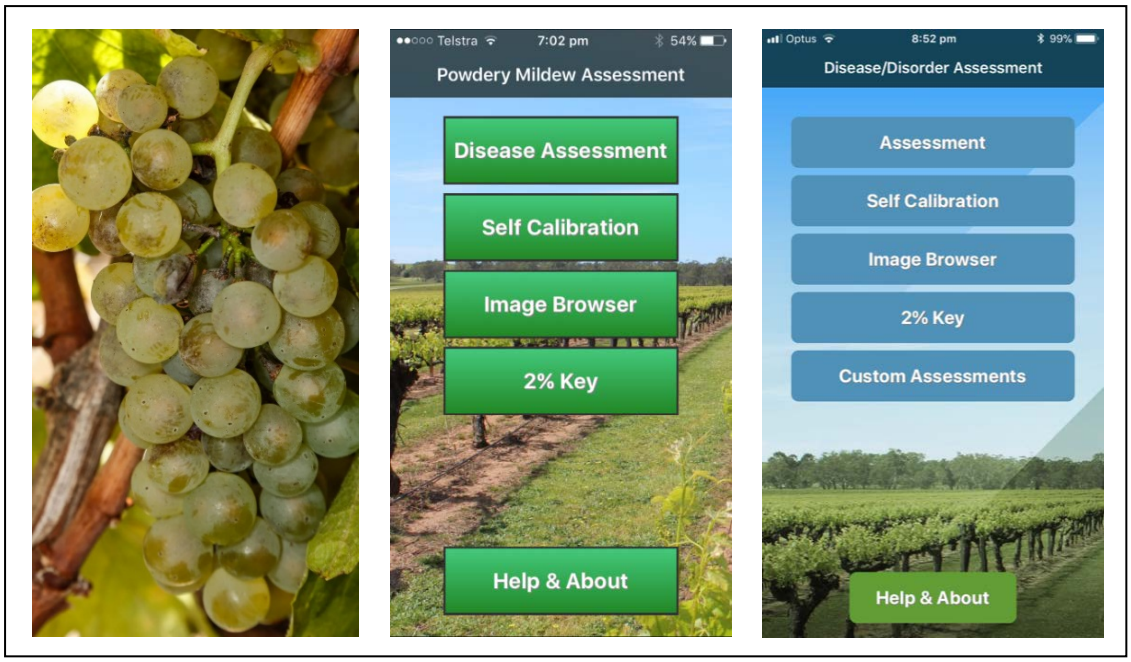
Australian Government

Wine Australia

THE UNIVERSITY of ADELAIDE

UPDATING PMAPP, SMARTPHONE APPLICATION FOR ASSESSING POWDERY MILDEW



FINAL REPORT TO WINE AUSTRALIA

Project Number: **UA1703**

Principal Investigator: **Prof. Eileen Scott**

Research Organisation: **The University of Adelaide**

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Updating PMapp, smartphone application for powdery mildew

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Table of Contents

1. Abstract ……..5
2. Executive summary ……..5
3. Background and aims…….....6
4. Methods ……7
5. Results and Discussion ……7
6. Conclusions and recommendations ……11
7. Appendix 1. Communications ……....11
8. Appendix 2. Intellectual property ……..13
9. Appendix 3. References ……...13
10. Appendix 4. Staff ……14

1. Abstract

Diseases, pests and disorders can compromise the yield and quality of grape harvests. A smartphone application, PMapp, was developed in project UA1202 to facilitate visual estimation of powdery mildew severity on bunches. In response to requests from users, the GPS capability was improved to allow more accurate recording of latitude and longitude. Also in response to demand, the assessment component of PMapp was expanded to allow the user to record in-field assessments of other conditions and to customise the assessment screens, in a new app, Grape Assess. The resulting apps, for Apple and Android systems, were released in June 2018 following evaluation by the Project Steering Group.

