Using UAV-acquired multi-spectral imagery to detect potassium deficiency and susceptibility to green peach aphids in canola

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Key messages

- Potassium (K) deficiency in canola decreased yield by up to 47% on average.
- Using reflectance data acquired from a multispectral camera, plots of potassium (K) deficient versus K-sufficient canola were classified more accurately at 120 m above ground (65 mm pixel size) than at 15 m (8.1 mm pixel size).
- Green peach aphid populations were significantly higher on K-deficient than K-sufficient plants.
- Multispectral images acquired from unmanned aerial vehicles (UAVs) may be useful to detect regions of canola crops experiencing nutrient deficiency and allow for targeted fertiliser application and targeted crop scouting for pests.

Aims

1. To test whether canola canopy reflectance data acquired from a six-band multispectral camera could be used to classify (i.e. differentiate) K-deficient canola relative to K-sufficient.
2. To examine whether K-deficiency in canola increases susceptibility to green peach aphid infestations.

Method

Field plots

As part of a CSBP experiment at Williams, Western Australia, plots (2 m x 20 m) of Crusher TT canola were sown on Marri gravelly sandy loam on 22 May, 2014 in a randomized block design with three replicates of various K fertiliser treatments. Oats were sown in 2012 and 2013. Three K fertilizer regimes consisted of 0, 50 or 100 kg/ha Muriate of Potash (MOP; potassium chloride) applied each year for three years during 2012-2014. A fourth regime consisted of 400 kg/ha MOP applied in 2012 with no further applications in 2013 or 2014. Weeds were controlled using herbicides and registered rates of chlorpyrifos and bifenthrin insecticides were applied post sowing and prior to emergence. Basal fertilizer without K: 103 kg/ha Agflow Extra® (CSBP Limited; %w/w 12.7 N, 17.7 P, 5.6 S, 0.1 Cu, 0.2 Zn, 0.01 Mn) and 80 L/ha liquid urea ammonium nitrate (CSBP Limited Flexi-N®; %w/w 32 N comprised of 8 NO3, 8 NH4, 16 urea) were banded into the soil at sowing for all plots in 2014. NS41 fertilizer (CSBP Limited; %w/w 35 N, 0.6 P, 8.9 S) was spread on all plots at 200 kg/ha on 30 June, 2014. Soil (0-30 cm) and plant tissue (youngest mature leaf) nutrient analyses were conducted for all plots at day 69 (4-8 leaf), 96 (stem elongation/budding) and 113 (early flowering) after sowing (DAS), and plots were harvested for seed yield.

Multi-spectral imaging and analyses

A Tetracam MCA6 multi-spectral camera was mounted under an eight-rotor remote controlled unmanned aerial vehicle (UAV), and images were acquired at 15 m and 120 m above ground at 69, 96 and 113 DAS. The 15 m and 120 m imaging heights equated to 8.1 mm and 65 mm pixel sizes, respectively. The camera recorded reflectance (10 nm bandwidth) for the following wavelengths: 490 (blue), 560 (green), 680 (red), 720 (near infrared; NIR), 800 (NIR) and 900 (NIR) nm. Average reflectance profiles were extracted from pixels in each plot, and stepwise discriminant analyses with five-fold cross validation were conducted for each combination of image date (69, 96 and 113 DAS), height (15 m and 120 m) and K treatment (K-deficient and K-sufficient). Normalised difference vegetation indices (NDVI) and leaf area indices (LAI) were calculated, using each plot divided into three subplots, to compare between K-deficient and K-sufficient treatments.

Green peach aphid infestation

At 113 DAS, all plots had become naturally infested with green peach aphids, and aphid counts were conducted on 50 whole plants per plot sampled in 5 x 10 randomized block design. Aphid data for the four K fertiliser regimes were compared using analysis of variance.

Results and discussion

Potassium deficiency

Of the four K fertiliser regimes, only the 0 kg/ha MOP treatment showed deficiency according to soil and plant tissue nutrient tests and plot yields (Table 1) (Brennan and Bolland 2007, Anderson et al. 2013).

