FORECASTING GREEN–BRIDGE MEDIATED DISEASES IN THE SOUTH–WEST OF AUSTRALIA: *BEAN YELLOW MOSAIC VIRUS* IN LUPINS

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ABSTRACT

Bean yellow mosaic virus **(BYMV) is a non–persistently aphid–borne virus which causes significant yield losses in lupin crops. Strains that occur in the Mediterranean–type environment of south–west Australia are seed–borne in clovers and its principle reservoir is infected annual clover pastures in which it survives over summer within dormant seeds. Spread to lupin crops occurs when a BYMV–infected pasture is adjacent to the lupin crop and aphid vectors transfer the infection. The BYMV–lupin pathosystem is driven by the magnitude of the 'green–bridge' which depends on the amount of soil moisture before lupins are sown. Aphids build up in the 'green–bridge' and the longer this occurs before lupins are sown, the larger the BYMV epidemic in the pasture and the higher the likelihood that aphids will transfer BYMV from the pasture to the lupin crop early, generating a substantial epidemic. The BYMV–lupin pathosystem model requires daily temperature, rainfall and evaporation data to function, which it accesses from an associated meteorological database. The framework we have developed automates BYMV risk forecasting for over 450 sites, allowing for higher resolution, more frequently updated forecasts than previously possible. These forecasts were validated with data collected over two years from four geographically isolated trial sites.**

KEYWORDS

aphids, disease, lupins, risk, simulation, prediction, modelling, BYMV

INTRODUCTION

Virus diseases cause major yield losses in lupin crops worldwide. *Bean yellow mosaic virus* (BYMV; Family *Potyviridae*, Genus *Potyvirus*) is a damaging pathogen of narrow–leafed lupin (*Lupinus angustifolius*) in south–west Australia. It is a non–persistently aphid–borne, with an external source consisting of infected annual clover pastures, and a largely monocyclic temporal spread in lupin crops (Jones 2001, 2005; Cheng *et al.* 2002). Yield losses exceeding 60% can occur in years when aphids arrive early in the life of the lupin crop. Conversely, in years when aphids arrive late incidences are generally low and infection causes little yield loss (Jones 2001; Jones *et al.* 2003).

The principal factors involved in BYMV epidemics include the magnitude of the BYMV infection source within the subterranean clover (*Trifolium subterraneum*) pasture reservoir and the proximity of the infected pasture to lupin crops; time of first arrival, abundance and activity of aphid vectors; which aphid species are involved and whether they colonise lupins or not; the length of the growing season; climatic factors including rainfall, temperature and wind which influence aphid numbers, aphid behaviour and virus transmission; and cultural factors determining plant density, time of canopy closure and extent of groundcover (Jones 2001, 2005). The timing and magnitude of rainfall events in March and April (early autumn) in a district is directly related to the date of first arrival of aphids in lupin crops there (Thackray *et al.* 2004). This is because the soil moisture they provide stimulates germination and supports the growth of pasture plants, weeds and crop volunteers on which the aphids propagate before they move to crops. When there is little or no rain at this time, very few plants are available to support aphids before crops are sown so aphids arrive much later (Jones, 2001).

This paper provides a summarised description of a simulation model developed by Maling *et al.* (2008) that forecasts spread of BYMV in lupin crops in the Mediterranean–type environment of south–west Australia. Knowledge of the BYMV–lupin pathosystem developed over many years of epidemiological research was used to develop this model. The model uses daily temperature, rainfall and evaporation data to calculate daily biomass or 'greenness' levels, which in turn are used to predict aphid population levels throughout the year. The movement of aphids into the lupin crop, and the subsequent spread of infection are then simulated. The availability of a localised forecast for BYMV will allow growers to decide when they need to implement components of the Integrated Disease Management (IDM) strategy for BYMV in lupin or deploy the full package (Jones, 2001; Jones *et al.* 2008).