2. Executive summary

Diseases, insect and vertebrate pests, and disorders can compromise the yield and quality of grape harvests and have the potential to cause considerable loss to the Australian grape and wine sector. Powdery mildew, downy mildew and bunch rot together have been estimated to cost the sector $191 million per annum. Many Australian wineries set thresholds for contamination of grape consignments caused by diseases and pests, commonly 3-5%, above which consignments may be downgraded or rejected. In the absence of widely applicable objective measures, such assessments are typically based on visual inspection in the vineyard and/or at the winery. An application for smartphones and tablets, PMapp, and a supporting website were developed as part of project UA1202, Objective measures for powdery mildew, with the aim of improving the accuracy and reliability of visual assessment of powdery mildew on bunches. These resources have been available since the 2015-2016 growing season.

Feedback from users of PMapp indicated that the tool was useful and generally well-received, but that the GPS (global positioning system which records latitude and longitude) was insufficiently accurate to provide the level of detail required by some assessors. Furthermore, the app was being used to assess diseases and disorders other than powdery mildew. The research reported in this document was undertaken to (i) improve the accuracy of the GPS component of PMapp and (ii) create a new app with expanded capability to allow users to record assessments of conditions other than powdery mildew.

The settings of the upgraded PMapp and the new app, Grape Assess, are such that the GPS offers accuracy of approximately 10 m, although this can depend on location. The additional features of Grape Assess are based on discussions with members of the Project Steering Group, the recommendations contained in the final report for project UA1202 and the quantum of funding available. Grape Assess provides the four components of PMapp, namely; (i) assessment data entry, (ii) image browser, (iii) self-calibration test for visual assessment and (iv) a diagrammatic key with 2% increments in the range 2-12% severity. The computer-generated images used in components ii-iv were designed to reflect the distribution of powdery mildew on grape bunches. The user is able to select from a built-in list of assessments and/or to customise assessments according to the condition and vine part being assessed, the severity categories required and the background colour for the buttons on the assessment entry screen. Grape Assess is linked to the online powdery mildew assessment resource at pmassessment.com.au. The detailed guidelines for use have been updated to reflect the new capabilities; in particular, a section on visualising the vineyard assessment has been added and codes prepared using the free computer software, R, made available on request. The updated PMapp and Grape Assess were made available globally as free downloads for Apple and Android devices in June 2018.

Outcomes have been communicated through the Project Steering Group, and users of PMapp will be prompted to update this app and to consider downloading Grape Assess. A presentation to industry is planned in the coming months, as are publications in industry and scientific journals; the short time-frame of the project limited such communications before submission of this report. PMapp and Grape Assess are or will be used in teaching viticulture and oenology students at the University of Adelaide, the University of Tasmania and Charles Sturt University.

Wine Australia and the School of Agriculture, Food and Wine of the University of Adelaide provided financial and in-kind support. Collaborators include RW Emmett Horticultural Pathology Research, the Tasmanian Institute of Agriculture, Accolade Wines and Lemur Software. This project benefited from an engaged and enthusiastic Project Steering Group that comprised personnel of large and small wine sector companies, research organisations and Wine Australia.

3. Background and aims

Diseases such as powdery and downy mildew and bunch rots, if not adequately controlled, can reduce yield and quality of grapes and the resulting wines. A report commissioned by the Grape and Wine Research and Development Corporation in 2008 estimated that powdery mildew, alone, costs the Australian wine industry $76 million per annum in terms of increased cost and reduced income (Scholefield and Morison 2010, Wine Australia project GWR08/04). Downy mildew and bunch rots were estimated to account for another $115 million and a range of other diseases and pests, a further $59.5 million. Powdery mildew and bunch rots, in particular, are well-documented to reduce to the quality of grapes for making wine (e.g. Stummer et al. 2003, 2005, Calonnec et al. 2004, Gadoury et al. 2007, Scott et al. 2010, Steel et al. 2013).

