



**Australian Government**

**Cotton Research and  
Development Corporation**

# FINAL REPORT

## ***Part 1 - Summary Details***

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Please use your TAB key to complete Parts 1 & 2.

**CRDC Project Number:** **CRDC1729**

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**Project Title:** **Verticillium Wilt Assessment using Drones**

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**Project Commencement Date:** 01/07/2017 **Project Completion Date:** 30/06/2017

## ***Part 2 – Contact Details***

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## ***Part 3 – Final Report***

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(The points below are to be used as a guideline when completing your final report.)

### ***Background***

Diseases of cotton pose a significant reduction to maximum cotton production, with pathology capacity and research has been identified as a key investment area. Verticillium wilt (VW), which is caused by the soil-borne fungus *Verticillium dahliae* Kleb, causes substantial economic losses in cotton. This disease is one of the most important biotic yield limiting factors for cotton in several growing regions in NSW. VW is of growing concern for cotton production because of its increasing severity, which can be associated with changes in cropping practices implemented to increase cotton yields. These changes include use of reduced or no tillage, irrigation practices and high inputs of fertilisers in fertile soils.

Management of VW is difficult for many producers and requires multiple management tactics to be implemented. Current management strategies, such as rotating cotton with a non-host followed by bare fallow are not reducing the impact of VW sufficiently, presents increasing concern.

To be able to understand the influence of environmental conditions and farming practice on disease development and to improve the use of available management tools, it is necessary to be able to detect early infection of cotton by the pathogen in the field. Detection of infected cotton by visual inspection is a time-consuming and onerous exercise.

Alternatively, tools available such as remote sensing, have been used successfully by researchers overseas to detect disease symptoms in various crops. These trials have proven to be a useful decision support system for crop management.

In combination with powerful data analysis methods, remote sensing becomes a tool for integrated disease management. Remote sensing has successfully been used to detect early symptoms of infection of VW in olive (Spain) and *Phymatotrichum* root rot in cotton (USA), enabling airborne multispectral imagery for detecting and mapping areas of disease in fields for site-specific management of the disease. Site-specific management included irrigation management and soil solarisation of “hot spots” for VW, and fungicide application in areas infected with root rot.

Strategies to manage VW are currently being investigated in CRDC funded project RRDP1724 “Improving the management of cotton disease in Australian Cotton farming systems”. A field trial is currently being conducted on a property east of North Star in NSW. This trial is being used as a platform to evaluate the potential of Drones (UAVs) to detect early symptoms of VW development.

### ***Objectives***

The primary aim of this project is to determine whether inexpensive Drones (UAVs) can be used to detect and define early stage VW in cotton. This scope of the project also specifies that equipment used must be easy to operate and be readily available to the farming community. To satisfy these criteria, this project used Red Green Blue (RGB) images obtained from a Phantom 3 Professional drone. Near Infrared (NIR) and multispectral analysis were outside the scope of this project.

Project requirements also specify that locations of VW affected plants must be determined.

### ***Methods***



**Figure 1: Field 6**

The aim of the trial is to determine whether Drones (UAVs) can be used to detect Verticillium Wilt in cotton. The trial was conducted at North Star/Yetman Road about 7.5 km east of North Star. The field used is field 6 (-28.96027, 150.617166) and is approximately 96 ha (Figure 1).

To obtain the high spatial accuracy required in this trial, Ground Control Points (GCPs) were installed and surveyed. They were positioned around the paddock boundary, serving as a known reference point and ensuring data was spatially accurate. A

total of 16 GCPs were installed.

Flights were conducted using the Pix4D mapper app, a commonly available free aerial surveying app. This app is known as a ground control station (GCS), it controls the flight path, image capture, camera setting and overlap. Overlap was set to 70% front 60% side; white balance was set to auto. Western Aerial Mapping (WAM) flew the trial site 6 times; 14 Feb, 17 Feb, 8 March, 10 March, 28 March and 13 May 2017. Raw data collected from each flight was processed and a geo-referenced orthomosaic was generated.

Ground truth photos, collected by Dr Linda Smith and her team (ground team), were used as a guide to help the WAM team identify VW characteristics. Using these characteristics and the expertise of the ground team, VW examples were identified, in orthomosaic, and a training sample was created from these examples. VW symptoms were relatively dormant until roughly 10 and 28 of March. It is for this reasons that training samples and results were only obtained from these dates.

A total of 150 and 59 training samples were generated for 10 and 28 March respectively. A machine learning classifier was then conducted on Red Green Blue (RGB) orthomosaic to identify VW. Using the training samples three main features were differentiated:

1. VW affect plants (dark grey)
2. VW unaffected plants (medium and light grey)
3. Ground (white)

### ***Results, Discussion and Outcomes***

Given the nature of aerial photography VW can only be observed if it is expressed in the canopy. Flights conducted on 14<sup>th</sup> Feb, 17<sup>th</sup> Feb and 8<sup>th</sup> of March appear to have no canopy expression of VW and machine learning was not applied to these datasets. These observations are consistent with findings of the ground team. However on flights conducted on the 10 and 28 of March, VW was successfully identified.