Table 1. Potassium (Muriate of Potash; MOP) fertiliser treatments applied per year during 2012-2014, soil and plant tissue K test results for 69 days after sowing (4-8 leaf) and final canola yields ± standard error of the mean.

MOP (kg/ha)	Soil K (mg/kg)	Plant K (%)	Yield (t/ha)
0	39.0 ± 6.1	1.68 ± 0.08	0.91 ± 0.05
50	57.3 ± 9.6	3.89 ± 0.17	1.73 ± 0.05
100	83.0 ± 19.9	4.68 ± 0.25	1.67 ± 0.06
400 (2012 only)	60.7 ± 3.2	4.17 ± 0.01	1.65 ± 0.06

Classification of canopy reflectance data

Using all pixels within images, K-deficient plots were more accurately classified at 120 m than at 15 m (Table 2). The highest classification accuracy was 99.9% at 120 m height and 113 DAS. Combining data from image dates (e.g. 69 + 96 DAS) reduced classification accuracies by approx. 15 %, indicating that temporal extrapolation is relatively inaccurate, so assessments for heterogeneity of K-deficiency in canola crops is best achieved on individual dates.

Table 2. Classification accuracies of multi-spectral imagery for K-deficient canola plots, relative to K-sufficient plots, at 69 (4-8 leaf), 96 (stem elongation/budding) and 113 (flowering) days after sowing.

Image date	15 m	120 m
Days after sowing	% accuracy	% accuracy
69	84.4	92.0
96	81.6	98.9
113	82.4	99.9

The amount of ground area covered by each image differed considerably between 15 m and 120 m imaging heights (Fig. 1). The 120 m images contributed the most reliable classification accuracies; this is advantageous because much less effort is required in the image processing workflow compared to 15 m images.

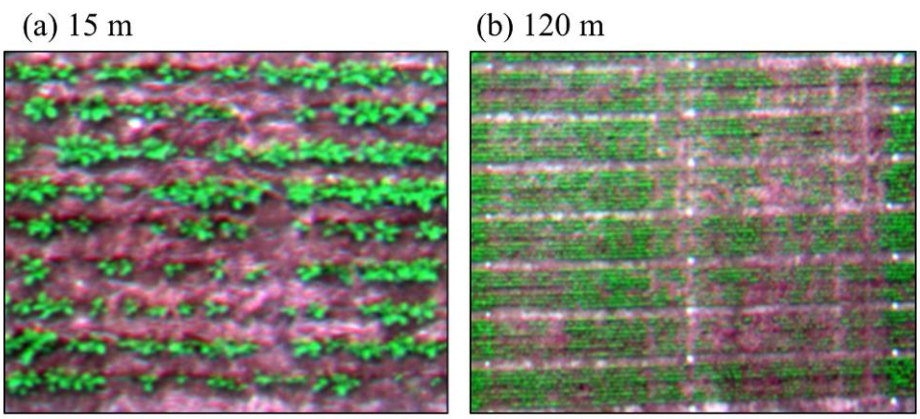

Figure 1. Images of 4-8 leaf canola plots (69 days after sowing) acquired at 15 m (a) and 120 (b) m above ground.

NDVI versus LAI

When LAI and NDVI values were plotted, it was apparent that increased LAI was strongly associated with increased NDVI regardless of imaging date and treatment (Fig. 2). Furthermore, much higher LAI and NDVI values were evident at 96 DAS compared to 69 DAS because more vegetation cover existed as plants were more advanced. However, most K-deficient subplots were lower in LAI and NDVI when compared to K-sufficient subplots for both 69 and 96 DAS.