Many wineries in Australia have thresholds for powdery mildew, downy mildew, botrytis rot, insect and bird damage on grape bunches which are based largely on visual inspection and typically set at 3-5% (Iland et al. 2014). Such thresholds may be based on severity (the percentage of the bunch surface area affected) or incidence (percentage of bunches affected of the number of bunches assessed) (Seem 1984, Nutter et al. 1991). However, the assessment criterion (incidence or severity) is not always clearly articulated in contractual negotiations, potentially leading to misunderstandings. Consignments of grapes that exceed the threshold specified by the winery may be downgraded or rejected.

A smartphone application, PMapp, was developed as part of Wine Australia project UA1202 to facilitate visual assessment of powdery mildew on bunches (Birchmore et al. 2015). PMapp was released in Australia in December 2015 and globally in November 2016, as a free download from the purpose-built supporting website www.pmassessment.com.au or directly from the Apple iTunes Store and Google Play (Scott et al. 2016). The original app consisted of four components: (i) an assessment screen for entering observations of powdery mildew severity; (ii) an image browser containing 139 images of computer-generated bunches with various areas shaded to represent the distribution of powdery mildew on berry surfaces and to assist with area assessment; (iii) a self-calibration function which allows the user to test his/her ability to assess area shaded on the computer-generated images; and (iv) a diagrammatic key which features 2% increments in the range 2-12% severity (Emmett et al. 2015, 2016, Scott et al. 2016, 2017). On completion of an assessment, the user would email the results to him/herself or a supervisor; the results would appear in an Excel spreadsheet with coordinates for latitude and longitude (via GPS, global positioning system) for each data point (severity value) entered. GPS accuracy had been set to provide reasonable accuracy while avoiding excessive drain on the battery of the device. The app also included detailed guidelines for use and a link to the website pmassessment.com.au, which provides support for assessment of powdery mildew in the form of (i) a vineyard best practice guide; (ii) training in recognition of powdery mildew symptoms and signs on bunches of white and black grapes and (iii) an area assessment training tool (Scott et al. 2016, 2017). Further details about PMapp and the supporting website can be found in Scott et al. (2016).

PMapp had been downloaded over 2700 times by May 2017, 60% of these downloads being in Australasia (Scott et al. 2017). Feedback received from wine sector users and would-be users was that the GPS settings in the version of PMapp released in 2015 and 2016 were not sufficiently accurate to allow inferences to be made about the distribution of disease in the vineyard.

Also, feedback from users indicated that PMapp was being used to record assessments of grape diseases, pests and disorders other than powdery mildew. It was therefore proposed to create a new, offshoot app with expanded functionality to cater for this more effectively. Creating a new app offered the opportunity to allow the user to customise the assessment (data entry) screen. These improvements would provide an app which was more broadly applicable and user-friendly, while retaining the original PMapp for users who required only an upgrade of the GPS capability. Expansion of PMapp had been foreshadowed in the recommendations section of the final report for UA1202 (Scott et al. 2016).

The aims of the current project were to:
Update and improve PMapp

- Increase the accuracy of the GPS function of PMapp, with instructions for users for simple mapping of a vineyard assessment (e.g. grid-map in Excel).
- Upgrade the Android version of PMapp to comply with operating system guidelines. Update all logos and place on the home page/welcome screen of PMapp.

Develop a new app, derived from PMapp, for assessment of multiple grapevine disorders

- Expand the functionality of PMapp to record assessment of multiple diseases and disorders (powdery mildew and, e.g. bunch rot, downy mildew, insect damage, sunburn), as well as the part of the vine that is being assessed.
- Allow the user to configure the assessment screen of the app to show only the buttons he/she uses regularly for a given disease or disorder.

4. Methods

Members of the Project Steering Group established during project UA1202 were consulted about the plans for upgrade. This group comprised representatives of wine companies, including disease assessors, independent consultant disease assessors and researchers, and members provided valuable guidance and feedback.