MATERIAL AND METHODS

MODEL DESCRIPTION

The data required to develop the model to simulate this pathosystem were acquired from published studies (Maling *et al.* 2008), validation blocks of lupins set up

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over two years at four sites, and unpublished studies on the impact of controlled environmental conditions simulating diverse regional seasonal conditions on aphid development, virus acquisition and virus transmission efficiencies (Maling *et al.* 2008). The principal assumptions made in developing the model were: (i) simulation was for a single lupin crop adjacent to a BYMV infected clover pasture which was the only source of the virus; (ii) aphid species were not accounted for individually but grouped into lupin colonising and lupin non–colonising species, and both were responsible for disseminating the virus, each with their own transmission efficiencies and flight behaviours; (iii) aphids flew from the adjacent BYMV infected clover pasture to the lupin crop perimeter, then from there to the crop interior, and each aphid flight within the crop involved movement from an infected plant to another plant which may be infected or uninfected, and vice–versa; (iv) the magnitude of local BYMV infection incidences in clover pastures depended on historical meteorological data and (modelled) aphid populations; (v) once a healthy lupin plant was inoculated by an aphid there was a period of 14 days latency before the infection became systemic, after which the plant could act as a BYMV source; (vi) infective aphids lost their ability to transmit BYMV after a 2 feeding events due to the non–persistent nature of the virus transmission by its aphid vector (Maling *et al.* 2008).

The simulation calculations involve four major processes: (i) build up of biomass in the adjacent clover pasture; (ii) build up and activity of aphids in the adjacent clover pasture and their migration to the lupin crop perimeter; (iii) build up, activity, and spread of BYMV by aphids within the crop; and (iv) effect of BYMV incidence on lupin biomass (Maling *et al.* 2008).

Model Framework and Forecasting

The model was written in the Java programming language and run on a customised IBM eServer 326 m connected to an Oracle database storing the meteorological data archive. All meteorological data were taken from the Patched Point Dataset (Jeffrey *et al.* 2001). The model automatically accessed 50 years worth of historical data from the weather station closest to each location being modelled. The java framework this model was run in, specifically its database integration, allowed us to run it over very large areas. Currently the model runs on 465 discrete 25 km by 25 km cells in south–west Australia. Each of these cells is associated with the nearest functional weather station, providing us with the meteorological data needed to run the model (Maling *et al.* 2008).

The model was designed to provide risk forecasts for the lupin growing season, and its initial forecasts are provided before this starts. As such, meteorological data predictions for the 'future' need to be employed. To do this we used 50 years worth of historical meteorological data. The current years data is taken up from 1 January until the date the model is run, and data from one of the archival years is appended to this to create a full years worth of data. This process is repeated for each of the 50 years in the database to give us 50 sets of weather data, each beginning with current data and ending with archival data. The model is then run for each location, with each of the 50 meteorological data sets, providing us with 50 BYMV infection incidence predictions for each site. The 15th, 50th and 85th percentile predictions were then taken to create our best, most likely, and worst case risk forecasts (Maling *et al.* 2008). The results are presented as three risk maps to be published annually as part of a suite of disease forecasts on the world wide web at www.agric.wa.gov.au/cropdiseases. Fig. 1 shows the worst case BYMV forecast for south–western Australia in 2008.

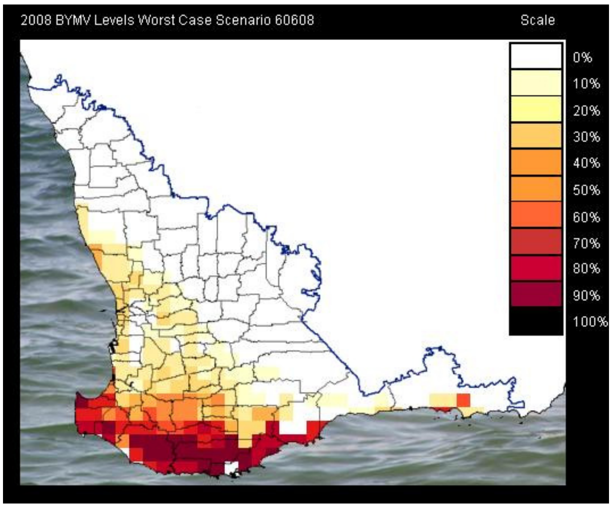

Fig. 1. The worst–case scenario forecast map for BYMV incidence in south–west Australia for 2008.

RESULTS AND DISCUSSION

Model simulations were done for a wide range of situations to verify the model calculations. Model validation was centred upon four sites across the grainbelt of south–west Australia, representing different rainfall and geographic zones. These were Badgingarra (30°20'S, 115°30'E), Avondale (32°7'S, 116°51'E), Mount Barker (34°38'S, 117°32'E) and Merredin (31°30'S, 118°14'E) and the data were for two years, 1998 and 1999. Biomass patterns were validated against monthly maps of normalised difference vegetation index imagery (NDVI) from the United States National Oceanic and Atmospheric Administration (NOAA) satellite from 1997–2005 (Maling *et al.* 2008).

