury with different doses of sprayed dicamba and investigate the potential of UAVs for precision weed management.

Materials and Methods

The field experiments were conducted in 2012, 2013, and 2014 at the research farm of the USDA-ARS Crop Production Systems Research Unit in Stoneville, Mississippi, USA (latitude: 33.445081^{o} and longitude: -90.869829^{o}). In 2014, the field experiment was conducted with thirty-two soybean plots established on a 4.5 ha field in the research farm. At the four-trifoliolate-leaf stage, soybean was treated with dicamba at rates of 0.0X, 0.05X, 0.1X, 0.2X, 0.3X, 0.5X, and 1.0X (X=0.56 kg ae ha^{-1}). The entire field was laid out in a randomized complete block design with four replications.

Five weeks after dicamba treatment (WAT), a series of digital RGB color images were acquired with a GoPro camera on a small octocopter flying over the field at an altitude of 45 m to offer a 2.8 cm pixel^{-1} ground resolution with a 95^{o} field of view low distortion lens. Selected images were geo-tagged and mosaicked to cover the entire field. At one and a half WAT and 10 WAT, digital RGB color images images were acquired by an unmodified Canon digital camera, and near-infrared (NIR) images were taken with a customized Canon digital camera with an NIR filter on a fixed-wing remotely controlled plane over the field at an altitude of 80 m, resulting in 4 cm pixel^{-1} ground spatial resolution. On both flights, selected RGB images and NIR images were geo-tagged, mosaicked, and stacked to generate CIR images of the entire field. Vegetation indices were extracted from the RGB and CIR images, including normalized difference photosynthetic vigor ratio (NDPVR) (Warren and Metternicht, 2005), normalized difference vegetation index (NDVI) (Rouse et al., 1973), and soil adjusted vegetation index (SAVI) (Huete, 1988). NDPVR is less popular than NDVI and SAVI, which are calculated from the green (Green) band and red (Red) band of the RGB images, while NDVI and SAVI are calculated from the NIR and red band of the CIR images, respectively, with 0.5 for soil brightness correction factor for SAVI.

Results and Discussion

Table 1 shows that, regardless of WAT, UAV type, and sensor/image type, all different indices are highly correlated with the soybean yield. This indicates that the high-resolution UAV image data performed consistently well in characterizing image features with the crop yield.

Table 1. Correlation of vegetation indices with soybean yield with different sensors/UAVs at different WAT.

Imaging Time (WAT)	UAV	Sensor	Index	Correlation with Yield
1.5	Fixed-Wing	Unmodified and modified Canon digital cameras	NDVI/SAVI	0.97/0.97
5	Octocopter	GoPro camera	NDPVR	0.98
10	Fixed-Wing	Unmodified and modified Canon digital cameras	NDVI/SAVI	0.97/0.97

Fig. 1 shows the relations of the vegetation indices to the spray rates of dicamba, which present consistently a monotonic trend of the vegetation indices with increasing rates of dicamba. This further indicates that the high-resolution UAV image data could perform well in assessing image features with the crop injury.

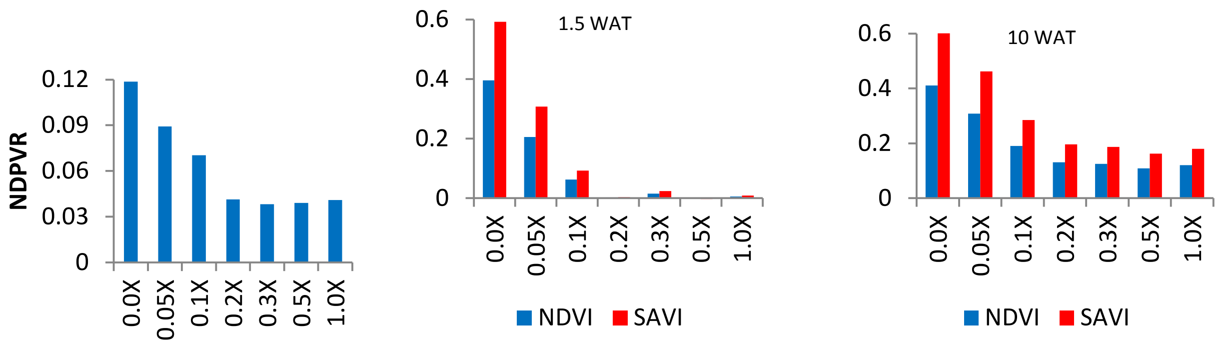

Fig 1. Vegetation indices vs dicamba spray rates (X=0.56 kg ae/ha).

Conclusion

This study demonstrated that the RGB and CIR centimeter-resolution images acquired on small UAVs have great potential in assessing crop injury from dicamba spray in the field.

Acknowledgements

Thanks to Mr. David Fisher for his calibration and operation of the octocopter imaging system in the field and post-processing of the RGB image data.

References

Huete, A.R. (1988). A soil-adjusted vegetation index (SAVI). *Remote Sensing of Environment,* 25,295-309.

Huang. Y., Thomson, S.J., Hoffmann, W.C., Lan, Y., & Fritz, B.K. (2013). Development and prospect of unmanned aerial vehicles for agricultural production management. *Int. J. Agric. Biol. Eng.* 6(3), 1–10.

Huang, Y., Thomson, S.J., Ortiz, B.V., Reddy, K.N., Ding, W., Zablotowicz, R.M., & Bright Jr. J R. (2010). Airborne remote sensing assessment of the damage to cotton caused by spray drift from aerially applied glyphosate through spray deposition measurements. *Biosystems Engineering,* 7, 212–220.

Huang, Y., Reddy, K.N., Thomson, S.J., & Yao, H. (2015). Assessment of soybean injury from glyphosate using airborne multispectral remote sensing. *Pesticide Management Science,* 71, 545–552.

Huang, Y., & Reddy, K.N. (2015). Unmanned aerial vehicles: A unique platform for low-altitude remote sensing for crop management. In Rao, A.N., & Yaduraju, N.T. (Ed.), Weed Science for Sustainable Agriculture, Environment and Biodiversity, Proceedings of the Plenary and Lead Papers of the 25th Asian-Pacific Weed Science Society Conference (pp. 185-192), Madhya Pradesh, India, Indian Society of Weed Science.

Rouse, J.W., Haas, R.H., Schell, J.A., & Deering, D.W. (1973). Monitoring vegetation systems in the great plain with ERTS. In: Proc. 3rd ERTS Symposium, NASA SP-351, Vol. 1, pp. 309-317, NASA, Washington, DC.

Warren, G., & Metternicht, G. (2005). Agricultural applications of high-resolution digital multispectral imagery: evaluating within-field spatial variability of canola (*Brassica napus*) in Western Australia. *Photogramm. Eng. Remote Sens.* 71(5), 595-602.