4.1 Update of PMapp. Feedback from users of the original PMapp that the accuracy of the GPS coordinates needed to be improved, albeit with resulting drain on the battery of the device, was discussed with members of the Project Steering Group and with Wade Perry of Lemur Software, who built the original app. Mr Perry undertook to adjust the settings to improve the accuracy of the GPS coordinates and make a prototype available for testing. Dr Olena Kravchuk undertook to write a paragraph about the use of the GPS data for inclusion in the Guidelines for use. Mr Perry also updated the Android version to comply with operating system guidelines.

4.2 Development of new application. The recommendations provided in the final report for project UA1202 relating the original version of PMapp were considered and two were deemed achievable within the current project, *viz*. (i) the severity assessment screen can be customised so that frequently-used buttons stand out; (ii) develop materials for parallel assessment of various diseases (e.g. bunch rots, leaf powdery and downy mildew) and disorders (e.g. sunburn, bird damage). Due to resource limitations, it was decided to prepare additional assessment screens which could be customised to display different background colours and severity categories. However, new computer-generated images to show entire berries affected (to reflect bunch rots) and area affected on leaves and other plant parts would not be created; rather, the bunch images shaded to represent powdery mildew would be retained for guidance about area affected by any condition. Requirements and feasibility were discussed with Mr Perry and a prototype was developed for testing.

4.3 Administrative aspects. Outputs and activities were delayed due to changes in the requirements of both app platforms, the need to revise the University of Adelaide's agreement with Apple, changes in personnel in the University's Research Applications Development group and the onset of vintage 2018 before the upgrades had been completed. Furthermore, the disbanding of Adelaide Research and Innovation, which owned the original application, and reassignment of its responsibilities required negotiation with Apple. Ms Kiara Bechta-Metti, Director, Adelaide Enterprise, and Mr Stephen Hardy, University of Adelaide Business Partnerships Specialist, assisted with negotiations and resolution of intellectual property issues, and Mr Tim Peters assisted with information technology matters.

Current logos were sought from the relevant participants for use in the apps. Plans or prototypes for use of the logos were then submitted to the respective organisations for approval before the apps were finalised.

5. Results and Discussion

The accuracy of the GPS coordinates was adjusted to the maximum possible and the amended PMapp made available first to Mr Perry's group of generic testers then to the project team for testing. The accuracy was deemed fit for purpose and these settings were used in the new, offshoot app.

The prototype of the new app, named Grape Assess, was tested by members of the project team and feedback on design and features was provided to Mr Perry. After a few iterations, the revised app was made available to the Project Steering Group via the platform TestFlight for beta-testing. The Steering Group met on 20 March 2018 to discuss and review the features of Grape Assess. Although the group was depleted due to vintage commitments, those who did attend had tested the app in the field and provided invaluable feedback. The GPS, which provides accuracy to approximately 10 metres, was deemed fit for purpose. A list of actions was drawn up, agreed and all actions were implemented as quickly as possible.

Grape Assess allows the user to access the severity categories used in PMapp for powdery mildew or to set up new customised assessments (Fig 1a). Setting up a new assessment via the Assessments screen allows the user to select from a built-in list (comprising powdery mildew, downy mildew, bunch rot, insect damage and sunburn) (Fig 1b,c) or to use the free text entry option. Likewise, the user can select the part of the vine being assessed from a built-in list (leaf, berries, trunk and roots) or use the free text entry option. The number of plant parts to be assessed per stop is also entered as free text. The heading displays the condition being assessed and the background colour varies with the assessment topic, but severity categories displayed are those of PMapp, namely increments of 1% in the range 1 to 10% then larger increments thereafter (Fig 1d). The Custom Assessments screen (Fig. 1e) allows the user to select the background colour and categories of severity to be used (Fig. 1f). The Image Browser, Self Calibration and Key components are included to provide guidance about area assessment; detailed descriptions of these components were provided in the final report for project UA1202 (Scott et al. 2016). A link to Grape Assess has been added to the online resource at pmassessment.com.au.