Examples of the models output for biomass, pasture aphid population, arrival and build up of the crop aphid population, and crop BYMV infection incidence are in Fig. 2. The graphs are for 1998 and 1999 at the Badgingarra site. A drier start to the year in 1998 than in 1999 lead to pasture biomass levels remaining low for a month longer than in 1999. This lead to a delayed build up of aphids in the clover pasture, aphids arriving later

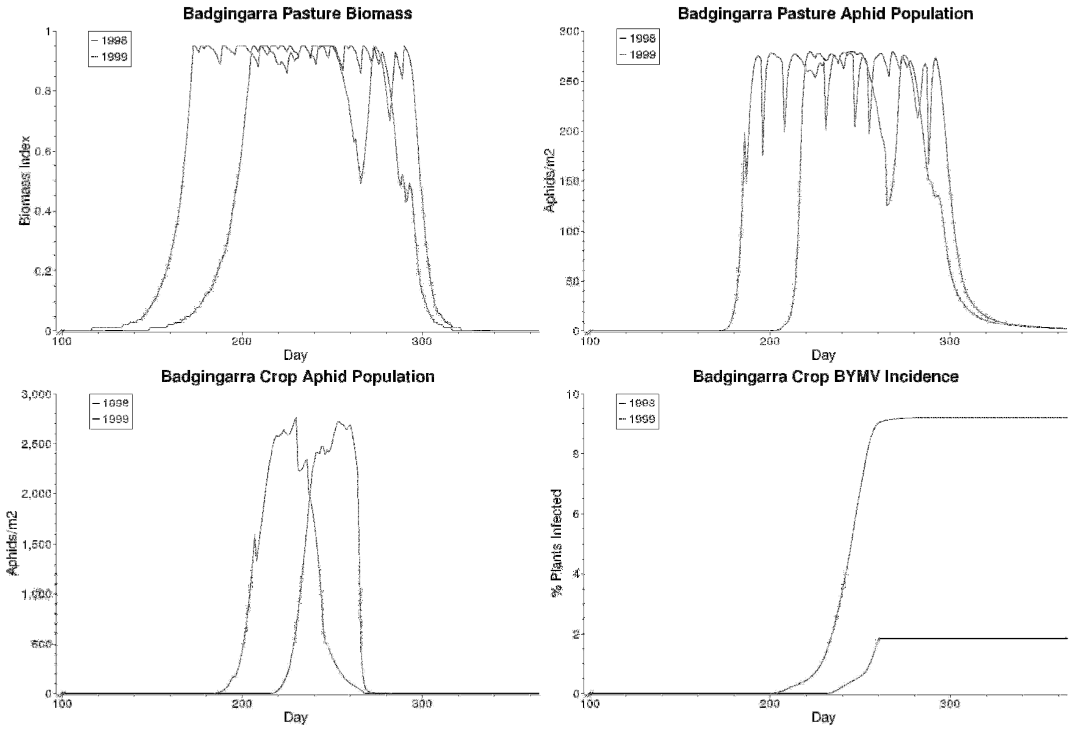

Fig. 2. Model simulation of pasture biomass, pasture aphids population, crop aphid populations and BYMV incidence during 1998 and 1999 at Badgingarra. (Figure is a modified version of Fig. 2 from Maling *et al.* 2008.)