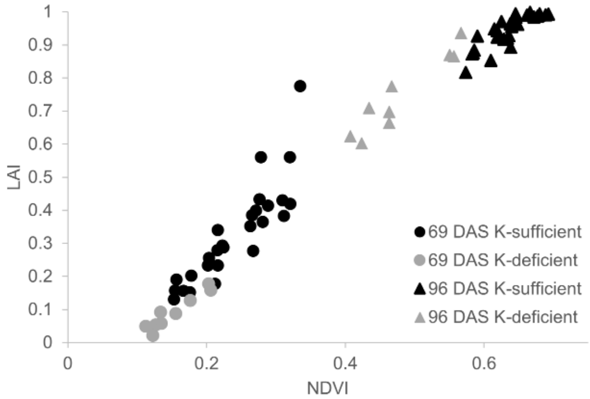

Figure 2. Leaf area indices (i.e. area of vertical leaf cover) versus Normalised difference vegetation indices (NDVI) for 120 m images at 69 (4-8 leaf) and 96 (stem elongation/budding) days after sowing (DAS) for K-deficient and K-sufficient treatments.

Green peach aphids

Green peach aphids were significantly higher in density within K-deficient plots (i.e. 0 kg/ha potash treatment) than K-sufficient plots (all other treatments) (Fig. 3a). Furthermore, it was found that canola plants containing lower amounts of K in plant tissue corresponded with higher concentrations of N in plant tissue (Fig. 3b). This indicates that N is under-utilised in plants deficient in K, and increased N concentrations may contribute to increased green peach aphid populations (Van Emden et al. 1969).

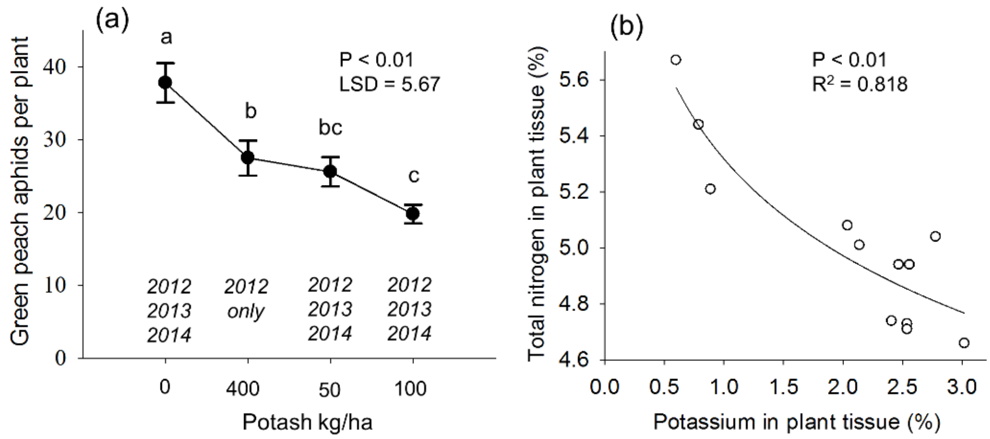

Figure 3. Average green peach aphids per K fertiliser regime with like letters indicating like means and least significant difference (LSD) between means at P<0.01 (a), and the correlation between plant tissue K and total plant tissue N for each plot (b).

Conclusion

The study supports findings that UAV-acquired multi-spectral imagery has potential to identify crop regions containing nutrient deficiency and likely increased performance of arthropod pests. Potassium deficiency caused increased concentrations of nitrogen in youngest mature leaves, an increase in green peach aphid numbers, a decrease in vegetation cover (LAI), a decrease in NDVI and a decrease in canola seed yield. It is anticipated that mapped field regions displaying significant reductions in LAI and NDVI may be targeted for on-ground inspection for nutrient deficiency and early detection of pests.

References

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Key words

UAV, multispectral imagery, canopy reflectance data, canola, green peach aphids

Acknowledgments

Appreciation is extended to Lloyd Groves, Genping Zhao, and UWA students for field technical support. Thanks also to CSBP for access to and maintenance of the trial site and analysis of soil and plant tissue samples. This research was funded by the Grains Research and Development Corporation and the Department of Agriculture and Food Western Australia.

GRDC Project Number: UWA00158

Paper reviewed by: Professor Raphael Didham, The University of Western Australia