VW has been identified in results from the 10 March onwards. VW expressions seem to appear as a yellowing of the leaves (Figure 2). Among the yellowing reddening/browning can be observed, which is consistent with training samples and observations of the ground team. Yellowing is the dominant colour and seems to be an early stage expression of VW. This spectral change is a clear indication of “stress” and is being used as an indicator of VW.

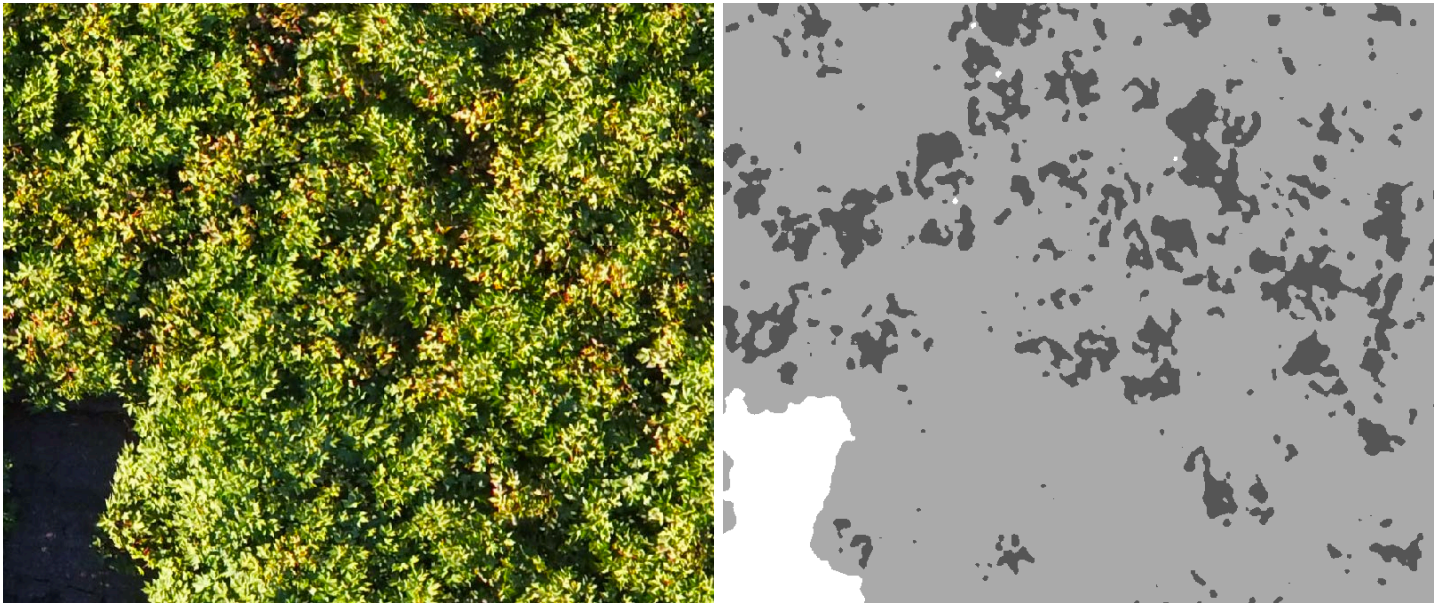


Figure 2: Mosaic and Classifier example. Flight 10 March 2017

Results from the 10 and 28 March have been separated into three categories (Figure 2):

1. VW symptoms (dark grey)
2. Unaffected VW (medium/light grey)
3. Ground (white)

Results from the 28 March seem to express significant evidence of VW. Redding and browning are the significant colour associated with this evidence with occasional yellowing as well. These symptoms are evidence of late stage VW. These results are also consistent with the findings of the ground team.

Variation in spectral appearance appeared to be the most definable feature to identify VW. More useful forms of spectral analysis, such as Near Infrared (NIR) and multispectral analysis could shed more light, however these platforms were not used as they were outside the scope of this project.

Although the findings and results from this project are extremely encouraging, WAM would caution farmers, agronomists or researchers not to rely on the results to provide a causal relationship to VW. The work conducted thus far is more an indicator of stress. In this project there is a strong correlation between plant stress and VW. Expressions of stress, which were used to identify VW affected areas, in cotton are not always caused by VW. Further work needs to be conducted to make

these findings more robust and ensure these results can be replicated across other datasets (transferred learning).