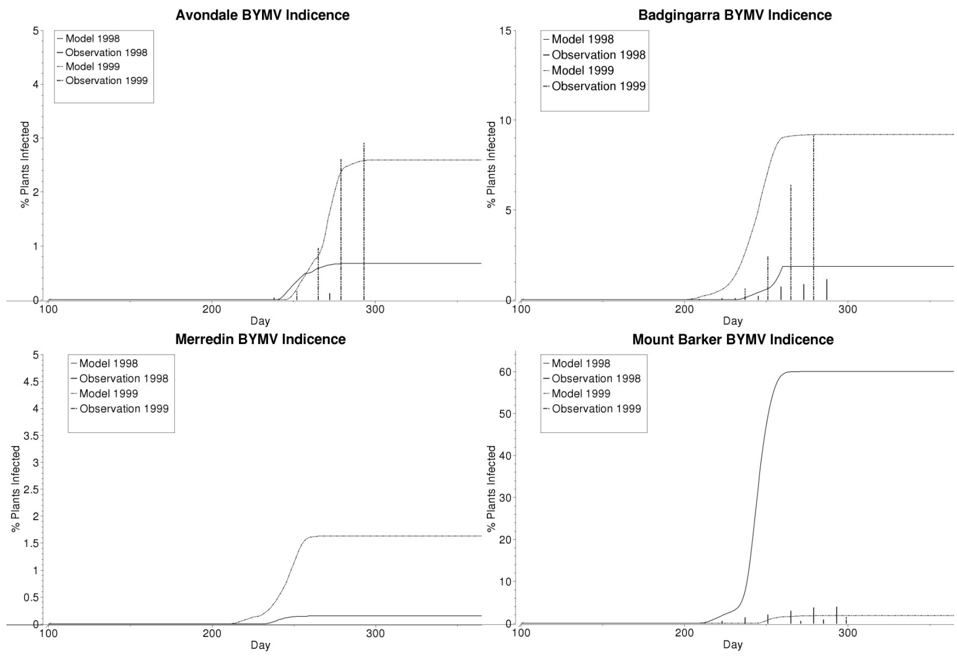

Fig. 3. Modelled versus observed BYMV incidences for 1998 and 1999 at Avondale, Badgingarra, Merredin and Mount Barker. (Figure is a modified version of Figure 4 from Maling *et al.* 2008.)

in the crop, and ultimately to a lower BYMV incidence in the crop than in 1999 (Maling *et al.* 2008).

BYMV incidence in lupins at the trial sites were recorded by counting the number of plants with characteristic necrotic symptoms on at least six occasions during the growing period. Observations and model predictions were compared as disease progress curves for 1998 and 1999 (Fig. 3). Predictions of BYMV incidence at Badgingarra and Avondale were in agreement in both years, with the model effectively resolving the differences between both sites and years. No BYMV infection was observed for either year in lupin plants at the Merredin trial site. For 1998 the model predicted this but in 1999 it predicted that BYMV incidence would reach approximately 1.5%. In 1999 the model accurately predicted the BYMV incidence at Mount Barker. However at the Mount Barker site in 1998 a much higher incidence was predicted than was actually observed, and this was a direct result of the over estimated aphid population (Maling *et al.* 2008).

These results provide confidence in the model's ability to predict both aphid populations and BYMV incidence in lupin crops adjacent to BYMV–infected clover pastures in the south–west Australian grainbelt. The predictions match the observed data for most of the aphid population and BYMV incidence scenarios. The only major disparity between observed and predicted data was for 1998 at the Mount Barker site. Our understanding of the BYMV–lupin pathosystem was reflected in the models prediction. The 1998 growing season started very early resulting in an extended period of pasture biomass on which aphids could thrive. As such we would have expected to have observed a large aphid population spreading BYMV throughout the cropping period. Instead there were minimal aphid numbers, the lowest across all sites for both years. The relatively accurate prediction of both aphid population and infection incidence in 1999 at Mount Barker indicate an additional factor affecting the aphid population in 1998 that was absent in 1999 and not accounted for in the model, possibly frost, extreme wind conditions, or an entomopathogenic disease outbreak (Maling *et al.* 2008).

By utilising existing knowledge of the factors that drive BYMV epidemics in lupin crops under Mediterranean–type conditions in south–west Australia we have built a detailed model describing pasture biomass, aphid population dynamics, and spread of BYMV infection within lupin crops. Calibrating the output of the model to emulate data representing different scenarios at four field sites allowed us to create a valuable forecasting tool. The framework developed allows for the automatic modelling of 465 localities throughout the grainbelt region and has greatly improved the speed and scope of the forecast which can be delivered. The features incorporated also simplify the creation of other green–bridge mediated disease models (Maling *et al.* 2008).

The ability to provide local BYMV incidence forecasts in a timely fashion to lupin growers provides the opportunity to weigh the economic and environmental cost of applying control measures against the potential loss in crop productivity (Maling *et al.* 2008). The IDM strategy available for BYMV includes control measures such as: isolation from clover pastures, rotation with non–host crops, sowing a perimeter non–host barrier of cereal, sowing lupin at high seeding rates, promoting rapid canopy closure, maximising groundcover, minimising tillage, all of which help to minimise the spread of BYMV (Jones, 2001; Jones *et al.* 2008). Effective targeting of this IDM strategy based on BYMV risk forecasts would decrease the financial loss from BYMV infection and encourage increased planting of lupins in regions of high BYMV risk (Maling *et al.* 2008).

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