The detailed Guidelines for use that were provided with PMapp version 1 were amended to take into account the new features. Guidelines for both apps include a new section about use of the GPS data, along with two examples of how the spatial information might be visualised. These examples (see Fig. 2) were prepared by Olena Kravchuk and Peter Kasprzak using PMapp and the open-source software R; the code is provided in appendix 7 and is available to users of the apps through the contact email address provided in the app (namely research@wineaustralia.com) or directly by email to biometryhotdesk@adelaide.edu.au. Although the current GPS resolution does not allow the user to distinguish between individual vines over a short distance, the number of sampling points in each grid permitted by the resolution can be added graphically as labels or colours. The Guidelines for Grape Assess also include instructions for customising assessments.

Branding has been improved, such that the apps open with a “splash screen” which displays the logos of Wine Australia, The University of Adelaide, RWE Horticultural Pathology Research and the Tasmanian Institute of Agriculture. The splash screen is displayed for 5 seconds, then disappears to reveal the components of the app.

The versions of Grape Assess for iOS (Apple) and Android format were prepared in tandem, and were approved and released globally in June.

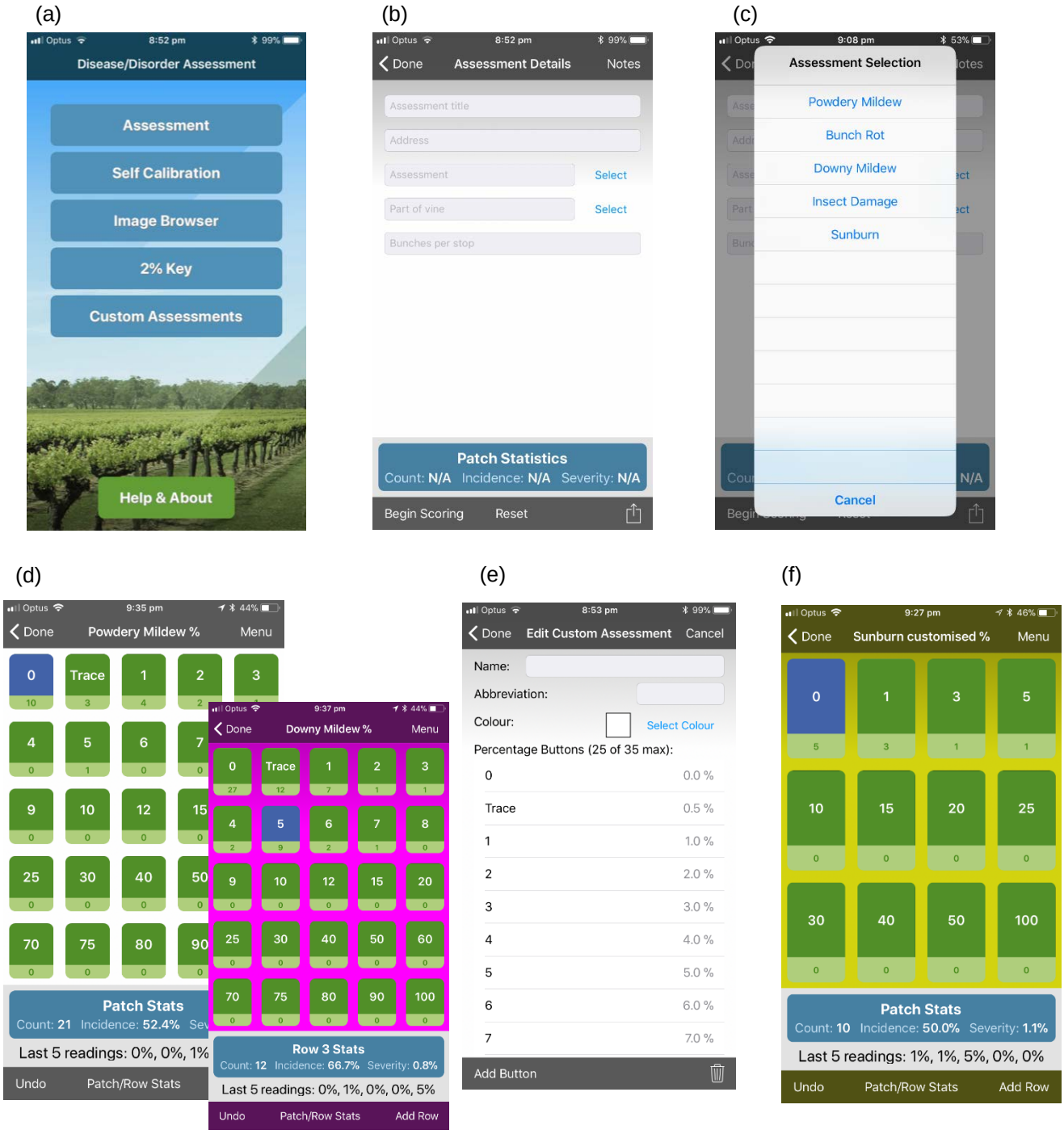
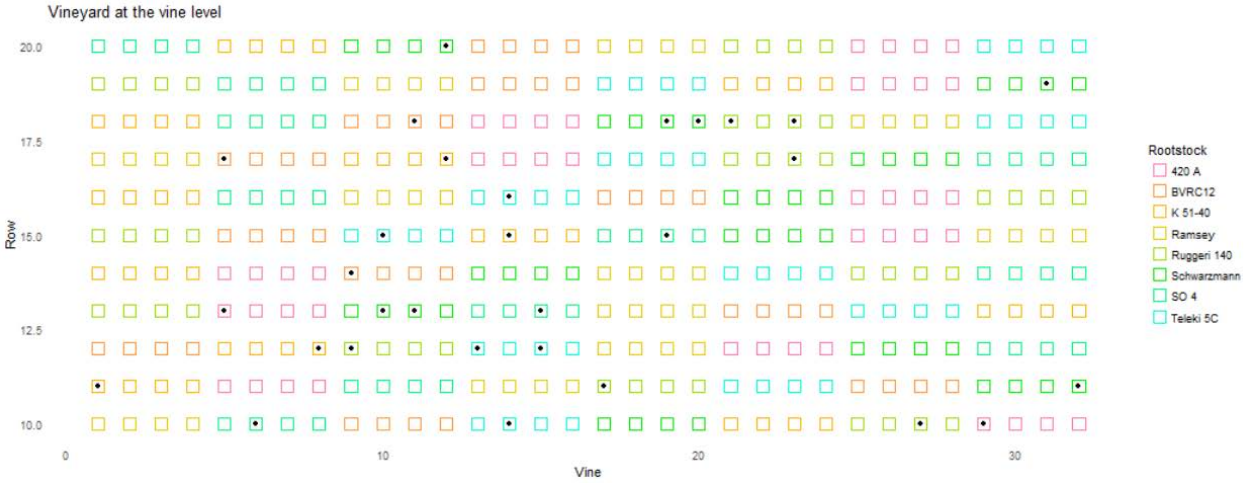


Figure 1. Screen-shots from Grape Assess; (a) home screen, (b) assessment options, (c) built-in list of assessments, (d) standard assessment categories for powdery mildew (left) and downy mildew (right), (e) options for customising an assessment (select categories from range displayed in d), (f) example of a customised assessment for sunburn displaying selection of yellow background and 12 of the 25 possible severity categories.