### *Issues of the Project*

A significant issue within the project was the considerable difficulty in generating the orthomosaics. This was due to a variety of factors, however the majority of the issues were surrounding overlap, wind and white balance. Given the limited flight time of Phantom 3 Professionals a high number of individual flights were required to survey the entire trial area. These individual flights must be manually created and this process can cause human errors in overlap from one flight to another. These overlap errors can cause significant issues in orthomosaic generation. Gaps found in the data can be attributed to these errors. To overcome these issues, future flights should be done with greater overlap, 80%+ forward and 70%+ side. More



**Figure 3: Evidence of white balance issue**

sophisticated GCS do not have these issues, as overlap between individual flights are accounted for in the software.

Wind can cause branches and leaves to move. This movement can cause errors in feature identification across overlapping images and cause problems in orthomosaic generation. Wind was observed on 14 Feb and 8 March and is the reason why orthomosaics were unable to be generated on those dates. These errors are often mitigated when flying above 60m, however given the high-resolution requirements of VW identification and that effect on altitude flown, this project was extremely susceptible to wind. Whilst causing issues with some datasets, the wind has not affected the overall results of this trial. Early VW symptoms have been observed from the 10 March and late stage VW on the 28 March. Wind errors can be minimised by collecting data in calm conditions.

There was also an issue related to the white balance, which is expressed as purpling/blueing of the orthomosaic image (Figure 3). This is a known issue and is an insitu issue with the Pix4d mapper app and could be resolved with superior payloads and GCS. This blueing can affect the ability of the software to generate an orthomosaic. However, when an orthomosaic can be generated, this affect appears to have little effect on VW identification.

### *Future Research*

This project has identified VW from aerial orthomosaics. For the project to become commercially viable, further testing needs to be completed to ensure transferred learning is applicable to other VW datasets. Meaning that the algorithm developed is able to detect VW in other paddocks, scenarios and datasets.

Given the parameters and requirements of this trial, orthomosaics have been analysed for VW. This ensures maps generated are spatially accurate, highlighting exactly where VW is found in the paddock.

Analysing orthomosaics for VW does have limitations which are caused by the fundamental way orthomosaic's are generated. Orthomosaics are generated by correlating common pixels across overlapping images and creating a 2/3D map of the area. As part of this process high spatial accuracy is achieved but image resolution is lost. This means less obvious signs of VW cannot be detected (Figure 4) and that significant features such as leaf analysis cannot be performed.



**Figure 4: VW Ground image**

Further research on identifying VW through spectral analysis, needs to be conducted as RGB spectral analysis does have limitations. Success has been found overseas in using multispectral imagery to identify VW in Olive groves. Given that variation in spectral appearances seems to be the most definable feature to identify VW, it would be recommended investigating the use of these cameras for VW cotton detection. WAM suggests investigating the use of near-infrared (NIR) and multispectral cameras, as they may provide better results when detecting plant stress. However, like the results in this trial, it is suspected this analysis will have limitations in defining a causal relationship to VW.

There are possible research alternatives which may help detect VW directly from aerial imagery. It is suggested investigating one of two methods; hyper-spectral analysis or high definition RGB image analysis. Hyper-spectral analysis could be used to determine if there is a unique VW spectral signature.

Alternatively, machine learning and AI could be used to detect VW in raw high resolution RGB images rather than orthomosaics. In this case high resolution refers to <0.5cm GSD. This increased resolution may allow the identification of early stage VW through the analysis of leaf features.

Leaf Analysis would also be another area to investigate, as it is a key symptomatic indicator of VW. The signature brown, red, yellow and green leaf features could be identified and a direct VW identified (Figure 4). Raw drone images could be analysed and it is suspected that less obvious signs of VW would be detectable,

through the gain in image resolution. VW locations could be estimated, using geo-registration, however, this would not be as spatially accurate as a geo-referenced orthomosaic.

### *Key Learnings*

- Can only detect VW if it has canopy expression
- 80% overlap front, 70% side
- Don't fly in wind
- Consider using superior payload then Phantom 3 Professional Camera

### *Budget*

The funding allocated to this project was spent on data processing and data acquisition. This is consistent with the projects budget items. However, WAM considerably underestimated the time required to deliver results. WAM has adjusted the actual budget spent and this additional time was added to it's in kind contribution. See the budgeted and actual project summary in Appendix 2.

### *Conclusion*

During this trial, areas of the paddock containing early and late stage VW were detected using inexpensive equipment that is available to farmers. VW affected plants were identified by the visible 'stress'. The reality is that these stresses can be caused by a variety of factors, including VW. More research needs to be conducted to increase the robustness of this analysis and ensure that VW identification can be replicated across many datasets. This research will be required before farmers and agronomists can consider this system as a commercial VW detection tool.

Possible research alternatives were also discussed. These methods include detecting VW using high-resolution RGB, NIR, multispectral and Hyperspectral analysis.

Given the scope and objectives of this project, early stage VW does appear to be detectable from aerial images. The CRDC should consider the continued development of this system from both a farmers' perspective or as a tool to help research projects quantify the VW infection in paddock