(a) Vineyard Row Vine Sampling



(b) Vineyard GPS Regular Grid Sampling

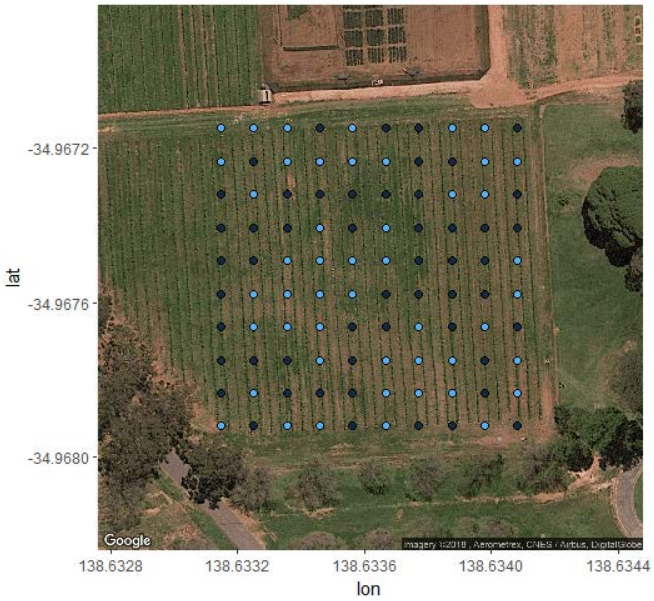


Figure 2. Examples of visualisation of spatial data collected in the Coombe Vineyard, Waite Campus, using the improved GPS capability; (a) Vineyard Row Vine Sampling, in which the sampling points are indicated for individual vines. This type of visualisation is suitable for assessment of small patches, (b) Vineyard GPS Regular Grid Sampling, in which the sampling points are presented with the current 10-m resolution on a regular grid in the same vineyard. Different colours indicated the presence/absence of a condition of interest.

6. Conclusions and recommendations

The updated PMapp and the new Grape Assess applications offer improved capability for in-field assessment of powdery mildew and a range of other diseases, pests, disorders and conditions. Both apps are available, free, for use on Apple and Android devices and have detailed guidelines to assist new users. Both are available from and link to the online resource (pmassessment.com.au) developed during project UA1202 to support diagnosis and assessment of powdery mildew.

Both PMapp and Grape Assess include images of bunches shaded to represent powdery mildew, a self-calibration component that allows the user to test their ability to assess area and a diagrammatic key for users who like to use a key when assessing severity. However, the current version of Grape Assess does not provide the equivalent support for assessment of area affected by bunch rot, which typically involves berries that are entirely symptomatic, nor for severity of conditions affecting leaves, shoots or other vine parts. These features should be considered for inclusion in future versions of Grape Assess.

It must be emphasised that PMapp and Grape Assess are not decision support tools; rather, they provide a means to facilitate data collection and assist with estimation of severity. The authors acknowledge that visual assessment is subjective and remains an interim measure until objective measures have been established and adopted widely (Petrovic et al. 2017, Knauer et al. 2017).

The principal recommendations arising from research project UA1703 are:

- Maintain Grape Assess by investing resources to upgrade the software as required. Continual upgrading of operating systems and changes to the requirements of the major platforms (currently Apple and Google) mean that the current versions will require upgrade in future;
- Develop and incorporate in the apps a sampling design functionality for simple random sampling of vines for assessment;
- Investigate the incorporation of pre-determined sampling plans in the vineyard (including stratified, cluster and ranked set sampling) to improve the robustness, accuracy and efficiency of the data collection;
- Support development of version 2 of Grape Assess to include computer-generated images to assist with assessment of conditions other than powdery mildew on bunches, such as bunch rots, leaf powdery and downy mildew, trunk diseases, and damage caused by insects, birds and sunburn. This would require creating images that show entire berries affected, as well as area affected on leaves, shoots, cordons and trunks;
- Support improvements to the online resource website that supports the apps:
    - Include materials to support assessment of other diseases, pests and disorders (as noted above);
    - Include materials that will assist the choice of statistically sound sampling methods and that will give reliable outputs;
    - Improve user engagement by making the disease recognition exercise more interactive, e.g. ask the user to outline berries/areas of the bunch with symptoms of powdery mildew or other conditions where symptoms of damage are relatively subtle;
    - Exploit developments in technology that will allow the use of 3-dimensional images of bunches to improve experience of recognising powdery mildew so that spore-bearing structures on the berry surface can be seen more clearly.

7. Appendix 1: Communication

Publications, Industry journals, Conferences and other presentations

The short duration of the project, essentially throughout vintage 2018, and the narrow scope have precluded publication of journal articles. However, the research team intends to prepare one scientific paper to report the development of the apps, drawing on the development of the original PMapp also, and an article on the updated and new apps for an industry journal.

Eileen Scott has been invited to present the apps at a forum to be held in McLaren Vale in 2018 (details to be advised).

PMapp is used in teaching undergraduate and postgraduate students at the University of Adelaide, The University of Tasmania and Charles Sturt University, and will be replaced by Grape Assess.

Other Communications

PMapp, an application for smart-phones and tablet devices available free to download via Apple iTunes Store (https://itunes.apple.com/au/app/powdery-mildew-assessment-tool/id957604112?mt=8) and Google Play (https://play.google.com/store/apps/details?id=com.lemursoftware.pmapp).

Grape Assess, an application for smart-phones and tablet devices available free to download via Apple iTunes Store (https://itunes.apple.com/au/app/grape-assess/id1342167843?mt=8) and Google Play (https://play.google.com/store/apps/details?id=com.lemursoftware.grapeassess).

Codes for software R for the visualisation of GPS coordinates, used to prepare the examples used in the Guidelines for use of Grape Assess and PMapp:

(a) Vineyard row sampling

```
Vine_level <- ggplot(frame , aes(x = vinenum, y = rownum)) +
      geom_point(aes(colour = rootstock), pch = 0, size = 3) +
      labs(title="Vineyard at the vine level", y="Row", x="Vine") +
      theme_minimal()+
      scale_colour_hue(h = c(0, 180),l = 80, c = 150) +
      theme(panel.grid.major.x = element_blank(),
            panel.grid.major.y = element_blank(),
            panel.grid.minor.x = element_blank(),
            panel.grid.minor.y = element_blank())
```

(b) Vineyard GPS Regular Grid Sampling

```
library(ggmap)
library(tidyverse)
X <- 100
Name <- c(1:100)
lon <- c(rep(seq(from = 138.633148, to = 138.634084, length.out = 10), each=10))
#Creates a vector of longitudial co-ords across vineyard
lat <- c(rep(seq(from = -34.967919, to = -34.967150,length.out = 10 ),times = 10))
#Creates a vector of latitudial co-ords across vineyard
Col <- sample(c(0,1), replace=TRUE, size=X)
#Sampling column of 1's and 0's
long_lat_dataframe <- as.data.frame(cbind(Name,lon,lat,Col))
#Bind columns in a data frame
bbox = c(left = 138.633148, bottom = -34.967919, right = 138.634084,
       top= -34.967150)
#sets the 4 corner limits of the satellite image
get_map(bbox, maptype = "satellite",zoom = 19,scale = 2) %>%
  ggmap() + geom_point(data = long_lat_dataframe, aes(x = lon, y = lat, fill = Col), size = 2, shape =
21) +
  guides(fill=FALSE)
#Select the type of map, the scale (1-21) and colours the points.
```

8. Appendix 2: Intellectual Property

PMapp version 2 and Grape Assess were made free to access, as had been agreed during project UA1202 and reinforced by Wine Australia program managers during the Project Steering Group meeting on 20 March 2018. As such, there is no commercialisable project intellectual property associated with these outputs.

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10. Appendix 4: Staff

Project staff

Eileen Scott	University of Adelaide (project leader)
Olena Kravchuk	University of Adelaide

Collaborators

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Software development for PMapp and Grape Assess

Wade Perry	Lemur Software (app development)
Sonia Tyndale	Assisted with design of Grape Assess screens
Jason Allen	Expansionware (assisted with Android versions)